Versatile Phonograph Preamplifier

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Design data for an excellent preamplifier.

AT THE COST of adding one more article to the mounting list of those intended to solve the phonograph preamplifier-equalizer problem, the writer offers a more detailed analysis and a more versatile solution than has yet come to his attention.

Before launching into a description of the unit, let us consider briefly the purpose of a preamplifier in a reproducing system. This done, we can deal with the design problems more intelligently.

It is our belief that in any A-B test, if a listener finds two units (or two settings of a given unit) which sound different, yet he has no particular preference for either—then it is safe to conclude that neither is the correct answer.

During a long period of experimentation efforts were constantly made to obtain the actual recording characteristics. It was of course obvious from the first that if these are available, the whole design problem is vastly simplified and most of the cut-and-try method—which is cumbersome and time-consuming at best —would be eliminated.

Such data are not easy to obtain, however; but after protracted effort, including tapping all known sources of information, the following table was built up. It is not necessarily accurate but represents the best known estimate of current recording curves:

	Low Freq. Turnover
Columbia 78	300
Columbia $33^1/_3$	500
Decca ffrr	400
R. C. A.	500
Technicord	650
Mercury	300

It is worthwhile at this point to consider the actual purpose of a preamplifier in a reproducing system. A preamplifier should bring the level of a device up to some standard. At this point in the system, switching generally occurs. The output level of the preamplifier should be comparable to that of the other units, such as AM and FM tuners, so that no appreciable change of main gain control setting will be needed on switching from one program source to another, and all sources should be nominally flat at the point of switching.

Rather careful compensation has to be included in a preamplifier to make records sound "right." Listening tests have evolved a series of corrective networks which does a far better job than the first fixed-curve system. With at least semi-certain information to design from, a unit can be built to fit the needs of the day.

Hi Freq. Preemp. db per octave	Freq. at which Preemp begins
6	1590
6	1590
3	3000
2.5	1000
6	2500

Our problem is, then, to use this information to design a simple, inexpensive preamplifier versatile enough to do its work of bringing a low-level pickup output up to some standard level and, at the same time, to produce a nominally flat response curve from the program material. Since a number of curves seem to be in use, the standard single-network preamplifier will not suit our needs. To do this, we place two equalizers, one a low-frequency type with five positions and one a high-frequency type with four positions, in the circuit with an isolating tube between. We now find that by proper choice of constants, we can complement all of the above curves either quite closely or with at most a 2-db error, as *Fig. 1* illustrates.

Gain Requirements

Fortunately, pickup performance data are easier to obtain than record curves. We find that to bring a Pickering, Clarkstan, or similar cartridge up to about 5-volt level under average conditions requires a gain, in the flat portion, of about 28 db. A GE pickup will require nearer 40.

We want, further, enough extra gain to complement the curve which needs the most boost, and this requires about 30 db more gain. The total is more than high-gain triodes can supply without loss of quality and without the feedback (with its attendant advantages) falling dangerously low at the bottom end. So we decide on a pair of pentodes.

The 6J7 is an excellent tube for the first stage, having low hum and little noise, yet it is inexpensive and readily available. In the second stage, a 6SJ7 eliminates the gridcap. We choose constants which give high gain consistent with freedom from erratic behavior on changing tubes. We adjust voltages to meet our output requirements and to minimize intermodulation without feedback (as evidenced by d-c plate voltage shift vs. signal level).

Operating the first heater on d.c. was found unnecessary; a variable center-tap and variable positive bias, as shown, suffice. Now we apply feedback to reduce the gain in the flat portion to that desired—28 db in this case. We allow the gain to rise at a 6 db rate by a conventional RC combination. But we supply five such combinations for the five curves. We also use screen bypass values which seem unnecessarily large until we consider that we are bypassing not a screen dropping resistor alone, but it and screen resistance in parallel. Furthermore, we feel that it is desirable not only to make the amplifier stable on the low end but also to achieve critical damping. This requires a 6 db per octave droop below the useful frequency range and on down to the point where the gain approaches unity.

Note that the low-frequency turnover selector switch is a shorting type. Otherwise opening the feedback loop between switch points results in a sudden and extremely annoying rise in level—about 30 db. The 10-megohm click suppressors are not merely gingerbread; the sharp transients generated in their absence create extremely high peaks in the power amplifier and speaker.

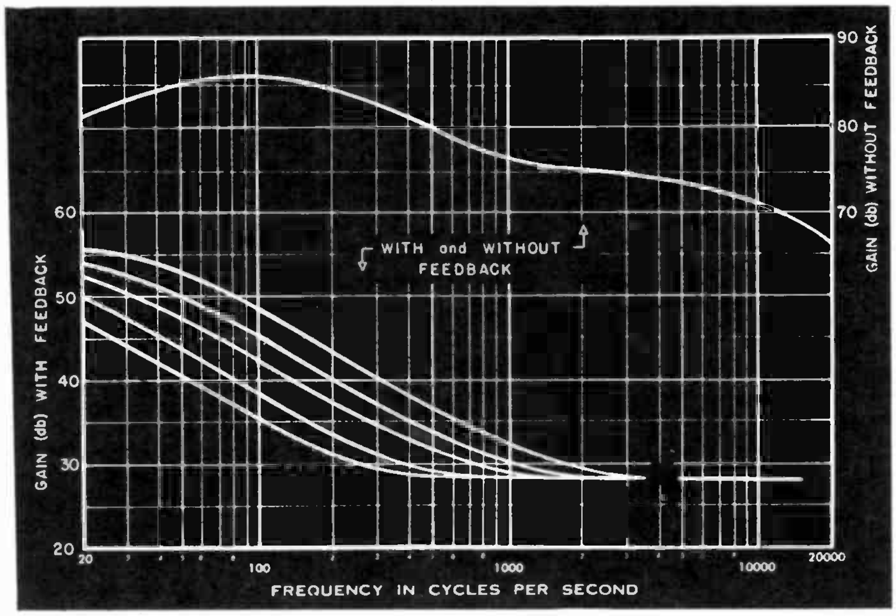


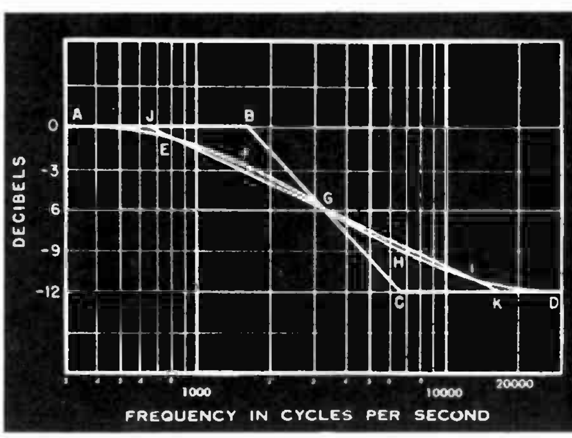
Fig. 1. Response curves of preamplifier with and without feedback.

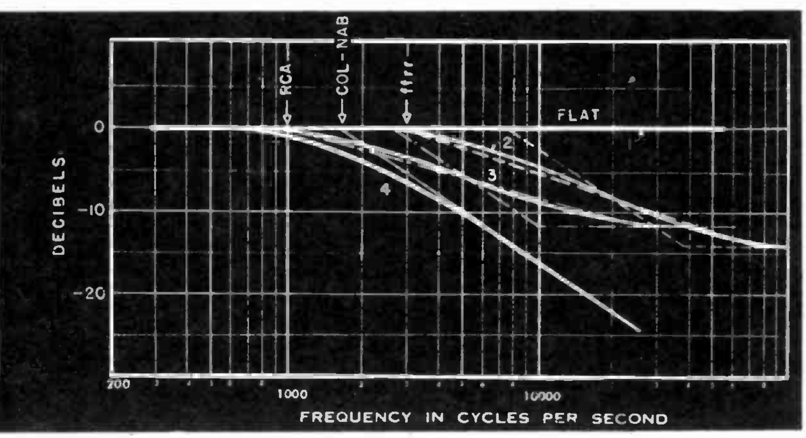
We now have a high-gain, low-noise, low-distortion, low-frequency-compensating preamplifier of simple construction, but one which still does not correct the upper end of the record spectrum. If we applied the feedback approach here, we would run into several difficulties: our gain when on the NAB-type curve would run perilously close to unity at the extreme high end, and our feedback would rise appreciably, with attendant disadvantages.

Further, there is no objection to a conventional losser in this application. We can feed it directly by the pickup and its design is simplified by being isolated by a tube. For the first we examine the NAB characteristic, which is a simple 6 db/octave rolloff, beginning at 1590 cps. This calls for a simple *RC* network, with a product of 100 microseconds; 0.1 meg and .001 μf is a good combination. With too small an *R*, we need to figure in pickup resistance and inductance. Since these vary with manufacturer, and we are designing a universal preamplifier, this is not desirable. At the opposite or high-impedance extreme we may run into hum pickup and tube input capacitance begins to cause some trouble.

A brief examination of the curve produced by the above and all other such networks shows us that at the nominal turnover frequency we are 3 db below the original level, and at exactly one octave either side are 1 db down from the respective asymptotes. The slope of the curve increases at the rate of 6 db per octave. This slope is fixed in character and cannot be changed; however, it can be stopped along its travel. Since we need other curves of less slope (2.5

Fig. 2 (left). Effect of resistor in series with shunt condenser. Fig. 4 (right). Derivation of actual high-frequency roll-off curves from graphical (dotted lines) construction.





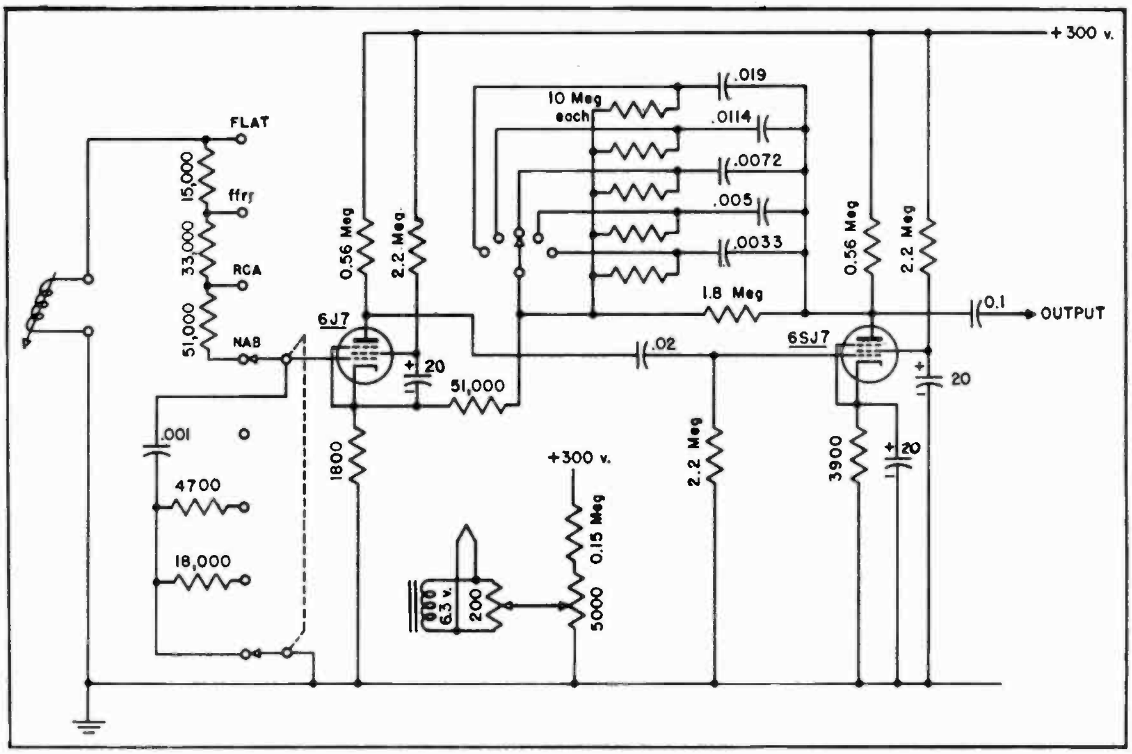


Fig. 3. Complete schematic of preamplifier.

db for RCA, 3 db for Decca), they can be obtained by stopping the 6 db curve at some empirically determined point.

Suppose we insert a resistor in series with the shunt condenser to give a second turnover two octaves above the first—as in *Fig. 2*. The asymptotes are the line *a b c d* ; as would be expected, the actual curve falls 3 db below *b* and above *c*. The actual curve is *aefghid*; and if we lay a rule along this curve, we find its closest approximation is line *jgk*, which has a slope of 2.5 db/octave with respect to a new pseudo turnover frequency which is about 0.39 times the mathematical turnover. It is easily seen that if *b* and *c* were farther apart, the realized slope would have been steeper, and in this manner we arrive at the constants shown in *Fig. 3*.

Now to the measured performance of the preamplifier. About a half-dozen have been built using 10% tolerance resistors picked at random rather than selected for exact value. Three amplifiers were carefully tested. The best of the lot had 93 db gain without feedback (100 μf across the first stage cathode resistor) and 30 db on the flat portion of the curve with feedback. The curves shown happen to be for the worst of the three, as are the performance data. With a Ballantine model 300 meter (0.5 meg) and a Dumont 208 scope (2.0 meg) as load, the maximum output was +20 dbv (db relative to one volt)—a peak-to-peak swing of 28 volts. At 1200-cycle turnover, which gives maximum bass boost, the output with a 600-ohm attenuator across the input, and no further signal, was -88 dbv. Since the gain at 60 cycles is 52 db this says that the hum voltage referred to the grid is about -120 dbv, or about one microvolt. It is not possible with ordinary test equipment to measure lower, which justifies the hum-bucking circuits used rather than the d-c heater supply with its attendant expense and bulk. The one-microvolt figure was attained in each case with the second 6J7 tried; the first, however, gave only about 10 db more, which is still in the excellent-performance bracket.

The *RC* time constants in the feedback path are, however, rather critical. It is not easy to measure a 1.8 megohm resistor with accuracy; hence the following procedure was followed. The amplifiers were assembled with parts out of the bin; in one case four of the five constants were correct, in another, three, as plotted curves showed. Examination of the curves showed clearly which capacitors to change, and in which direction and amount to achieve the intended result.

Such an equalizer has been in use nearly a year in conjunction with an amplifier-speaker system which we confidently believe to be ± 2½ db from 48 to 13000 cycles and reasonably free from transient defects. The one outstanding change that appeared to coincide with the installation of the equalizer was that listeners started, for the first time, comparing the music to the original rather than to some other reproducing equipment with which they were familiar.

Even though the curve of a particular record is not known, a little listening experience enables one to select quite readily the proper equalizing characteristic; indeed, in the case of many records, only one setting sounds at all satisfactory, others being very obviously wrong. Occasionally a record turns up for which no settings will provide any illusion of realism.

After having lived with this preamplifier for several months, we feel tempted to conclude somewhat as follows: The input data, upon which the whole design was based is certainly in error by much more than 2 db in certain frequency ranges and on certain recordings. The probable error in over-all equalization in the next record played will very likely be well over 3 db, which is about the maximum deviation between characteristics obtainable with the foregoing circuits. This says that further progress is impossible or unwise until more reliable input data is on hand.

The finished product is compact, simple to construct, and inexpensive. It does not demand critical tolerances nor particularly careful pyhsical layout. It will accommodate any current low-level wide-range cartridge and correct any current known or alleged response curve. Its hum, noise, and distortion content are a lot better than most commercially available equipment.