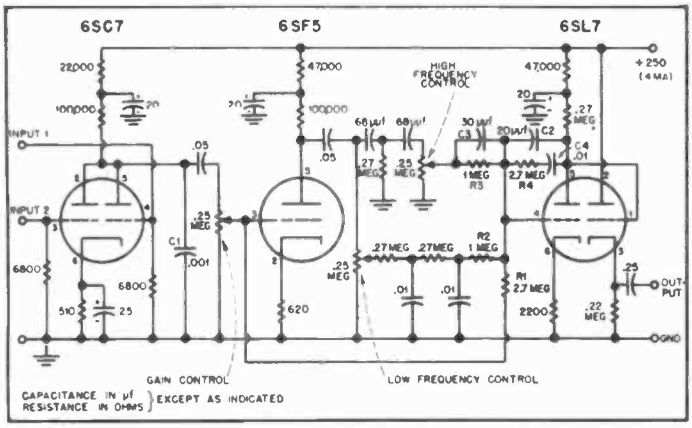

Fig. 1. Schematic of versatile pre-amplifier with two phono inputs, cathode-follower output.

A Continuously Variable Equalizing Pre-amplifier

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THE reproduction of phonograph records has long been complicated by a lack of uniformity in the recording characteristics. While broadcast transcriptions have been fairly consistently made with a standard low end roll-off and high end pre-emphasis, the recordings available to the general public have not been so standardized. As a result, it is difficult to choose a frequency characteristic for reproduction which will produce satisfactory results for all commercial pressings. The advent of microgroove recordings, with identical characteristics as published, promises hope for the future, but at the moment it further complicates the problem by adding yet another characteristic to the list.

One evident solution to the problem is an adjustable equalizer which permits the reproducing characteristic to complement that of the recording, whatever it may be. This is practicable only when all the required characteristics are known. Lacking knowledge of the exact requirements, the approach may be a continuously variable equalizer which will approximate all possible recording characteristics. Then an adjustment may be made by ear. While this method does lack exactness, it can lead to aural satisfaction which, after all, is its purpose.

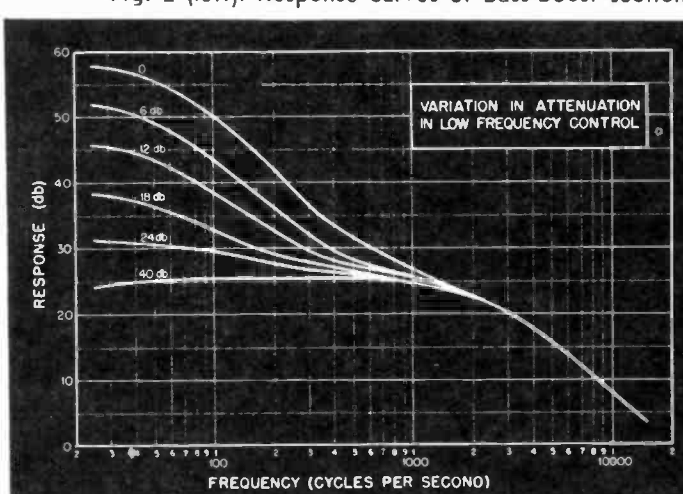
Equalization

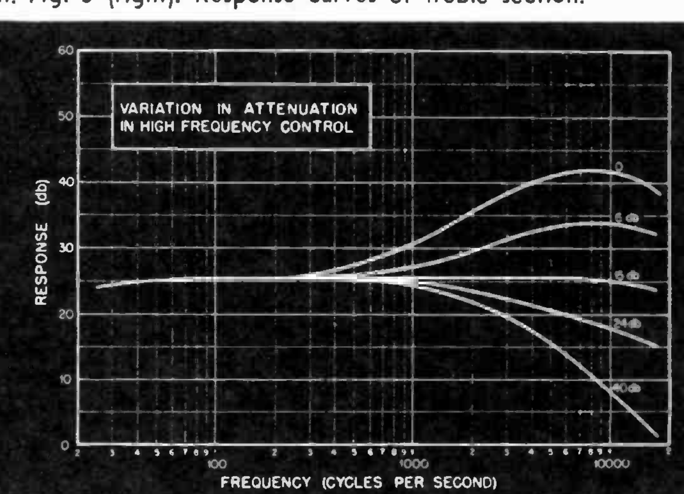
Equalization is normally achieved by what might be considered a "multiplication" process. By this is meant that the gain-frequency characteristic (in the form of input-output ratio) is multiplied by some function of frequency. Any reasonable function of frequency is obtainable with *R*, *L* and *C* networks, but a continuously variable function of frequency is another matter.

An alternative method of equalization might be termed "additive." That is, a rise in gain at some frequency, for example, is accomplished by the addition of extra voltage at that frequency. To produce an equalizing characteristic, a function of frequency must be applied to the amplitude characteristic of the added voltage, and the addition will thus have phase shift which varies with frequency. The design process, therefore, involves vector addition instead of the vector multiplication of the ordinary design. While this process is somewhat troublesome, the realization of the design in circuit form is readily accomplished, since the variable control element is a potentiometer.

The continuously variable equalizing pre-amplifier presented here utilizes the additive method, with three transmission channels. One channel has a characteristic which is essentially flat at frequencies below 1000 cps, and falls off at the rate of 12 db per octave at higher frequencies. This is the basic channel, to which voltages from the auxiliary channels are added. The second channel has, at very low frequencies, 40 db more gain than the basic channel, but its gain falls at the rate of 12 db per octave above about 50 cps. The third channel gain rises at the rate of 12 db per octave up to 15,000 cps; above this frequency its gain is also 40 db more than the basic channel. Outputs from the three channels are added in a single tube feedback summing amplifier; potentiometers which add flat loss in the auxiliary channels permit control of the resultant transmission characteristic.

Fig. 2 (left). Response curves of bass-boost section. Fig. 3 (right). Response curves of treble section.





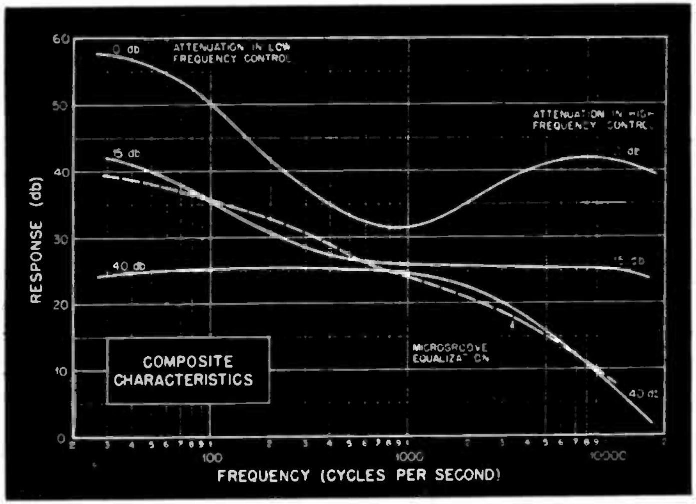


Fig. 4. Limits of available response curves.

The pre-amplifier schematic is shown in *Fig. 1*. In this particular embodiment, as used in the author's home, the input is a double triode, to accept signals from two variable reluctance phonograph pick-ups simultaneously. After amplification in this tube, the signals are fed to a potentiometer for gain control, and then split into two channels. One of these, the basic channel, goes directly to the summing amplifier. The other, which is further amplified by a triode stage, is subdivided into the two auxiliary channels by low-pass and high-pass *RC* networks. These networks produce frequency functions suitable for additive equalization.

The feedback amplifier in which the three channels are added has a capacitor, C_2, across its feedback resistor, R_4. This, and the capacitor C_1 shunting the plate circuit of the input tube, cause the 12 db per octave high-frequency cut-off of the basic channel. The input resistor, R_3, for the high-frequency auxiliary channel has a capacitor, C_3, in shunt for partial compensation of the effect of these elements on the high-frequency auxiliary voltage.

The summing amplifier output is direct-coupled to the grid of a cathode follower, which permits the use of the pre-amplifier at a moderately remote location. The maximum output of the pre-amplifier is not limited by the output stage, which is capable of swinging almost 200 volts peak-to-peak. Overload occurs first at the grid of the auxiliary channel amplifier, which can swing only about one volt peak-to-peak. Since the mid-frequency gain from this grid is unity, the maximum output is also one volt peak-to-peak. This is comparable to the output from a crystal pick-up, insofar as voltage is concerned. Because of the low output impedance of the cathode follower, the output power level of the pre-amplifier is considerably above that of a crystal.

The measured performance of the pre-amplifier is shown in *Figs. 2, 3* and *4*. *Fig. 2* shows the effect of varying the attenuation in the low-frequency channel, with large attenuation in the high-frequency channel. In *Fig. 3* these conditions are reversed. It is seen that the two auxiliary channels overlap in the region of 500 to 1000 cps. The effect of this overlap is seen in the composite characteristics of *Fig. 4*; it is less than 2 db for attenuation greater than 15 db in the auxiliary channels. Smaller attenuation will be used only to compensate unusually poor recordings, or to create special sound effects.

Only three characteristics are shown in *Fig. 4*. Two of these represent extremes, with either no attenuation, or large attenuation, in both auxiliary channels. Between these extremes is a large number of possible characteristics, of which only one is illustrated.

The required equalization for microgroove recordings is also shown in *Fig. 4*. This characteristic may be achieved within a variation of ± 2.5 db with attenuation settings of 15 db in the low-frequency channel and 40 db in the high-frequency channel.

The method of equalization presented here is not new. Circuits utilizing the addition of several channels have been described before, but meagre performance data were given. The data shown here are the results of measurements made after the circuit was tailored to produce what were considered to be desirable characteristics. Experience with the pre-amplifier has given convincing evidence that this degree of flexibility is profitable.