Balanced Clipper Noise Suppressor

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A simplified noise suppressor with many features. Group listening tests indicate its superiority over conventional filtering methods.

IMPROVED PERFORMANCE of pickups and of recording techniques has made it possible to realize a higher frequency response from disc recordings than has been practical in the past. For some years now, increasing numbers of records with the higher frequencies recorded on them have been appearing on the market. In those instances where poor material has been used in making the pressings it has been necessary to tolerate the surface noise or to compromise between frequency response and surface noise. High-frequency pre-emphasis recording lessens the compromise, but this technique seems to be used only in the recording of the leading manufacturers. Also, it must not be forgotten that there are already many recordings in use today which do not embody the pre-emphasis feature. We are, therefore, still faced with the surface noise problem.

The various approaches made in the past to solve this surface noise problem have been watched with much interest and anticipation. Pickups with good response vs. frequency characteristics, low distortion, low transient effects, and low response to displacement of the stylus in other than the desired plane, are now available at a reasonable cost. Amplifiers are not a problem and loudspeakers are continually being improved. However, surface noise remains the stumbling block to the greater enjoyment of much recorded material. The proper place to attack this problem is at its source, i.e., in the manufacture of recordings. However, as already mentioned, existing recordings must also be accommodated.

Pre-emphasis, volume expansion, dynamic noise suppression, and fixed filters all contribute towards a reduction of surface noise and all leave something to be desired. The author, therefore, set out to see if he could develop something that would be a worthwhile contribution to the solution of the noise-suppression problem.

Basic Circuit

The noise-suppressor circuit which is described in this article has proven to be effective in reducing the surface noise in record and transcription reproduction, without sacrificing the high-frequency register of the recordings. Observations in the form of listening tests to check the effectiveness of the suppressor were made by small groups of engineers, musicians and laymen. A unanimous preference was shown for reproduction with the suppressor to reproduction using conventional filtering methods.

The basic ideas incorporated in this noise suppressor are similar to those described elsewhere.[1, 2] However, this suppressor differs from Olson's in several respects and is capable of covering a wider frequency band while using fewer filter components.

Operation of the suppressor is simplicity in itself. One control adjusts the degree of suppression. Surface noise is reduced while preserving many delicate tones of high frequency such as tinkling bells, triangles, etc., as well as the higher overtones most of which would otherwise be lost.

[1] H. F. Olson, "Audio Noise Reduction Circuits," *Electronics*, Dec., 1947.

[2] Charles D. Cole, "Experimental Noise Suppressor," see page 64.

Fundamental Requirements

Before experiments were started, careful consideration was given to the factors which would detract from the faithful reproduction of phono recordings and transcriptions. A noise-reducing system for high-quality reproduction of phono recordings and transcriptions should:

1—Be capable of faithfully reproducing, in their proper perspective, all useful signals which are impressed on the recording and should provide wide-range reproduction when wide-range recordings are available.

2—Have various degrees of noise suppression which would introduce a minimum of amplitude, intermodulation and harmonic distortion.

3—Have means of controlling the response vs. frequency characteristic of the system when recordings with objectional distortion are being played through the system.

4—Have automatic control systems or circuits which do not vary the frequency response of the system or the reproduced noise level in such a way that the listener would be conscious of the change.

5—Under average listening conditions, be capable of reducing the noise level of a reasonably good shellac pressing to an unobjectionable level without sacrificing the high frequencies and overtones of the recorded material when used in conjunction with good reproduction equipment.

6—Provide noise suppression during high-level passages as well as low-level passages.

7—Not materially alter the dynamic range of the recording.

8—Not audibly exhibit any delayed action or time constant phenomenon.

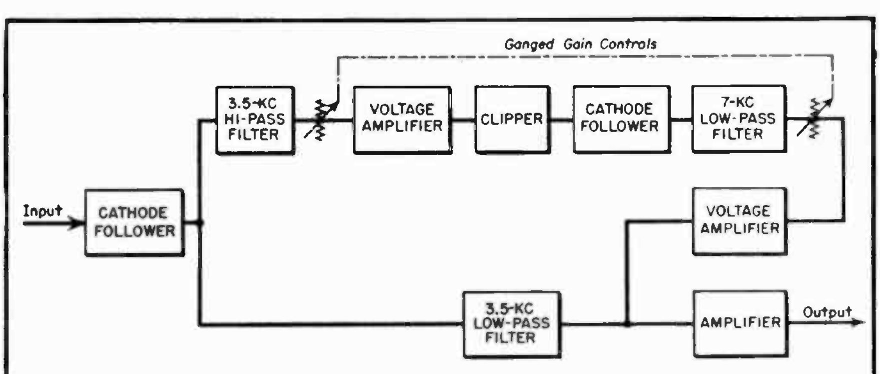

Fig. 1. Block diagram of the first noise suppressor setup, tried experimentally.

First Experimental Circuit

Incorporation of the above requirements in a noise suppressor become the problem and many of them do not lend themselves to an easy solution. *Fig. 1* shows a block diagram of the first experimental suppressor which performed sufficiently well to encourage further investigation with this approach.

The audio spectrum is divided into consecutive bands, the first point of separation being at the highest frequency consistent with reproduced noise that is not of objectionable intensity. Since each frequency band above this point contains an objectionable amount of surface noise, it is passed through a non-linear element which will offer a high impedance to the passage of low-intensity signals and a low impedance to the passage of high-intensity signals.

The signal level is adjusted so that the larger portion of surface noise will fall below the transition point of the non-linear circuit and will be effectively rejected. Any useful signals having an intensity above the noise level will rise above the transition point and be passed on to the following circuits. Biased rectifiers such as small copper oxide selenium or germanium rectifiers, biased diodes and biased amplifiers will all function as this type of non-linear element.

An amplifier biased beyond cutoff was used for these first experiments. Tubes were used to provide a sharp cutoff characteristic and the gain of the preceding amplifier adjusted to place the peak noise signals just below cutoff. With this adjustment, all noise signals which did not exceed the cutoff value were not admitted by the tube and all signals which exceeded this value were amplified by the tube.

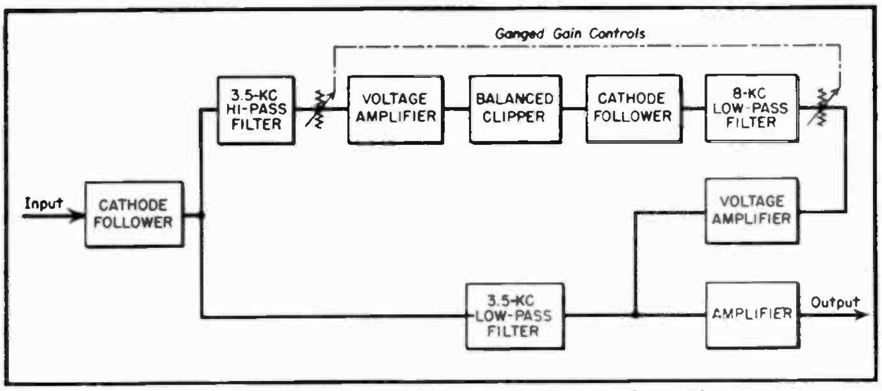

Fig. 2. Second experimental circuit, incorporating fewer filters.

The distortion resulting from this treatment must be reduced to a low value in order that the final results will be satisfactory. This can be accomplished by limiting the frequencies passing through the non-linear or clipper circuit to slightly less than one octave. Then the second harmonic of the lowest frequency admitted to the clipper will fall outside its pass band. The outputs of the various channels may then be combined in their proper relationship so that the resultant signal is essentially the same as the input signal except that the noise and the low intensity signals are considerably reduced. With this system, several filters of one octave width are needed in order to include all of the high frequencies needed for high quality reproduction.

An Improved Circuit

The same over-all bandwidth may be covered, however, with fewer filters by using a push-pull clipper circuit. The second harmonic distortion generated by each clipper will be greatly reduced when the output signals are combined in the

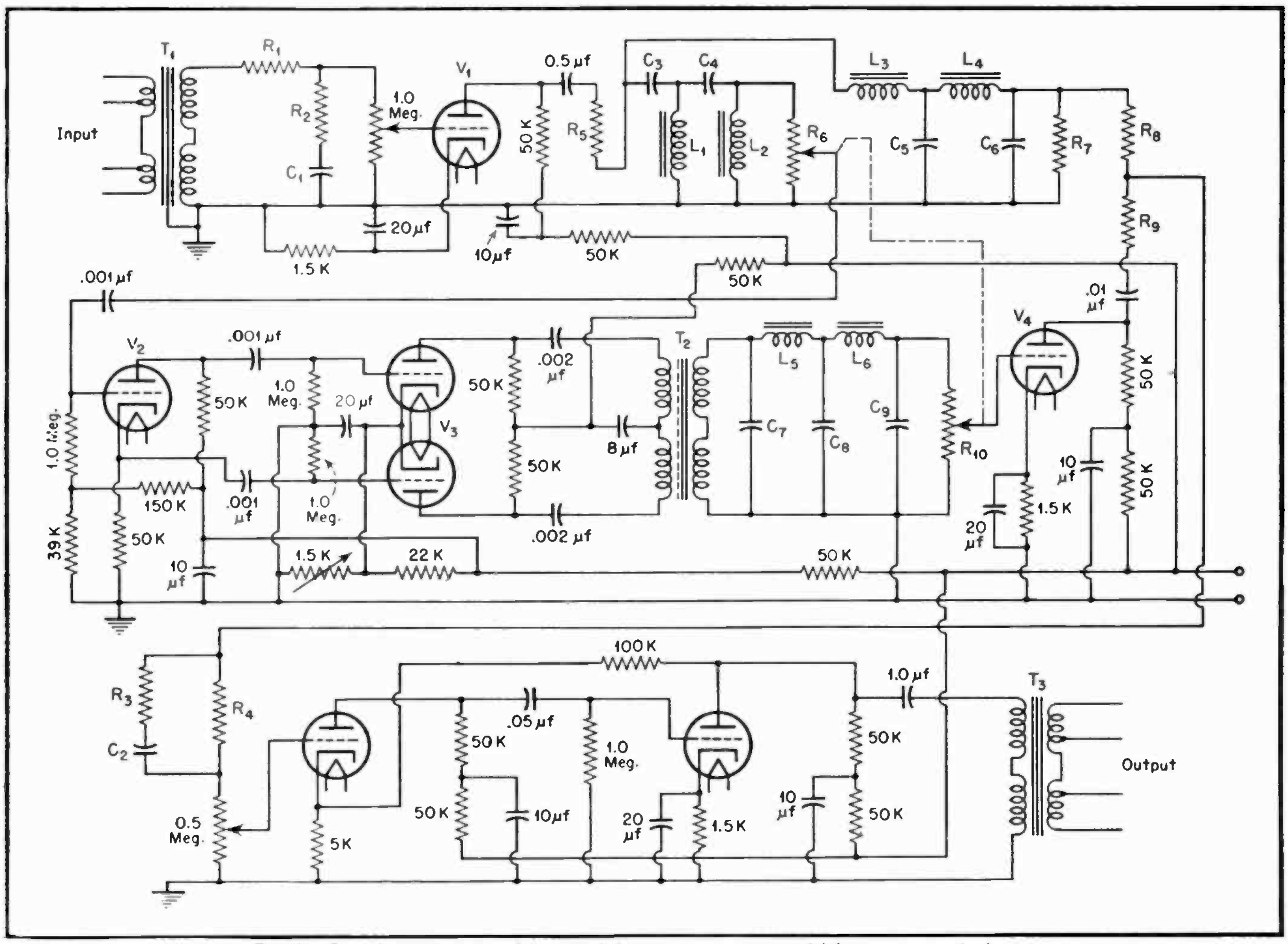

Fig. 3. Complete schematic diagram of the noise suppressor. Values not specified are:

C_1	150 $\mu\mu f$	C_5	.0076 μf	C_8	.003 μf	R_5	3800	L_1	.227 Hy.
C_2	80 $\mu\mu f$	C_6	.0038 μf	R_1, R_2	0.25 meg	R_6, R_7, R_{10}	12,000	L_2	.1135 Hy.
C_3, C_4	.0019 μf	C_7, C_9	.0015 μf	R_3, R_4	0.5 meg	R_8, R_9	50,000	L_3, L_4, L_5, L_6	.398 Hy.

Proper performance of filters is important. Adjust loads individually for best results after setting input levels.

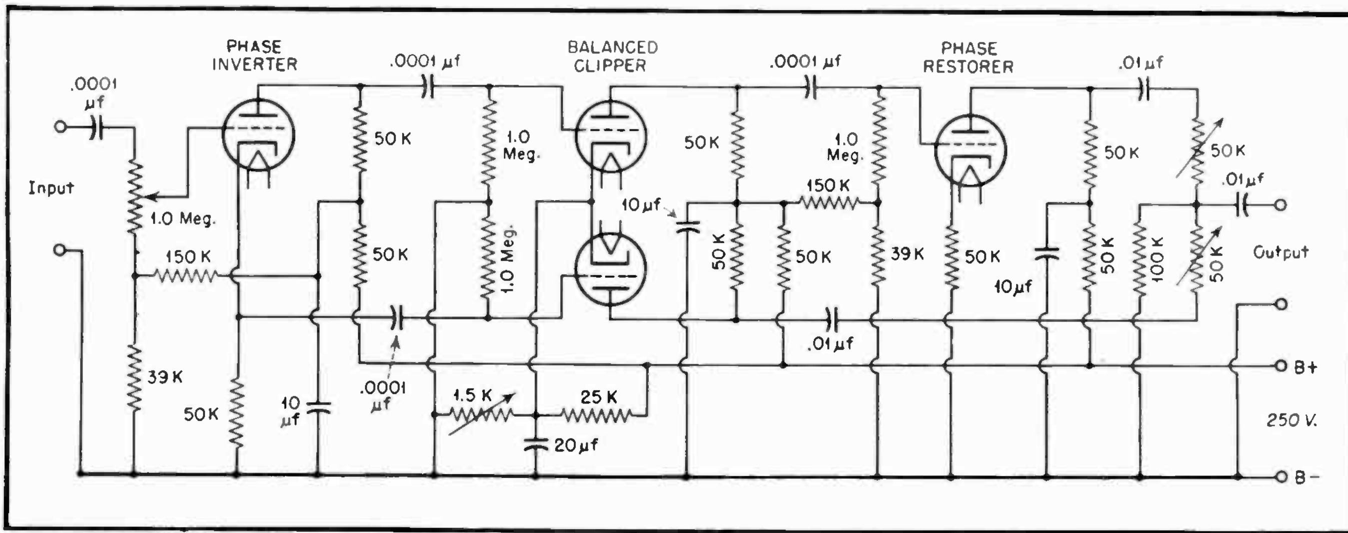

Fig. 4. This circuit may be employed to replace the transformer-terminated design shown in Fig. 3.

proper phase. With the second harmonic reduced to an acceptable level, the next order of distortion will be the third harmonic. The pass bands can then be designed to include slightly less than one and one-half octaves while still providing proper attenuation of the third and high harmonics.

The block diagram, *Fig. 2*, shows how the second experimental model was arranged to take advantage of this feature. *Fig. 3* is a circuit diagram of a suppressor which incorporates these ideas. R_1, R_2, and C_1 adjust the frequency response of the system to give an approximate flat amplitude to the surface noise of shellac records in accordance with Olson's data. V_1 builds the signal up to a level which places the surface noise signals just below the cutoff value of V_3; V_2 is a phase inverter; V_4 restores the energy lost in the preceding circuits. The output of V_4 is combined with the output of the low-pass filter in the correct relationship. R_3, R_4, and C_2 restore the frequency response of the system. V_3 in conjunction with T_2 is the balanced push-pull circuit described above.

The frequency response curve of this system is essentially flat up to 8 kc when adjusted for a normal amount of suppression. *Figure* 4 is a circuit to replace the transformer-coupled section including tubes V_2 and V_3.

Cathode followers were used in the experimental models because they conveniently matched the filters which were on hand. Better results will be had when band-pass filters are used preceding and following the clipper circuits. The use of band-pass filters, when used in place of the filters shown, will reduce intermodulation and will increase the effectiveness of the suppressor.

The block diagram in *Fig. 5* outlines a circuit which takes full advantage of the ideas brought out above. Note that the first crossover frequency in this arrangement appears at three thousand cycles per second, the second crossover appears at seven thousand cycles per second, and that the third harmonic of seven thousand cycles per second falls beyond the response of many amplifiers and speakers, and is beyond the normal hearing range. It then only becomes necessary to provide sufficient attenuation of the frequencies at the high-frequency limit of the higher frequency channel to guard against intermodulation in this stage.

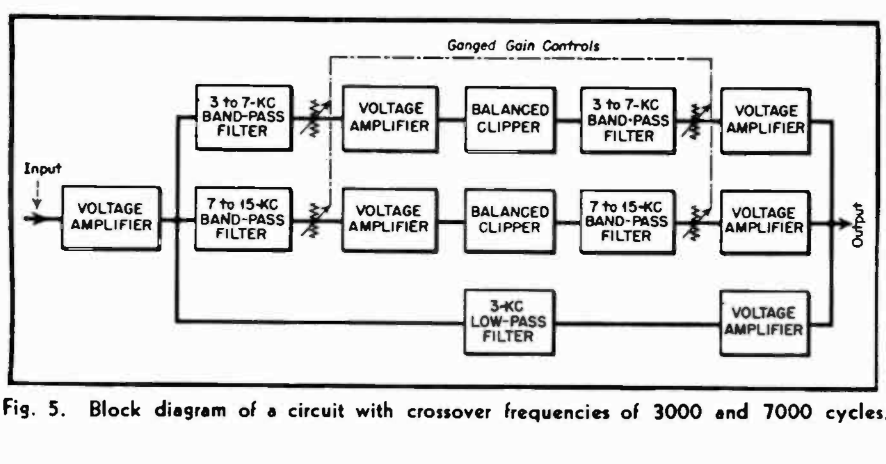

Fig. 5. Block diagram of a circuit with crossover frequencies of 3000 and 7000 cycles.

At the present time, little if any useful signal can be found above the surface noise at frequencies beyond twelve thousand cycles per second on available recordings. The high-frequency cutoff should therefore, appear just beyond twelve thousand cycles per second but can be extended to a higher frequency when recordings and pickups have developed to a point that will justify this extended range.

Reproducer Quality

In order that the advantages offered by this type of noise suppressor can be fully realized, high-quality performance of reproducers is essential. The units used for the experimental work and listening tests were of the variable reluctance type and were checked for their performance characteristics before they were put into service. Best results were obtained when compensation for recording characteristics was made before the signal entered the suppressor. Therefore it is not necessary to duplicate the correction equalizers in the suppressor.

Equalizers other than those needed for post recording response-frequency correction are not needed for reproduction of good recordings when the above suppressor is being used. Reproduction of recordings in fair condition is noticeably improved while recordings which are worn or gritty have no place in high quality reproduction systems. The problem of turntable rumble and low frequency noise reduction was not considered in this undertaking inasmuch as the problem has been dealt with elsewhere.

With increased use of materials which result in lower surface noise and with the marked improvements being made in reproducers, loudspeakers, and methods of noise suppression, the realization of higher quality reproduction from recordings is rapidly approaching.