The Dynamic Noise Suppressor

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This article describes the principles and circuits for the dynamic suppression of background noise developed by Hermon Hosmer Scott.

IN ALL METHODS of music reproduction, background noise is a limiting factor. In the reproduction of disc recordings, the irritation of needle scratch was accepted for many years as an evil unavoidably associated with wide range reproduction. Countless methods of eliminating the noise without affecting the brilliance of the reproduction were investigated and rejected.

Many engineers and listeners with a high degree of tonal appreciation found it necessary to develop a psychological rejection of the needle scratch in order to enjoy full range reproduction. This was so prevalent a concept that upon first hearing the Dynamic Noise Suppressor in action at the National Electronics Conference in 1946, many observers were incredulous to the point of refusing to believe that there was no trick involved in the demonstration. Others were so thoroughly "acclimatized" to the presence of scratch that they believed they were observing an appreciable change in the quality of reproduction when the scratch was removed, until they had listened repeatedly to the same passages with the dynamic suppression circuits in and out of the system.

The Dynamic Noise Suppressor will not remove all the background noise. It will not preserve all of the frequencies present in every record under conditions of maximum suppression. It *will* improve the signal-to-noise ratio incredibly, and with proper adjustment will preserve the band pass necessary for full range reproduction to a degree that makes it impossible for most listeners to observe a change in tonal quality even when the suppressor is rapidly switched in and out of the system during the playing of records. The reduction in noise obtained will vary with the hearing characteristics of the listener and with other factors of a psychological nature. Obviously, with a listener incapable of observing anything over 4000 cycles per second, the effective noise reduction will not be as appreciable as with one whose hearing has wide range response characteristics. As a practical matter, the reduction in high- and low-frequency noise is approximately 20 db. The losses involved in quality of reproduction are in an order of magnitude that places them in the category of laboratory observation. The design and construction of the noise suppressor for application in any particular amplifying system requires careful engineering, and the adjustment of the controls requires some experience in order to obtain optimum results.

There are countless possible variations of the basic circuits to fit special problems. Each manufacturer producing a Dynamic Noise Suppressor has developed switching and control facilities, as well as more or less elaborate circuits in accordance with the viewpoints of various engineers and the requirements of the equipment in which it is incorporated. There is also a certain amount of individual opinion as to the most desirable conditions of operation, which is typical of all equipment designed in the highly controversial field of audio engineering.

Fundamental Circuits

The fundamental circuits consist of controlled reactance tubes. In *Fig. 1* is shown a relatively simple Dynamic Noise Suppressor using one high-frequency and one low-frequency section. V_2 is designed to appear as a variable capacitance. In series with L_2 it forms a sharply tuned filter shunted across the system. The capacitor between grid and plate of the reactance tube in series with the grid return forms a phase shifting network. A portion of the signal passing through the system is thus applied to the grid so as to produce an alternating current in the tube that leads the signal voltage applied to the plate by 90 degrees. The magnitude of the voltage applied to the grid

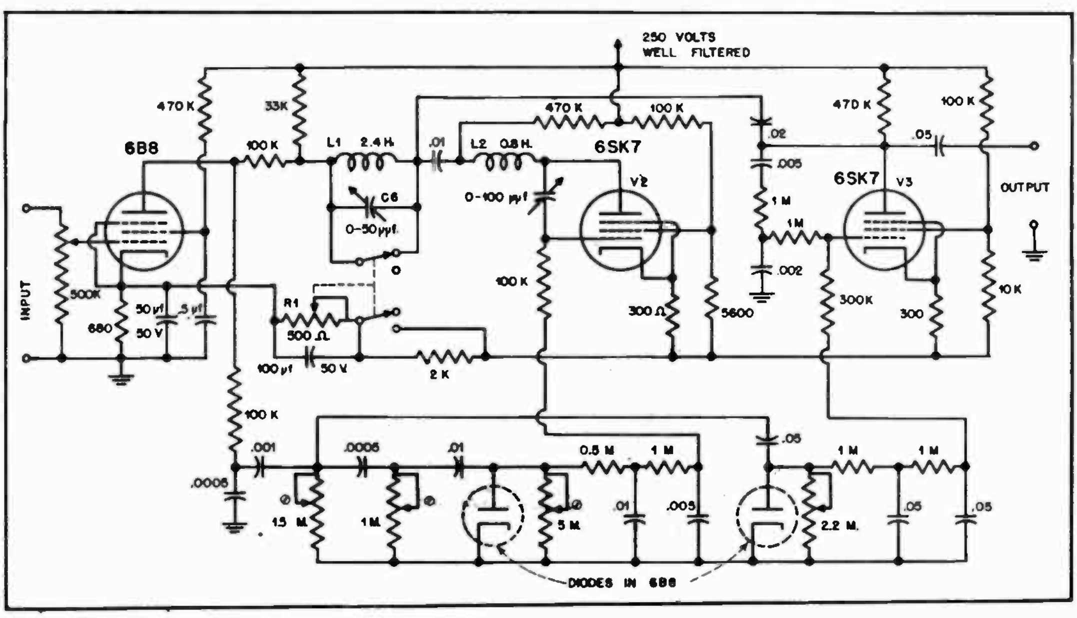

Fig. 1. Dynamic Noise Suppressor. Many variations of switching circuits are possible. R1 is often 5-position switch. Circuit parameters and component values are typical of designs for conventional home radio phonographs but are not necessarily identical to those used by any particular manufacturer. 6SJ7s are sometimes used as reactance tubes. Various voltage amplifier tube types may be substituted. 6H6 may be used for diodes.

at any frequency is a function of the impedance of the capacitor between grid and plate. Consequently the capacitive current through the tube and the effective value of the tube viewed as a capacitance will vary with the tuning of this capacitor and will change the resonant frequency of the series *LC* circuit.

The effective mutual conductance

$$\left(g_m = \frac{\Delta\, ip}{\Delta\, eg}\right)$$

of the tube under static conditions is a function of the screen voltage produced by the dividing network in the screen circuit and the cathode bias resistance, since these values determine respectively the plate current versus grid voltage curves and the static operating point. Increasing the effective mutual conductance creates the effect of making the tube appear as a smaller capacitance and tunes the circuit towards a higher frequency. The opposite effect is produced by lower-

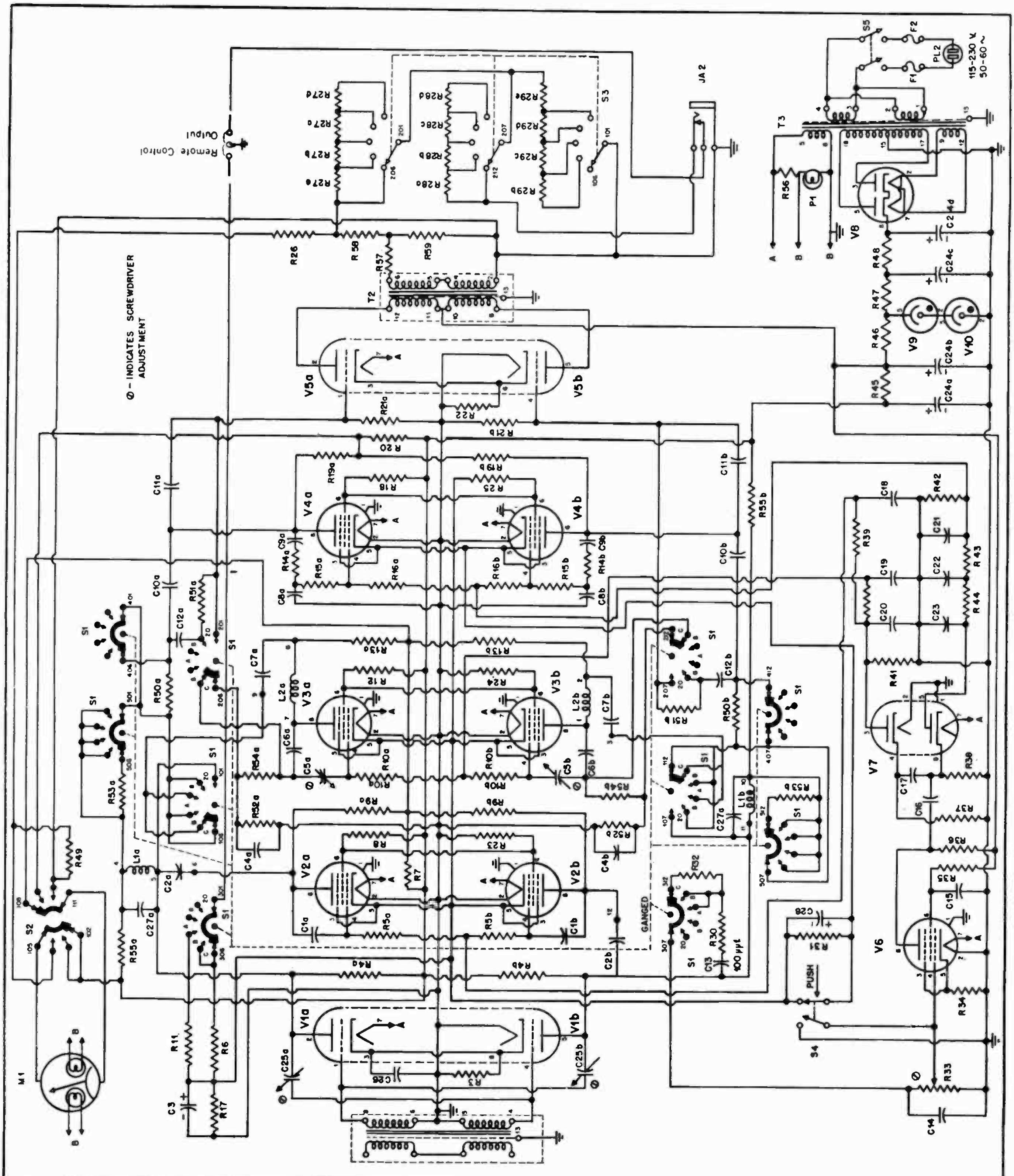

Fig. 2. The 910-A Dynamic Noise Suppressor for broadcast stations. Push-pull circuits conform to standard broadcast engineering practice with usual advantages of push-pull arrangements. Elaborate switching and remote control facilities aid in obtaining optimum conditions on wide variety of records with convenience to operation.

PARTS LIST

R_1 600

R_2 47

R_3, R_{22} 1000

R_{4a}, R_{4b}, R_8, R_{10a}, R_{10b}, R_{12}, R_{18}, R_{36} 0.1 meg

R_6 22

R_7 440

R_{9a}, $R9_b$, R_{13a}, R_{13b}, R_{19a}, R_{19b}, R_{30}, R_{35}, R_{37}, R_{38} 0.47 meg

R_{11} 110

R_{14a}, R_{14b}, R_{15a}, R_{15b}, R_{21a}, R_{21b}, R_{39}, R_{40}, R_{41}, R_{42}, R_{43}, R_{44} 1 meg

R_{16a}, R_{16b}, R_{32}, R_{52a}, R_{52b} 0.22 meg

R_{17} 2200

R_{20} 800

R_{23}, R_{31} 6800

R_{24}, R_{25} 5600

R_{26} 5500

R_{27}, R_{28}, R_{29} Output T-pad, special

R_{33} 0.5 meg

R_{34} 550

R_{45}, R_{48} 1000, 10-watt

R_{46} 470

R_{49} 3300

R_{50a}, R_{50b} 10,000

R_{51a}, R_{51b}, R_{54a}, R_{54b} 4.7 meg

R_{53a}, R_{53b} 15,000

R_{55a}, R_{55b} 0.33 meg

R_{56a} R_{50b} 5

R_{57}, R_{58} 235

R_{59} 687

C_{1a}, C_{1b}, C_{4a}, C_{4b} 200 $\mu\mu f$

C_{2a}, C_{2b}, C_{7a}, C_{7b}, C_{11a}, C_{11b}, C_{12a}, C_{12b}, C_{15}, C_{22}, C_{23} .01 μf

C_3 500 μf, 25 v.

C_{5a}, C_{5b}, C_{14} 100 $\mu\mu f$

C_{6a}, C_{6b}, C_{16} 2500 $\mu\mu f$

C_{8a}, C_{8b}, C_{9a}, C_{9b}, C_{18}, C_{19}, C_{20}, C_{21} 5000 $\mu\mu f$

C_{10a}, C_{10b} .02 μf

C_{13} 250 μf

C_{24} 20 μf, 4 sec.

C_{25a}, C_{25b} 7 $\mu\mu f$, dual unit

C_{26} 100 μf, 25 v.

C_{27a}, C_{27b} 15 $\mu\mu f$

C_{28} 25 μf, 25 v.

M_1 std. VU meter

T_1 TRAE-1 transformer

T_2 TRA4-1 transformer

T_3 TRIP-1 transformer

L_1 CHI-A (2 coils)

L_2 CHI-B (2 coils)

V_1 6SL7

V_{2a}, V_{2b}, V_3, V_4 6SK7

V_5 6SN7

V_6 6SJ7

V_7 6H6

V_{8b} 6X5GT

V_9, V_{10} OD3

ing the effective mutual conductance. The cathode bias, of course, tends toward degenerative self adjustment in terms of the signal and thereby affects the apparent Q of the entire circuit.

A portion of the input voltage to the system is obtained from V_1, which is simply a voltage amplifier stage, and is filtered and rectified through the d-c control circuits. The rectified voltage is applied to the grid of the reactance tube so that the mutual conductance is under dynamic control of the input signal. These filter circuits must be so designed that the control voltage is obtained from components of the signal in the upper fundamental range of the musical scale. Fortunately the region it is desirable to attenuate to reduce high-frequency noise is in the extreme upper fundamental and harmonic portion of the musical spectrum. Thus, whenever appreciable signal energy is present in the high-frequency region, there must be fundamentals present in the upper mid-range. If the control voltage is derived from the range it is desirable to attenuate, it becomes possible to drive the reactance tube "open" with the noise. If the control voltage is obtained from a low-frequency range where no appreciable high harmonic content exists, the "gate" is driven open during passages when there is only noise present in the high-frequency spectrum.

Time Constants

For proper operation of the suppressor it is essential that the control voltages be derived from carefully selected bands of frequencies. The time constants of the control circuits must be designed to provide rapid opening of the "gates" so that the brilliance of staccato passages and cymbal crashes will be maintained. The time constants controlling the "gate" closing are equally important. These values must permit sufficiently rapid closing to eliminate the hangover of needle scratch described as "swish," but must not close so abruptly as to have an appreciable effect upon the reverberation following abrupt crescendos. For optimum results on all types of records, elaborate systems may provide switching facilities for these components. The choice of these values is one of the important factors in eliminating any recognition of the gate action by the listener.

Tube Adjustment

The potentiometer in the cathode circuits is used to adjust the static mutual conductance of the reactance tubes, thus setting the minimum band pass. It will be clear that many different tube types may be used for the reactance tubes with somewhat different results and requiring, of course, an adjustment of component values for optimum conditions.

The low-frequency reactance tube V_3 is designed with a phase shifting voltage divider in its plate to grid circuit such that the signal developed on the grid produces an alternation of the current through the tube that lags the voltage signal applied to the plate by 90 degrees. This circuit appears as an inductive reactance shunted across the system. The effective mutual conductance of the tube is varied by a control voltage applied to its grid, thus tuning the inductive current to produce varying degrees of low-frequency attenuation.

To produce the most desirable results, the high-frequency circuits are designed for sharp cut-off characteristics. The low-frequency circuits do not require such sharp attenuation but should be somewhat steeper than that obtained with the usual RC arrangements. Clearly, the low-frequency control voltage must be obtained from a portion of the spectrum that does not include high-frequency fundamentals, but must not be developed from low frequencies in the range of motor rumbles and other noises it is desirable to attenuate.

In these, as in all analogous filter circuits, the shape of the curves, particularly with regard to steepness of cut-off, will be considerably affected by the input and output terminating impedances.

The tuned circuit consisting of L_1 and C_6 is adjusted to produce sharp cut-off in a region between 10 kc and 16 kc, depending on associated designing. The purpose of this circuit is to attenuate all frequencies beyond the maximum pass band and to eliminate noise that might appear in a region where the resonant curve of the reactance tube circuit rises above its point of sharpest tuning. Obviously it is possible to tune a single reactance tube circuit only over a limited range with the control voltage available. In the more elaborate systems, an additional high-frequency reactance tube is used to permit a wider maximum pass band and tuning of the fixed filter to 16 kc. Theoretically, this principle could be carried on indefinitely if there were any application where frequencies reaching into the ultrasonic range were to be included in the maximum pass band. In the simpler systems, or through switching arrangements, it is often desirable to tune the fixed filter to 10 kc in order to eliminate heterodyne whistles from adjacent radio channels when used for radio reception.

In table model sets, where the low-frequency cut-off is sufficiently high to eliminate motor rumble, a one-tube Dynamic Noise Suppressor consisting of a single high-frequency reactance tube circuit is often adequate. Many engineers have been so plagued with high-frequency needle scratch for years that they have paid little attention to low-frequency motor rumble as a serious factor with reasonably good motor mountings. In experiments with various versions of the Dynamic Noise Suppressor it has been found that elimination of the high-frequency noise immediately makes the low-frequency noises more apparent and more irritating. For this reason alone the low frequency circuit is well worth including. Actually, it is essential to include the low-frequency section for reasons associated with maintaining a correct aural balance. It is well known that the characteristics of human hearing are such that a band pass of correct balance is more acceptable than an extension of either end of the spectrum when one end is attenuated. This is usually expressed in terms of the product of the lowest and highest frequencies in the pass band. By proper coordination of the high and low frequency reactance sections and their associated control circuits, it is possible to maintain a very satisfactory balance in the action of the Dynamic Noise Suppressor. In high-quality systems this characteristic is imperative if satisfactory results are to be obtained.

Other Advantages

There are a number of secondary advantages obtained with the Dynamic Noise Suppressor. Among these is the fact that tendencies toward oscillation through mechanical or acoustic coupling in systems with extended low frequency response are greatly minimized. In the reception of recorded programs from radio stations, particularly FM, where the noise suppressor is not used in the transmitting system, the background noise may be limited just as effectively as in phonograph operation. Other types of interference, such as tube noises in pre-amplifiers, transmission line noises, hum and ordinary static, are greatly reduced in nuisance value.

The remarkable results obtainable with properly designed and operated dynamic noise suppressors are aided considerably by inherent characteristics of human hearing and by the structure of musical sounds. Most music contains passages where the required pass band is very limited. It is also true that the frequency response range of the ear is greatly restricted at low intensity levels. Under many conditions of playback, listeners find it desirable to operate the reproducing equipment at high average intensity levels. Under these circumstances the observed noise level during quiet passages of the music or during intervals between notes is particularly distracting.

It is this latter circumstance that makes it possible to produce limited noise reduction with volume expanders and other "vertical" noise suppressors. These systems operate on a variation in amplitude of the entire (or block portions of) the frequency spectrum. For various reasons, including the fact that the control voltages are not derived from limited frequency bands, these systems are generally inadequate. This is particularly evident in connection with abrupt transients, such as the sharp clicks that characterize noise developed by vinylite and similar record materials. One form of vertical noise suppressor is a selective volume expander where the frequency spectrum is divided into three channels. The high and low-frequency channels may be independently driven by obtaining the control voltage after the dividing networks. A serious disadvantage is the fact that the entire high and low frequency ranges are opened "vertically" when only a limited portion may be needed for full range reproduction. An inverse form of this effect has been described.[1]

Pass Band

The Dynamic Noise Suppressor is of the "horizontal" type, providing dynamic adjustment of the pass band from approximately 2½ octaves to full range. This means that the signal-to-noise ratio is optimum at all times in terms of the instantaneous requirements of the music versus background noise. In broadcast work and in some home radio-phonograph installations, it is advantageous to be able to extend the controls electrically for remote operation. Fortunately, the controlled components are in portions of the circuits to facilitate this arrangement.

The most convincing evidence of the success of this method of noise suppression is actual demonstration. Many devices that work wonders in the laboratory do not prove successful in the field. The Dynamic Noise Suppressor is no longer questionable in this regard for it has withstood the test of widespread installation in radio stations and in home radio-phonographs and has won wide acclaim among engineers and music critics. It is of some importance to emphasize that the effectiveness of the results obtained may sometimes be limited by associated components and economic compromises in design policies. A serious problem in the industry is the selection and training of sales personnel in dealers' stores to learn enough about the merchandise they sell to make effective demonstrations and to instruct their customers properly. The finest radio-phonograph, with or without a Dynamic Noise Suppressor, makes a poor showing if it is improperly operated.

The Dynamic Noise Suppressor does not eliminate the value of tone control circuits, but, on the contrary, makes it possible to operate high and low boosting circuits without the usual attendant increase in noise level. It will not produce music from blocks of concrete, but it will produce the most music and the least noise possible from any given record.

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1. Goodell, John D., and Michel, B. M. H., Auditory Perception, *Electronics*, July 1946.