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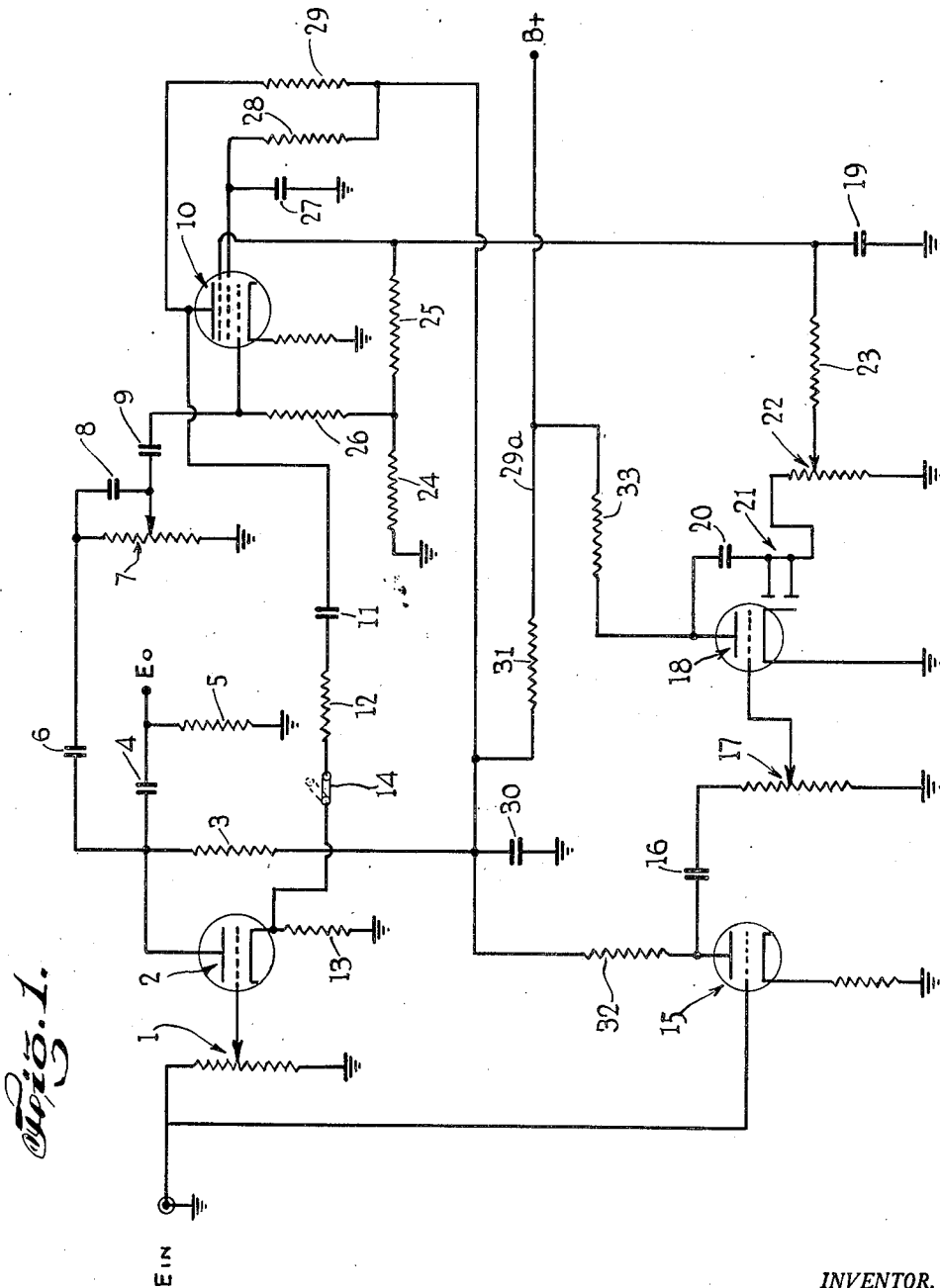
A. D. BIELEK

2,541,326

DYNAMIC NOISE AND SCRATCH SUPPRESSION

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4 Sheets-Sheet 1



INVENTOR.
ALFRED D. BIELEK
BY *Harold Weber*
ATTORNEY

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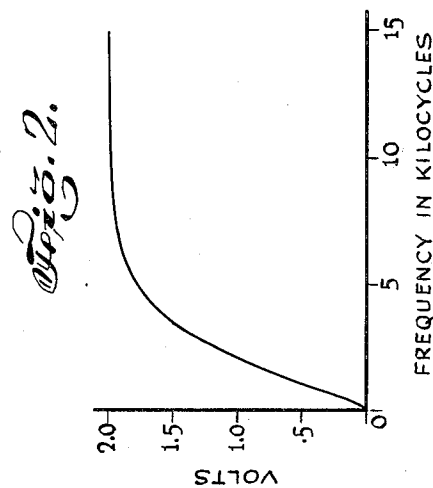
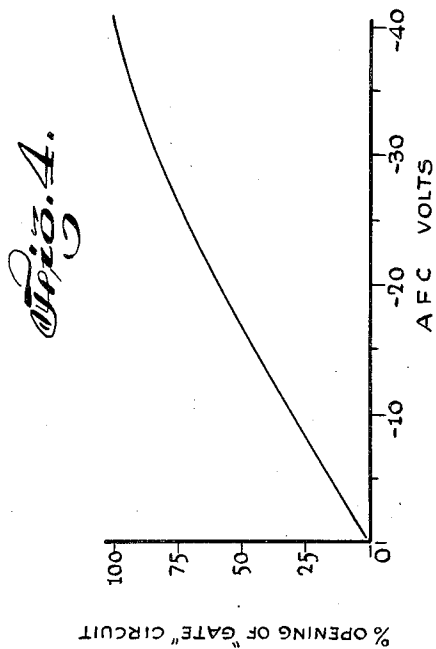
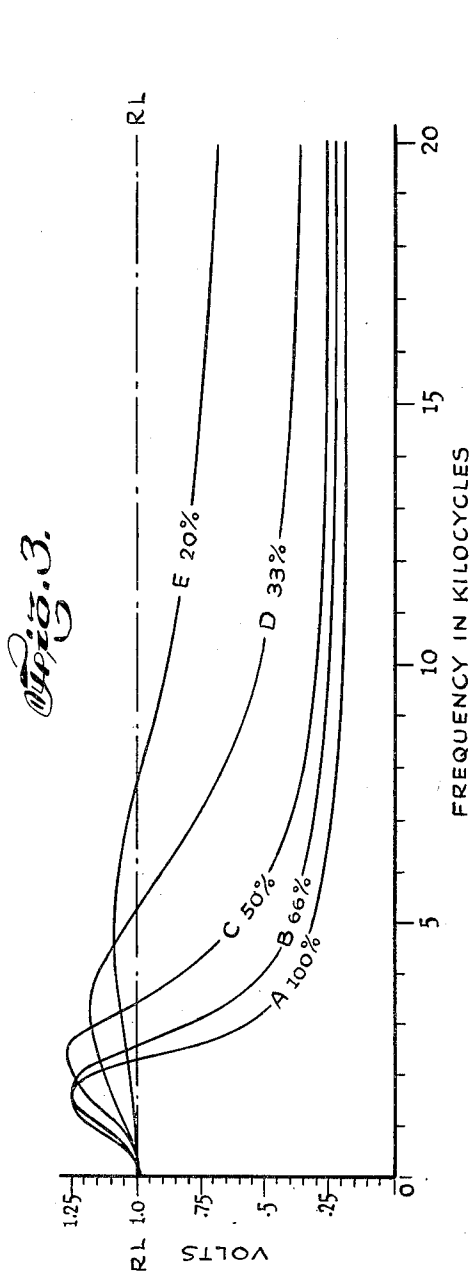
A. D. BIELEK

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DYNAMIC NOISE AND SCRATCH SUPPRESSION

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4 Sheets-Sheet 2



INVENTOR.
ALFRED D. BIELEK
BY *Alfred D. Bielek*
ATTORNEY

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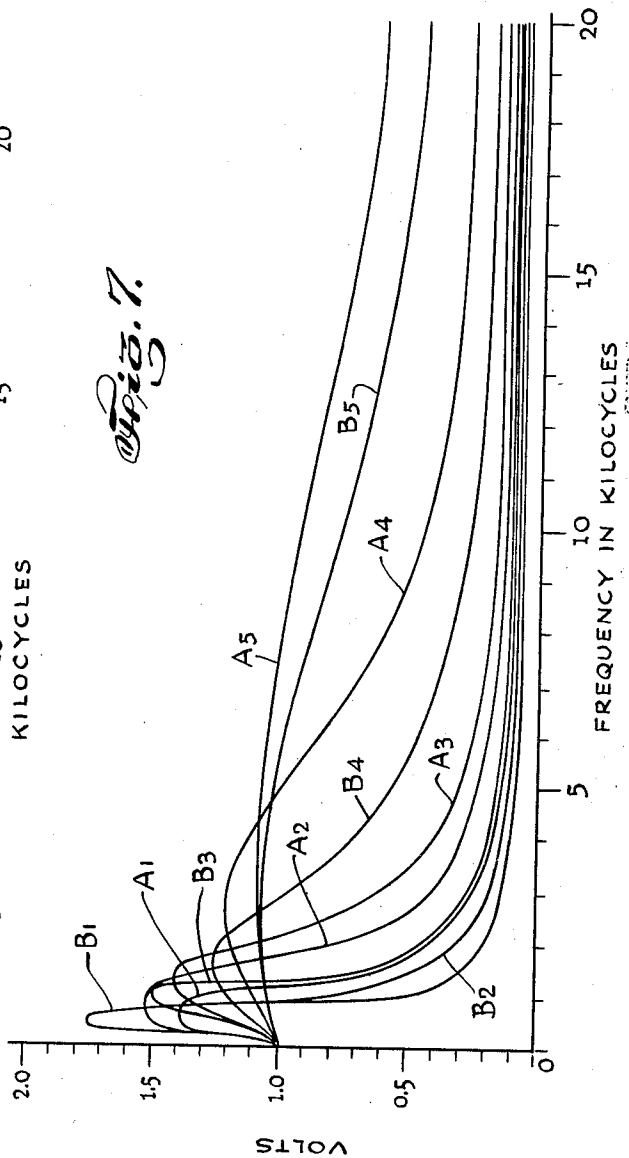
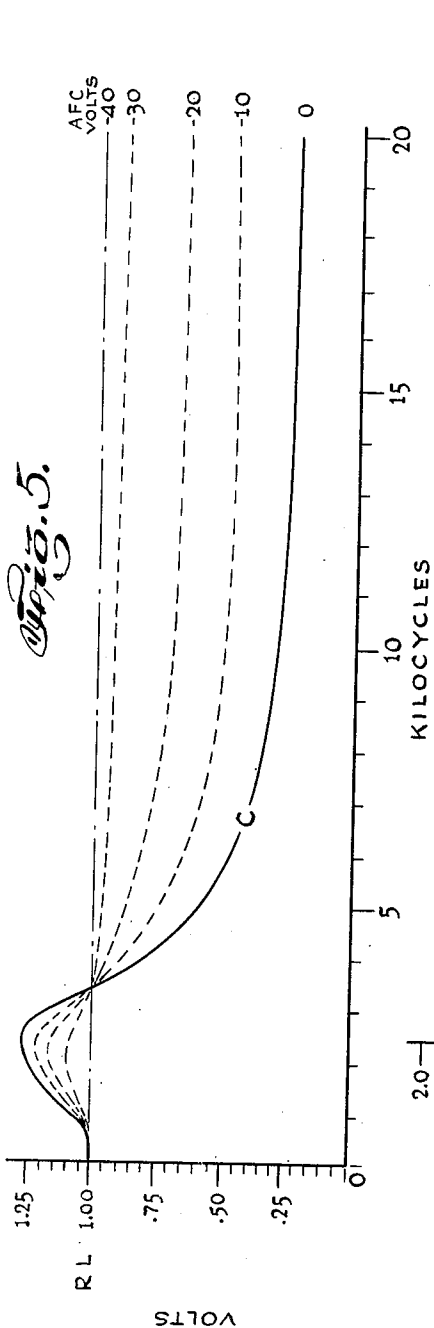
A. D. BIELEK

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DYNAMIC NOISE AND SCRATCH SUPPRESSION

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4 Sheets-Sheet 3



INVENTOR.
ALFRED D. BIELEK
BY *Paul H. Weber*
ATTORNEY

Feb. 13, 1951

A. D. BIELEK

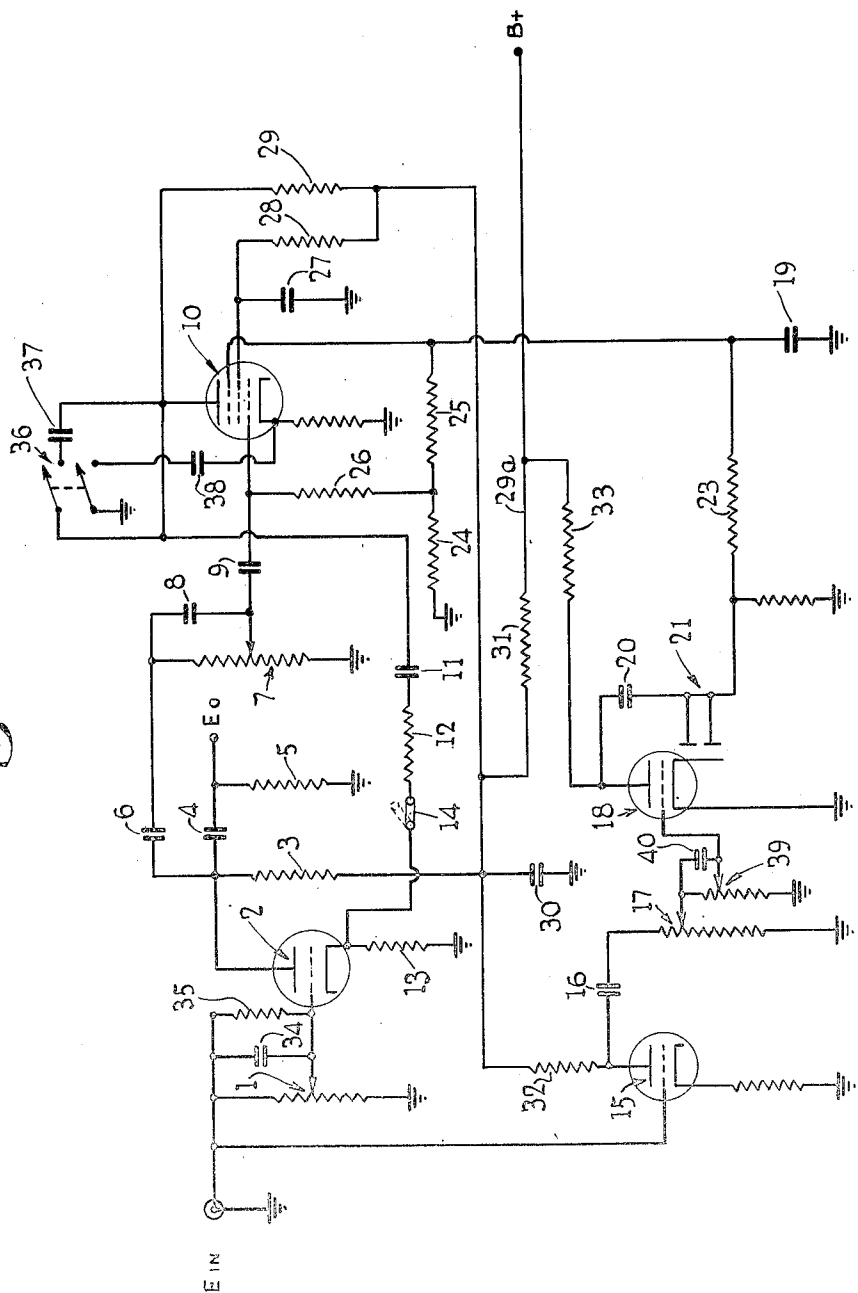
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4 Sheets-Sheet 4

Fig. 3.



INVENTOR.
ALFRED D. BIELEK
BY *Alfred D. Bielek*
ATTORNEY

UNITED STATES PATENT OFFICE

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DYNAMIC NOISE AND SCRATCH
SUPPRESSION

Alfred D. Bielek, Nutley, N. J.

Application December 3, 1948, Serial No. 63,321

4 Claims. (Cl. 178—44)

1

The present invention relates to an apparatus for the suppression of audible noise distortion in the reproduced or amplified reception of music, etc., and more particularly to an electrical feedback type dynamic noise and scratch suppressing apparatus.

Various devices have been proposed to improve the transmission of music, speech, etc., by reducing the audible distortion of sounds due to atmospheric disturbances and scratch noises, e. g. scratch noises of phonograph recordings. Generally, such devices deal with filtration means whereby all frequencies above or below an established cut-off are suppressed. The established cut-off, being effective within the audible frequency range, greatly reduces noise at, for example, the higher frequencies within the audible range, with, however, an accompanying suppression of other desirable sounds above the cut-off point. A manual control is usually provided to produce selective cut-off in the audible range. A control for such cut-off has heretofore usually been horizontal in performance in that the manual manipulation of the control means results in a series of sharp cut-offs, for example at selective frequencies, which, when illustrated graphically, indicate a horizontal performance of the cut-off control system along the audible frequency range. Suppression, which is controlled horizontally with a sharp cut-off, eliminates the harmonic content and musical timbre in the higher audible frequencies above the cut-off—as in the case of the reproduction of amplification of music whereby the sounds of certain musical instruments are eliminated. Moreover, a sharp cut-off is undesirable because of a break in the continuity of tone transmissions, which results not only in the loss in the effect of certain musical instruments, e. g. cymbals, but in a total loss of higher harmonics.

A dynamic noise suppressor apparatus of the sharp cut-off and horizontal bandpass type generally comprises Hi-Q tuned L. C. circuits, which produce a change in suppression characteristics with signal level, and, therefore, produces rapidly varying frequency cut-off points with constant suppression above and below the cut-off. In such apparatus, which is designed to keep the noise level practically inaudible, the choice between high fidelity and noise is limited to either almost full reproduction of the audible range or almost total elimination of the noise level with a loss of higher harmonics and musical timbre. Such limitation, due to the horizontal performance of the control means, does not result in high fidelity

2

and the retaining of harmonics and musical timbre. Consequently, the listener is apt to choose the full reproduction of the audible range because of the shortcomings of such type of filtered system. Moreover, the design of horizontal bandpass dynamic noise suppressors is such that full range audio reproduction cannot be obtained unless the suppressor is completely removed from the circuit.

It is one object of this invention to provide an apparatus for the suppression of undesirable audible noise and distortion. It is another object of this invention to provide an electrical feedback type dynamic noise and scratch suppressing apparatus. It is a further object of this invention to provide an apparatus which will retain harmonic content and musical timbre of the audible frequencies beyond a variable frequency cut-off point. It is a still further object of this invention to provide a suppression apparatus of comparatively simple construction, great flexibility of use, and which can be set to operate for long periods of time under average reproducing conditions without resetting and adjustment. Other objects and advantages of this invention will become apparent from the description herein after following and the drawings forming part hereof, in which:

Fig. 1 illustrates a schematic diagram of a dynamic noise and scratch suppressor according to the invention,

Fig. 2 illustrates the curve characteristics of an embodiment of this invention,

Fig. 3 illustrates the curve characteristics according to different settings of an embodiment of this invention,

Fig. 4 illustrates the curve characteristics of the action of another embodiment of this invention,

Fig. 5 illustrates the curve characteristics of vertical suppression according to the invention,

Fig. 6 illustrates a schematic diagram of a dynamic noise and scratch suppressor including the combination of various preferred embodiments, and

Fig. 7 illustrates the curve characteristics of a preferred embodiment in combination with the dynamic noise and scratch suppressor of this invention.

According to the present invention, suppression of audible distortion, instead of being controlled horizontally with a sharp cut-off at the cut-off frequency—thus eliminating harmonic content and musical timbre—is controlled vertically from a fixed but manually variable cut-off frequency point beyond which all higher frequencies are at-

tenuated but not eliminated. Thus, the harmonic content is retained and the musical timbre is preserved while all audible noise and distortion are effectively suppressed. The apparatus features suppression of audible noise in a simple manner with a complete absence of tuned L. C. circuits which introduce change in suppressor characteristics with time. In the case of musical transcriptions and high quality shellac records, the apparatus of the invention reduces scratch noise to a negligible level so that it is extremely difficult to distinguish any surface noise or loss of high response at low amplitude levels even from a no-suppression condition, while loss of scratch and other noises are very pronounced.

Referring to Fig. 1, an input signal is applied across the potentiometer 1, which is set to apply a fraction of the input voltage, e. g. $\frac{1}{10}$ of the input voltage, to the electronic amplifier 2. This amplifier may have a voltage gain of, for example, ten times the fractioned voltage applied to the amplifier. Where the potentiometer is set to apply $\frac{1}{10}$ of the input voltage to the amplifier and the amplifier has a voltage gain of ten, then the output voltage of the amplifier will equal the input voltage applied across the potentiometer, or will control the voltage in the apparatus at this stage to zero db gain. However, where the input voltage from one source may differ from that of another, the potentiometer may be reset so that an amplifier with a voltage gain of ten can bring up a -20 db signal to zero dbm, which is the normal operating level. This control permits great flexibility of operation in regard to input and output voltages. A suitable resistance 3 is provided as a plate load for the amplifier 2, and the capacitor 4 together with a substantially high ohm resistor 5 comprise a high impedance output termination for the amplifier 2. The amplifier signal, e. g. a zero dbm signal, is transferred from the plate load 3 of the amplifier 2 through the capacitor 6 to the potentiometer 7, which is actually the control means for dynamic scratch noise suppression. The capacitors 6 and 8 and the potentiometer 7 are a frequency determining network which acts as a variable high-pass filter having a low frequency cut-off of about 2500 cycles when the arm of the potentiometer is at a maximum clockwise position. The characteristic of this network is such that amplitude increases with frequency so that essentially full amplitude is transmitted through the network from about 5000 cycles and upward. As the arm of the potentiometer is rotated counter-clockwise, the low frequency cut-off through the network increases gradually to about 6000 cycles, while maintaining the frequency pass characteristic above 10,000 cycles per second within -3 db of the maximum position amplitude level. Increasing counter-clockwise rotation beyond approximately 70% merely decreases the overall amplitude of the transmitted frequency band while only slightly altering the low-frequency cut-off point. The control, or potentiometer 7, may be manipulated so that a signal input of zero to maximum can be applied through the decoupling capacitor 9 to grid No. 1 of the amplifier 10. The amplifier 10 is a variable gain tube or a super-control variable gain amplifier essentially Class A in operation with a maximum voltage gain of about ten with a low impedance load. It applies a high frequency feedback signal of varying amplitude through the capacitor 11 and the resistor 12, which are elements of a

frequency determining network of high-pass characteristics with a low frequency cut-off of about 2500 C. P. S., as more particularly illustrated by Fig. 2, and which, in conjunction with the network 6, 7 and 8, produces a fairly sharp cut-off characteristic at the lowest frequency point of the potentiometer 7. The feedback signal then goes to the cathode of the amplifier 2, forming a variable degenerative circuit which is most effective at the higher audio frequencies which fall within the scratch or noise distortion bands. The feedback signal is in phase with the A. C. voltage across a substantially low impedance 13 provided as the terminal of the cathode of the amplifier 2 in the feedback circuit. The switch 14 is an "on-off" switch positioned in the feedback voltage line. However, the switch may be positioned at any applicable position, preferably in the feedback circuit.

Simultaneously with the impression of voltage across the potentiometer 1 to the amplifier 2, a full input voltage is applied to the grid of the amplifier 15, which is an automatic frequency control voltage amplifier having a voltage gain of about 10, and the amplified voltage passes through the capacitor 16 to the potentiometer 17, the capacitor 16 and the potentiometer 17 forming a high-pass network to attenuate all frequencies below 1000 C. P. S. The band of passed frequencies is then applied to the grid of the amplifier 18, which, for example, may have a voltage gain of about forty-five. Potentiometer 17 is preset in an individual amplifier system so that an AFC voltage of -40 volts may be developed across the capacitor 19 for peak amplitudes in the higher frequency region of, for example, average commercial records. This -40 volts potential is sufficient to cause complete cut-off of the amplifier 10. However, before the -40 volts potential reaches the capacitor 19, it is applied to the grid of said amplifier 18, having a grounded cathode and acting as an AF amplifier-diode detector, through the capacitor 20 and the diode rectifier 21, which causes a rectified D. C. voltage to be developed across the potentiometer 22, which is a variable potentiometer so that any potential from 0 to -40 volts AFC voltage can be applied to the amplifier 10, and through the resistor 23 which, in conjunction with the capacitor 19, forms a high frequency filter network. The system 19, 22 and 23 is a frequency expansion control enabling a controllable cut-off characteristic for the amplifier 10 so that a zero to a fully open

"gate" action can be obtained on peak passages.

Since the capacitors 16 and 20 and the potentiometers 17 and 22 attenuate all frequencies below 1000 C. P. S., no "gate" action in the amplifier will occur until sufficient high frequency components are present to mask undesirable noise or, for example, record scratch. The filter network 19 and 23 has a time constant of about .22 second which, according to the present invention, is an optimum time constant to prevent excessively rapid "gate" action so that there is no rush or "popping" audible, so that there is no loss of timbre due to a too rapid closing of the "gate" circuit, and so that all A. C. components are adequately removed from the D. C. control voltage—which would otherwise cause a distortion of the feedback signal.

Having thus provided an AFC voltage control system to operate in combination with the high frequency feedback system hereinbefore described, I apply such AFC voltage to grid No. 1

and grid No. 3 of the amplifier 10. The AFC voltage to grid No. 3 is the total AFC controlled voltage, e. g. -10 volts, if enough signal is present to develop -10 volts. However, because I provide a divided network, illustrated by the resistors 24 and 25, only a fraction of the AFC voltage is applied to grid No. 1 of the amplifier 10 through the resistor 26. The fraction of the dividing network 24 and 25 may be for example, a five to seven ratio of the AFC voltage, which is a constant fraction, or it may be any other suitable fraction as long as it remains non-variable. Therefore, if the total AFC controlled voltage is -10 volts, the voltage applied to grid No. 1 would be -7.1 volts. Since the ratio is constant, a linear rate of rise of AFC voltages would normally produce a substantially straight line gate characteristic, but due to the saturation of amplifier 18, starting at about 25 volts with complete saturation at -40 volts, a modified logarithmic control of the feedback voltage to amplifier 2 is provided. When no signal is present, no AFC voltage is developed and suppression is maximum according to the setting of potentiometer 7. For example, Fig. 3 illustrates the various maximum suppressions according to the different settings of potentiometer 7 as seen visually on an oscilloscope screen, the line RL being the reference line at no suppression, ABCDE showing the curve characteristics for settings of the potentiometer 7 at 100%, 66%, 50%, 33% and 20% of maximum clockwise rotation respectively with suppression at 15 kc. being 14 db, 12 db, 8 db and 1.70 db respectively. As a signal is developed, for example from a record, low levels of music and scratch noise (even if of a comparatively high level) will produce only very slight opening of the "gate" of amplifier 10. As high content is increased, AFC voltage increases at a linear rate to about 50% open "gate," and then, due to logarithmic scaling, the "gate" opens less rapidly. This "gate" action is particularly illustrated graphically by Fig. 4, which also shows that when highs approach their peak level the gate circuit opens even still more slowly, being wide open at peak levels or at -40 volts potential which causes a complete cut-off of the amplifier 10.

Therefore, when the AFC voltage control circuit is activated by an input signal, the feedback voltage to amplifier 2 is varied so that at, for example, 66% of maximum clockwise rotation of potentiometer 7 (Figure 3), a vertically controlled suppression characteristic is obtained whereby the suppression curve as shown with zero AFC voltage is altered with changes in the AFC signal. For example, at 66% clockwise rotation with zero AFC voltage, the suppression at 15 kc. is approximately 12 db. However, while still maintaining 66% clockwise rotation of potentiometer 7, and with an application of AFC signal, the suppression will decrease from 12 db to zero db according to the strength of the AFC signal components. Figure 5 illustrates the vertical performance of the suppression curve, e. g. curve C of Figure 3 with 66% clockwise rotation of potentiometer 7 under changing voltage control signals of -10, -20, and -30 AFC volts.

The screen grid B+ potential of the gate control circuits is returned from the amplifier 10 through a decoupling filter formed by the capacitor 27 and resistor 28 and in conjunction with the load resistor 29 to the B+ potential bus 29a. Amplifier 15 is returned through the load resistance 32 to the B+ bus. The B+ bus is then returned to the B+ potential source through an-

other decoupling filter formed by the capacitor 30 and resistor 31. The amplifier 17 circuit is returned through the load resistor 33 directly to the B+ potential source.

Therefore, according to the combination comprising the high frequency feedback system and the AFC voltage control system hereinbefore described, it is apparent that I have provided an electrical feedback type dynamic noise and scratch suppressing apparatus whereby suppression is controlled vertically from a fixed but manually variable cut-off frequency point beyond which all higher frequencies are attenuated but not eliminated.

The dynamic noise and scratch suppressor hereinbefore described comprises the basic apparatus of my invention. I have, therefore, provided a preferred embodiment involving the basic combination of AFC voltage control and high frequency feedback systems heretofore set forth. The preferred embodiment is particularly described in accordance with Fig. 6. Figure 6 in comparison with Fig. 1 shows the addition of a filter formed by the capacitor 34 and the resistor 35 for the purpose of eliminating a possible Miller effect across the potentiometer 1 when the potentiometer is set for various positions below maximum. As much as 6 db attenuation of the input signal at about 15 kc. could exist without the added filter. With this filter, a flat response is produced to within 1 db at all settings of the potentiometer.

With respect to recordings, experimentation has shown that it would be desirable to have two characteristic suppression curves—one for new or high quality recordings and one for old or badly worn recordings. Therefore, switch 36 has been provided in combination with capacitors 37 and 38 in parallel, primarily for use with old or badly worn recordings. When the switch 36 is open, the capacitor 37 is not activated and this position produces the best fidelity vs. noise reduction characteristic for high quality recordings, while when the switch is closed, the frequency cut-off point is lowered, for example from 2500 cycles to 1500 cycles, the capacitor 38 by-passes the cathode resistor of the amplifier 19 and thereby increases maximum suppression from about 4 db to about 22.5 db at 15 kc., the total effect of which is the best fidelity vs. noise for old recordings. It is, therefore, apparent at this stage that the high frequency system of Fig. 5 differs from the high frequency feedback system of Fig. 1 in that a second switch 36, capacitors 37 and 38, and a filter network (capacitor 34 and resistor 35) have been added. The characteristic curves of such addition, in combination with the feedback circuit hereinbefore described, are illustrated by Fig. 6, wherein the lines A1, A2, A3, A4 and A5 denote suppression when switch 36 is open, and lines B1, B2, B3, B4 and B5, denote suppression when switch 36 is closed.

Referring to the AFC voltage control system of Fig. 5, the potentiometer 39, being identical to potentiometer 22 of Fig. 1, has been moved to a new location and capacitor 40 has been added. Previously, turning potentiometer 22 (Fig. 7) from its maximum position would limit maximum gate opening to the percentage its arm was removed from ground. In its new position, when potentiometer 39 is turned partway down, the threshold sensitivity is reduced, but fully open gate action can still be obtained with a higher signal voltage, e. g. as in the case of old

recordings. Otherwise, its control over gate action is substantially the same as in potentiometer 22 of Fig. 1. The addition of capacitor 40, however, will cause a change in the frequency characteristic of the D. C. gate control voltage. Such change being that there is no effect when the arm of the potentiometer 39 is at the top position, but that when the potentiometer is rotated counter-clockwise, the capacitor 40 passes audio frequencies above 5000 C. P. S. as if the arm were almost fully clockwise and at the same time attenuates frequencies below 5000 C. P. S. at an increasing rate so that at about 2000 cycles and lower the potentiometer acts as if the capacitor were not present. The value of this action, which ceases to be apparent when the arm of the potentiometer 39 is rotated more than 70% clockwise, becomes most apparent on recordings which are of high quality but which have more than the usual surface noise, and most particularly when reproducing piano recordings. Due to the nature of a piano, most of its sound output falls below 6000 C. P. S. and little harmonic content is generated. Add to this the fact that it is of a pizzicato nature, and it becomes apparent that at the occurrence of loud passages the gate will open, but insufficient high frequency sounds will be present to properly mask the noise level of the record material. Therefore, in loud piano passages, swishes may be heard during and after each loud note. By rotating the potentiometer 39 counter-clockwise to about 30%, with capacitor 40 in the circuit, this effect is virtually eliminated and sufficient gate action is provided for musical realism and brilliance.

Therefore, while other types of dynamic noise suppressors, e. g. suppressors controlled horizontally with sharp cut-offs, will produce more complete elimination of surface noise with an accompanying destruction of musical presence, the present invention provides a dynamic noise suppressor controlled vertically which enhances musical quality by reducing surface or other noises to the point where they can be dismissed as negligible and yet retain all the musical values with no noticeable destruction of their quality.

What I claim is:

1. A dynamic noise and scratch suppressing apparatus comprising in combination, a high frequency feedback system connected to a source of input voltage by means of a variable potentiometer connected in series with said source of voltage, said feedback system including an amplifier for controlling the input signal at a desired level and a variable gain amplifier for applying a high frequency feedback signal to the cathode of said signal controlling amplifier to form a degenerative feedback circuit, said signal controlling amplifier having an anode connected in series to a grid of said variable gain amplifier through a variable high-pass filter comprising a capacitor in series with a resistor means for selecting a suitable cut-off frequency, the anode of said variable gain amplifier connected in series to the cathode of said signal controlling amplifier through a network of high-pass characteristics comprising a capacitor in series with a resistor; and an automatic frequency control system including a first amplifier connected in series with said source of voltage for applying a full input voltage to a high-pass network in series therewith for attenuating all frequencies below 1000 cycles per second, said high-pass network being connected in series to the anode of said amplifier

and comprising a capacitor in series with a potentiometer set to apply up to the maximum potential necessary to completely cut off said variable gain amplifier of said feedback system, a second amplifier in series with said potentiometer, a rectifier in series combination with the anode of said second amplifier for providing an amplified band of passed frequencies with D. C. voltage to said variable gain amplifier of said feedback system through a time constant filter consisting of a resistor in series with a capacitor, said time constant filter being connected in series with a plurality of resistors arranged to apply a fraction of the total frequency control voltage to a grid of said variable gain amplifier of said feedback system, said plurality of resistors being under the saturation influence of said second amplifier-rectifier combination to produce an automatic gate action of said feedback variable gain amplifier according to a signal passed through said frequency control system.

2. A dynamic noise and scratch suppressing apparatus comprising a high frequency feedback system in combination with an automatic frequency control system according to claim 1, wherein suppression is controlled vertically by means of said resistor means for selecting a suitable cut-off frequency, e. g. a variable potentiometer in conjunction with said combined high frequency feedback and automatic frequency control systems, the signal of said high frequency feedback systems being influenced by the signal of said automatic frequency control system whereby suppression is characteristically vertical in performance according to the strength of the automatic frequency signal components.

3. In a dynamic noise and scratch suppressing apparatus according to claim 1, the combination comprising a filter network connected between said voltage source potentiometer and said signal controlling amplifier, said filter network consisting of a resistor shunted by a capacitor and connected to the grid of said amplifier for providing a flat response at all settings of said potentiometer, switch means for providing the best fidelity against noise reduction for both high quality recordings and old recordings, said means connected in series between said network of high-pass characteristics and the anode of said variable gain amplifier, a potentiometer in combination with a capacitor in the automatic frequency control system between said cut-off potentiometer and said second amplifier-rectifier combination for passing frequencies attenuated below 5000 cycles per second.

4. A dynamic noise and scratch suppressing apparatus comprising in combination, a high frequency feedback system connected to a source of input voltage through a variable potentiometer connected in series with said source of voltage and a filter network in parallel with said potentiometer for providing a flat response at all settings of said potentiometer, said feedback system including an amplifier for controlling the input signal at a desired level and a variable gain amplifier for applying a high frequency feedback signal to the cathode of said signal controlling amplifier to form a degenerative feedback circuit, said signal controlling amplifier having an anode connected in series to a grid of said variable gain amplifier through a variable high-pass filter comprising a capacitor in series with a resistor means for selecting a suitable cut-off frequency, the anode of said variable gain amplifier connected in series to the cathode of said signal controlling

amplifier through a switch means for providing the best fidelity against noise reduction for both high quality and old recordings in parallel with a network of high-pass characteristics comprising a capacitor in series with a resistor, and an automatic frequency control system including a first amplifier connected in series with said source of voltage for applying a full input voltage to a first high-pass network in series therewith for attenuating all frequencies below 1000 cycles per second, said high-pass network being connected in series to the anode of said amplifier and comprising a capacitor in series with a potentiometer set to apply up to the maximum potential necessary to completely cut off said variable gain amplifier of said feedback system, a second high-pass network in series with said first high-pass network for passing attenuated frequencies below 5000 cycles per second, said second high-pass network consisting of a capacitor in series with a potentiometer, a second amplifier connected in series with said second high-pass network, a rectifier in series combination with the anode of said second amplifier for providing an amplified band of passed frequencies with D. C. voltage to

said variable gain amplifier of said feedback system through a time constant filter consisting of a resistor in series with a capacitor, said time constant filter being connected in series with a plurality of resistors arranged to apply a fraction of the total frequency control voltage to a grid of said variable gain amplifier of said feedback system, said plurality of resistors being under the saturation influence of said second amplifier-rectifier combination to produce an automatic gate action of said feedback variable gain amplifier according to a signal passed through said frequency control system.

ALFRED D. BIELEK.

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