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NOISE REDUCTION AMPLIFIER CIRCUIT FOR SOUND RECORDING SYSTEMS

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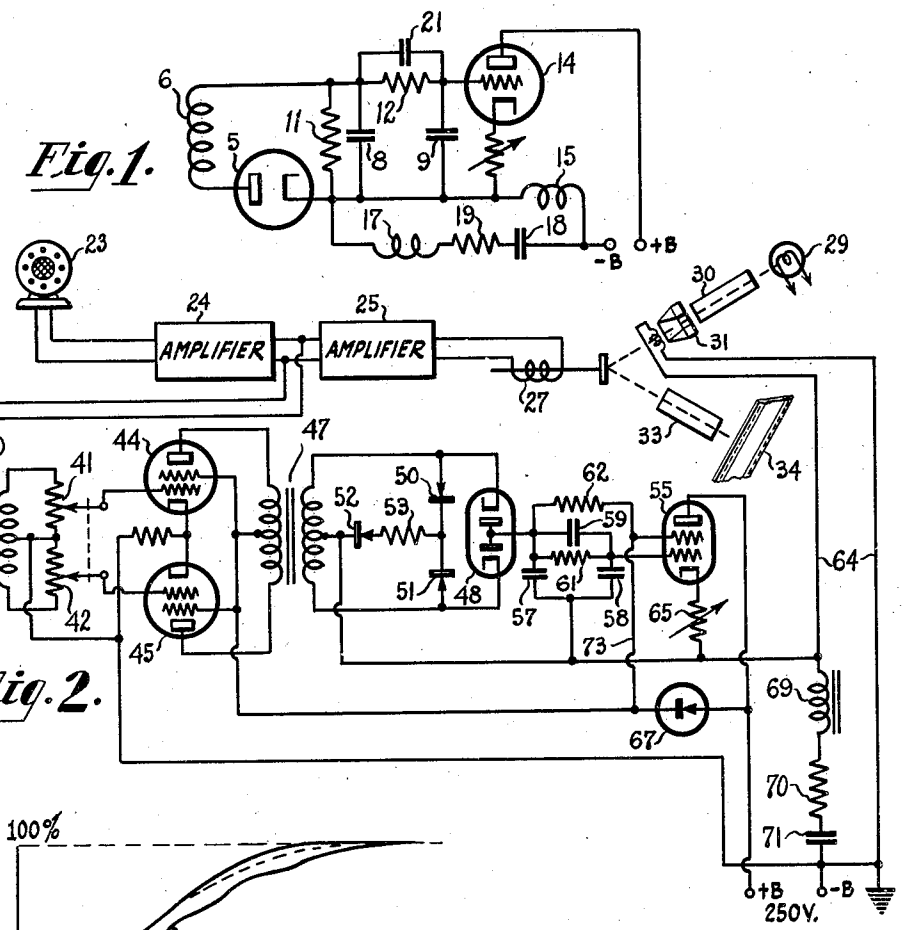

Fig. 1.

Fig. 2.

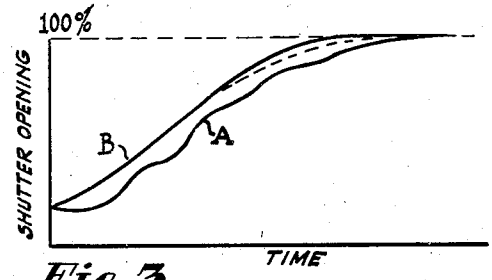

Fig. 3.

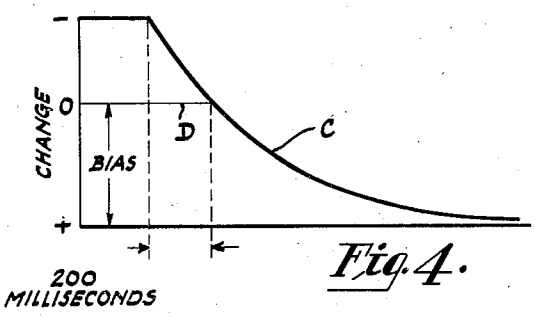

Fig. 4.

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NOISE REDUCTION AMPLIFIER CIRCUIT FOR SOUND RECORDING SYSTEMS

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11 Claims. (Cl. 179—100.3)

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This invention relates to current control systems, and particularly to rectifier-filter combinations for translating alternating currents into direct currents having predetermined voltage variations with respect to the alternating current variations.

In the art of sound recording wherein alternating current signals are recorded on film, noise reduction is generally applied in one form or another. In the application of noise reduction, it is usually necessary to rectify the signal currents and pass the rectified components through a filter before impression upon the noise reduction element of the recording system, the noise reduction elements varying with the type of recording system. For instance, the noise reduction current may be used for varying the position of a light intercepting shutter, a galvanometer reflecting mirror, or light valve ribbons, in accordance with the average amplitude variations of the signal. The filter circuits are used to eliminate the ripple components and to impart the proper movements to these elements during increases and decreases in the alternating current signal. Since the noise reduction signal varies the average value of the light beam impressed on the photocell during reproduction, these light variations should not be so rapid that they themselves introduce noise into the reproduced sound, but they must be sufficiently rapid to avoid clipping a substantial number of the peaks of the initial portion of the signal during recording. To avoid introducing noise in the form of "thumps," the movement of the noise reduction elements should provide a waveform in which there is no frequency above the cut off frequency of the reproducing system.

There have been many circuits suggested for controlling noise reduction elements in sound recording, and reference is hereby made to Kreuzer Patents No. 2 224,914 of December 17, 1940, and No. 2,260,717 of October 28, 1941, which disclose and claim certain types of noise reduction amplifier circuits to obtain certain results during increases in a signal. Kellogg patents No. 2,227,906 of January 7, 1941, and No. 2,357,661 of September 5, 1944, also show other types of combination rectifier-filter circuits for controlling noise reduction elements. The present invention, however, has a closing characteristic similar to the noise reduction circuits shown in Haynes Patents No. 2,357,652 of September 5, 1944, and No. 2,359,989 of October 10, 1944, although improved operating results are obtainable with the present circuits, as will be pointed out hereinafter.

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Some of the chief advantages of the invention are the elimination of the effect of resonance in the mechanical noise reduction element, more rapid opening action to reduce peak clipping, and the provision of a rectifier-direct current amplifier characteristic to produce an average light variation which does not contain frequencies above the cut off frequency of the reproducing system. A feature of the invention is the arrangement of the rectifier-filter combination to avoid the effect of leakage in the windings of the rectifier-transformer, while providing a desirable linear closing characteristic when the alternating current signal ceases or decreases.

The principal object of the invention, therefore, is to facilitate the recording of sound with noise reduction.

Another object of the invention is to provide an improved noise reduction system which neutralizes resonance of the mechanical load.

A further object of the invention is to provide an improved rectifier-filter combination which produces a voltage variation having frequencies below the cut off frequency of the reproducing system.

A further object of the invention is to provide a rectifier circuit having a predetermined relationship between its input and output voltages.

A still further object of the invention is to provide a rectifier-filter combination which provides a rapid opening characteristic and a linear closing characteristic and in which the rectifier is used as a limiter.

Although the novel features which are believed to be characteristic of this invention will be pointed out with particularity in the appended claims, the manner of its organization and the mode of its operation will be better understood by referring to the following description read in conjunction with the accompanying drawings forming a part hereof, in which:

Fig. 1 is a schematic drawing of a rectifier-filter circuit in which the principles of the invention have been applied.

Fig. 2 is a schematic circuit of a new noise reduction amplifier embodying the principles of the invention.

Fig. 3 is a graph showing the shutter opening characteristic, and

Fig. 4 is a graph showing the shutter closing characteristic.

Referring now to Fig. 1, in which the basic elements of a commercial type of noise reduction circuit are shown, a half-wave rectifier 5 receives alternating current from a transformer secondary

winding 6, the rectified impulses being impressed upon a filter-timing circuit including shunt condensers 8 and 9, a shunt resistor 11, and a series resistor 12, the output of the filter being impressed on the grid of a direct current amplifier 14. The amplified output from amplifier 14 is impressed on a coil 15 which may be the activating coil for noise reduction shutters or the noise reduction bias coil of a galvanometer. It has been found that due to the resonance of a shutter load, the movement of the shutter is irregular, that is, contains a ripple above the cut off frequency of the reproducing system and is thus audible when the sound record is reproduced. In the case of the shutter, this resonance frequency is approximately 140 cycles, and its effect is the wavy opening characteristic shown in curve A in Fig. 3. Curve A also shows the slow starting action of the shutter at the beginning of a signal, which is considerably shortened by the present invention without introducing "thumps," as will be explained hereinafter.

To neutralize or overcome the load resonance, a series tuned filter tuned to the resonance frequency of the load is shunted across the shutter winding 15 and includes an inductance 17, a condenser 18, and a resistor 19. Where the load resonance occurred at 140 cycles, the inductance 17 was approximately one henry and the capacity approximately 1.5 mf. To match the Q factor of the series tuned circuit to the Q of the shutter load, the resistor 19 had a value of approximately 75 ohms. This shunt circuit was found to completely damp the shutter so that no oscillation was introduced, as shown by curve B in Fig. 3.

To increase the starting speed of the opening of the shutter or galvanometer, as shown by the toe of curve B, a condenser 21 is connected in shunt to resistor 12 in the timing circuit proper, this capacitor functioning to permit the charging voltage to be impressed upon the condenser 9 simultaneously with its impression on condenser 8, and consequently, on the grid of the tube 14. In this manner, the starting delay action of the resistor 12 at the beginning of the signal is removed, the condenser 21 being given a value which will not affect the overall timing of the circuit or interfere with its ability to reduce the amplitude of the rectifier ripple components. In a typical circuit where condenser 8 had a value of .03 mf., condenser 9, a value of .003 mf., resistor 12, a value of 4 megohms, and resistor 11, a value of 1.5 megohms, the condenser 21 had a value of .001 mf. Although the action of the series tuned circuit 17—18—19 has a slight tendency to slow the opening time, the use of condenser 21 not only overcame this tendency, but reduced the starting time from 5 milliseconds to 1.5 milliseconds to provide a faster opening and thus minimize peak clipping.

Referring now to Fig. 2, a noise reduction circuit is shown in which the features shown in Fig. 1 are included in addition to a rectifier-filter combination and a linear direct current amplifier to provide an improved margin for the noise reduction action. Diagrammatically shown in Fig. 2, is a microphone 23 connected to a preamplifier 24, the output of which is impressed on an amplifier 25 connected to the modulating coil of a galvanometer 27. The galvanometer is shown in a sound recording system diagrammatically represented by a light source 29, a mask optical unit 30, a noise reduction shutter unit 31, a slit optical unit 33, and a film 34. This recording system is a typical commercial type wherein the average intensity or length of the recording light beam is controlled by the shutters 31, while the light is varied in accordance with the instantaneous values of the signal variations by the galvanometer 27.

Bridged between the amplifiers 24 and 25, is a noise reduction amplifier which includes an input transformer 40 across the secondary of which is a unitary double potentiometer having resistances 41—42 of 50,000 ohms each, to which is connected a push-pull amplifier having vacuum tubes 44 and 45. The output of the push-pull amplifier is connected through the transformer 47 to a full-wave rectifier tube 48, which may be of the RCA 6H6 type. Connected across the secondary of the transformer 47 and the center tap which feeds the rectifier tube 48, are three selenium rectifiers 50, 51, and 52 with a load resistor 53, the purpose of which will be explained hereinafter. The output of the rectifier is connected to a linear direct current amplifier tube 55 of the RCA 6V6 type, through a timing circuit comprising shunt condensers 57 and 58, series condenser 59, and resistors 61 and 62. The output of the direct current amplifier is impressed on the actuating coil of the shutters 31 over a circuit from the cathode of tube 55 and conductors 64 to the anode potential supply and the anode of tube 55. A variable resistor 65 of approximately 1000 ohms is used in the cathode circuit to adjust the initial shutter opening to the proper amount. A voltage regulator tube 67 is provided, which, in the present circuit, reduces a potential of 250 volts at the B plus terminal to 145 volts for the screen grid of tube 55 and the plates and screens of tubes 44 and 45.

It will be noted that two of the features of Fig. 1 are provided in the circuit of Fig. 2; namely, a series tuned circuit shunting the winding of shutters 31 and including an inductance 69, a resistor 70, and a capacitor 71, these units having the same values as in Fig. 1 when the resonance peak of the shutter load occurs at approximately 140 cycles. This shunt circuit damps and stabilizes the shutter action during increases in the signal currents to provide the straight portion of curve B in Fig. 3. Also in the timing circuit of Fig. 2, is the shunt condenser 59, which speeds up the initial shutter action as shown in the toe portion of curve B. Typical values for this timing filter are: condenser 57, .01 mf.; condenser 58, .003 mf.; condenser 59, .001 mf.; resistor 61, 2 megohms; and resistor 62, 20 megohms.

Referring now to the rectifier circuit, it will be noted that the rectifier not only provides for full-wave rectification, but also that the control grid of the direct current amplifier is connected to the anodes or plates of the rectifier without going through the secondary winding of the transformer. This connection provides a negative potential on the control grid of the tube 55 in the usual manner, but avoids the effect of leakage in the windings of the transformer 47. In prior noise reduction amplifiers where the anode or anodes of the rectifier were connected to the timing circuit through the winding of the transformer, the direct current resistance between the winding and other components of the transformer provided a leakage path which varied with different transformers and with humidity and temperature. This condition varied the timing of the filter by varying the discharge rate of the timing condensers. In the present invention, the anodes of the rectifier are connected directly to the timing circuit and because of the

excellent insulation between the anodes and other components of the rectifier, the discharge resistance is maintained at a constant value. It will be noted that the mid-tap of the transformer **47** is substantially at ground potential and differs therefrom only by the impedance of the shutter winding which is approximately 800 ohms.

As explained in Haynes Patent No. 2,357,652, mentioned above, the normal RC discharge curve of a condenser is exponential, which provides too long a closing time and permits a "swishing" noise to be introduced at the end of a signal. The Haynes patent discloses several types of circuits for decreasing this closing time by making the discharge characteristic linear instead of exponential. He accomplishes this by the use of an additional shunt rectifier with a fixed potential bias. The present circuit accomplishes the same closing time in a similar manner, but does so with the same rectifier used for the rectification of the signal currents. In Fig. 4, the normal discharge time of the condenser is shown by curve C. However, only the straight portion of the curve shown above the bias line D is desired to permit the shutter to close linearly. That is, with the maximum negative charge, the shutter is wide open, and at zero charge, it is closed, the curved portion of curve C being eliminated by the use of the bias and the voltage limiter action of the rectifier **48**.

In the present circuit, this bias is obtained over resistor **62** and conductor **73** connected to the 145 volt side of the voltage regulator tube **67**. Thus, at the cessation of a signal, the shutter movement will be linear to the zero charge point of the condenser **57** after which the rectifier **48** will transmit current from the B supply and prevent the charge on condensers **57** and **58** from becoming positive. The high value of resistor **62** lengthens the linear portion of the discharge curve to correspond to the desired length of closing time; namely, about 200 milliseconds.

The shutter action in many noise reduction systems at high signal levels is asymptotic to full open position, as shown by the upper portion of curve A and the dotted lines from curve B in Fig. 3. This is due to the non-linearity of the rectifier and the exponential characteristic of the direct current amplifier. To obtain a better margin at high amplitudes, a reversal of the curvature of the characteristic between the input to the rectifier and the output of the direct current amplifier is desired. In the present circuit, this is accomplished by the use of selenium rectifiers **50**, **51**, and **52** as non-linear resistances, and the current limiting resistor **53** connected as shown in Fig. 2. The polarization of rectifiers **50**, **51**, and **52** is such as to neutralize or compensate for not only the non-linearity of the rectifier **48** but actually over-compensates to produce a larger margin at low level signal inputs than at the higher levels. This reduces the amount of clipping at low levels where clipping is most noticeable. Although a similar action could be obtained by the use of two reversed rectifiers shunted across the full secondary winding of the transformer, the rectifiers thus having the full voltage of the secondary impressed thereon, the present bridge arrangement reduces the voltage on each rectifier to one-fourth of the total voltage. Thus, rectifiers **50** and **51** need not be as accurately balanced or matched while rectifier **52** may have any value, since it is common to both rectifiers.

To maintain this relationship, an RCA 6V6 vacuum tube is used as a direct current amplifier, this tube providing substantially linear amplification as compared with previously used tubes RCA 6K7's. This overall relationship between input at **47** and output at **64** provides the upper solid line shoulder to the curve B in Fig. 3 instead of a shoulder as shown by the dotted line.

The circuit above-described eliminates the ripple caused by resonance of the load, reduces the starting time of the noise reduction action to reduce peak clipping to a minimum, and has a characteristic to provide a desirable margin. In one adjustment of the circuit, it was found that the overall noise reduction characteristic, as shown by curve B in Fig. 3, approximates a pure 50 cycle sine wave, that is, the lower toe has a curvature corresponding to that of a 50 cycle wave, the linear section of the curve has a slope corresponding to a 50 cycle wave, and the upper shoulder of the curve has a curvature corresponding to less than a 50 cycle wave. This results in a noise reduction envelope which can contain no frequencies above 50 cycles, and since many commercial types of sound reproducing systems cut off at 50 cycles or above, no sound caused by the noise reduction action will be reproduced by such systems. This frequency can, of course, be adjusted to suit any other lower cut off frequency of the reproducing system.

Certain features of the invention may be applied to present types of noise reduction systems, as shown in Fig. 1, or all features may be incorporated in the noise reduction circuit shown in Fig. 2.

I claim as my invention:

1. A noise reduction amplifier system comprising a rectifier, a timing circuit connected to the output of said rectifier, a direct current amplifier connected to said timing circuit, a load circuit for utilizing the output of said amplifier, said load circuit having a resonant frequency, and means connected across said load circuit for eliminating resonant frequency currents from said load circuit.

2. A noise reduction amplifier system in accordance with claim 1, in which said timing circuit includes a plurality of shunting condensers separated by a resistor and a condenser in shunt to said resistor to permit the initial charging of said shunting condensers to be simultaneous.

3. A noise reduction circuit comprising a push-pull alternating current amplifier, a full-wave rectifier connected to the output of said amplifier, a direct current amplifier, a capacitance-resistance timing circuit for directly interconnecting the anodes of said rectifier with the control grid of said direct current amplifier, a load circuit connected to the output of said direct current amplifier, and a tuned circuit in shunt to said load circuit for eliminating from said load circuit currents of a frequency to which said load circuit is resonant.

4. A noise reduction circuit comprising a push-pull alternating current amplifier, a full-wave rectifier connected to the output of said amplifier, a direct current amplifier, a capacitance-resistance timing circuit for directly interconnecting the anodes of said rectifier with the control grid of said direct current amplifier, and a plurality of rectifiers bridged between said alternating current amplifier and said full-wave rectifier, said plurality of rectifiers being polarized to over-compensate for the non-linearity of said full-wave rectifier to produce a predetermined overall relationship between the input to said rectifier and the output therefrom.

5. A noise reduction circuit comprising a push-

pull alternating current amplifier, a full-wave rectifier connected to the output of said amplifier, a direct current amplifier, a capacitance-resistance timing circuit for directly interconnecting the anodes of said rectifier with the control grid of said direct current amplifier, and a bias source of potential for said interconnecting timing circuit to utilize only the straight portion of the discharge characteristic of one of said condensers, said full-wave rectifier passing current from said bias source to prevent a reversal of polarity on said condenser.

6. A noise reduction circuit comprising a full-wave rectifier, a direct current amplifier, a resistive-capacitive filter interconnecting the output of said rectifier and the input of said amplifier, the anodes of said rectifier being connected directly to said filter, a load circuit connected to the output of said amplifier, said filter including a shunt condenser, a shunt resistor, a series resistor shunted by a condenser, and a source of bias potential in series with said shunt resistor.

7. A noise reduction circuit comprising a full-wave rectifier, a direct current amplifier, a resistive-capacitive filter interconnecting the output of said rectifier and the input of said amplifier, the anodes of said rectifier being connected directly to said filter, a load circuit connected to the output of said amplifier, an input transformer for said full-wave rectifier, the cathodes of said rectifier being connected across the full secondary winding of said transformer, and three additional rectifiers, two of said additional rectifiers being connected in series and in opposing polarity across said secondary and the third of said additional rectifiers being connected between the mid-tap of said secondary and a point between said two rectifiers.

8. A noise reduction timing circuit comprising a pair of shunting condensers, a series resistor between said condensers, a condenser in shunt to said resistor for initially charging said shunting condensers simultaneously, a shunting resistor, a source of potential for said shunting resistor, and means in series with said shunting resistor for preventing the charge on said shunting condenser from reversing in polarity when the charge on said condensers reaches zero.

9. A noise reduction circuit for a sound recording system, said circuit comprising an alternating current amplifier, a rectifier connected to said amplifier, a timing filter connected to said rectifier, a direct current amplifier connected to said filter, a noise reduction element connected to said direct current amplifier, the input to said filter being connected directly to the anode of said rectifier, and a plurality of additional rectifiers bridged across said first mentioned rectifier for over-compensating for the non-linearity of said first mentioned rectifier.

10. A noise reduction circuit for a sound recording system, said circuit comprising an alternating current amplifier, a rectifier connected to said amplifier, a timing filter connected to said rectifier, a direct current amplifier connected to said filter, and a noise reduction element connected to said direct current amplifier, the input to said filter being connected directly to the anode of said rectifier, said timing filter having a series resistor, a plurality of shunting condensers, and a condenser shunting said resistor to permit said shunting condensers to be initially charged simultaneously.

11. A noise reduction circuit comprising a full-wave rectifier, a resistance-condenser filter connected to the output of said rectifier, said filter having a plurality of shunting condensers and a resistor, a series resistor shunted by a condenser, a direct current amplifier connected to said filter, a noise reduction shutter unit connected to said amplifier, and a series tuned circuit shunting said shutter unit and tuned to the resonant frequency of said shutter.

ALEXIS BADMAIEFF.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,357,661	Kellogg	Sept. 5, 1944
2,359,989	Haynes	Oct. 10, 1944