A noise-reduction amplifier in an optical-sound recording system for motion pictures wherein the noise-reduction amplifier furnishes a variable bias signal to a galvanometer, the magnitude of the bias signal varying in accordance with the modulation of the sound being recorded. The noise-reduction amplifier includes a DC amplifier network having an operational amplifier and transmission means for transmitting voltage of one sign to the operational amplifier while preventing voltage of the opposite sign from passing therethrough. The transmission means, which include a diode connected across the operational amplifier, operate as a switch to electrically cut off the operational amplifier from the remainder of the DC amplifier network when voltage of the opposite sign enters the DC amplifier network.

8 Claims, 2 Drawing Figures
NOISE-REDUCTION AMPLIFIER

This invention is directed to new and useful improvements in optical-sound recording systems and more particularly to a noise-reduction amplifier for providing a predetermined range of biasing current to a galvanometer.

Optical-sound tracks for filmed motion pictures are usually recorded on the film alongside the visual images. One type of optical-sound track generally known as a variable-area sound track comprises substantially transparent patterns of clear film provided within the borders of a generally nontransparent sound track stripe. The sound-producing portion of the sound track is usually defined by the variations in area of the clear portions within the borders of the sound track stripe.

The system for recording a variable-area sound track normally requires a light source to be directed onto a light-sensitive sound track stripe. The light source is focused as a narrow light beam of fixed intensity onto the light-sensitive stripe to expose discrete areas of the stripe during running of the film past the beam. Exposed area variations of the stripe are accomplished by varying the width of the light beam so that it ordinarily does not exceed the width of the stripe. One known method of varying light beam width is to pass the light source through a geometrically shaped aperture such as a triangle and to reflect the triangular beam from a pivotally movable mirror onto a narrow slit that leads to the sound track stripe. When the pivotally movable mirror reflects the apex of the triangular beam onto the slit, a minimum band of light passes through the slit onto the sound track stripe. Conversely, when the movable mirror reflects a base of the triangular beam onto the slit, a maximum band of light passes through the slit onto the sound track stripe. Thus movement of the triangular beam back and forth past the slit serves to project a light beam of variable width onto the light-sensitive sound track stripe to expose variable areas of the stripe.

In the process of recording sound, the mirror can be vibrated by conventionally mounting it to a galvanometer that receives sound signals. The vibrations of the mirror are thus varied in accordance with the characteristics of the sound signal being recorded, the vibrations serving to move the light beam back and forth past the slit. The electrical impulses transmitted to the galvanometer to vibrate the mirror can be obtained from a standard recording amplifier wherein sound is converted to electrical signals. The electrical signals usually have the characteristics of a sine wave and consequently the vibrating light beam that passes through the slit forms an exposed pattern on the light-sensitive stripe that is substantially sinusoidal.

The sound from a variable-area sound track is reproduced in a known manner by passing a beam of light through the clear portions of a moving sound track to a photocell. The clear area portions within the non-transparent borders of the sound track stripe vary the width of the light beam passing through the stripe to the photocell. Light reaching the photocell is thus varied in the same manner in which it was originally vibrated through the slit during sound recording. The photocell converts the light variations to an electrical signal which is in turn converted in a known manner to intelligible sound.

During moments when no sound is being recorded to accompany the visual images the sound track stripe is generally left with a linear band of clear film. During sound reproduction the light passing through this linear band to the photocell is of constant band width and produces an undesirable low level sound commonly known as ground noise. Another type of ground noise problem arises when the film has abrasions, dirt or other imperfections in the area of the sound track stripe. These imperfections provide unwanted interruptions to the photocell of the sound-reproducing light beam, which interruptions cause an undesirable sound that is also known as ground noise. Most ground noise is usually hidden in the background of a reproduced sound modulation but becomes readily apparent during periods of low modulation or recorded silence (zero modulation).

Noise-reduction systems for dealing with the aforementioned ground noise problems in optical-sound recording are well-known. One known noise-reduction system employs shutter devices for limiting the passage of reflected light to the light-sensitive stripe during periods of recorded silence or low modulation. These shutters are controlled by a noise-reduction amplifier having complex circuitry and an intricate mechanical arrangement to ensure that the shutters are timed to move incrementally in accordance with the modulation being recorded. Obtaining properly timed incremental shutter movement has always been a problem.

Among the several objects of the present invention may be noted the provision of a novel noise-reduction amplifier; a novel shutterless noise-reduction amplifier; a novel noise-reduction amplifier for providing a predetermined range of biasing current to a galvanometer; a novel noise-reduction amplifier for providing a predetermined range of biasing current to a galvanometer during a predetermined range of modulation; a novel noise-reduction amplifier having a DC amplifier network employing a DC operational amplifier; a novel noise-reduction amplifier having a novel DC amplifier network that can operate as a switch; and a novel noise-reduction amplifier for biasing a galvanometer in one direction and having novel means for preventing a reversal of galvanometer bias. Other objects and features will be in part apparent and in part pointed out hereinafter.

The present invention relates to a novel noise-reduction amplifier for an optical-sound recording system. In one embodiment of the invention the noise-reduction amplifier comprises a signal amplifier branch which receives a portion of the variable voltage audio signal from the recording amplifier and steps up the voltage thereof. The noise-reduction amplifier further includes a full wave rectifier and a filter and time delay network which feed the audio signal to a DC amplifier network. Also included in the noise-reduction amplifier is a DC supply source feeding the DC amplifier network with a constant negative DC voltage to be mixed with the variable rectified audio voltage signal.

The DC amplifier network includes an operational DC amplifier that is connected therein as an inverting amplifier to convert negative voltage to positive current.

The components of the DC amplifier network are arranged such that the rectified audio signal opposes the negative DC voltage. At predetermined modulations the magnitude of the rectified audio signal will
be less than the magnitude of the DC voltage so as to provide a net negative voltage input to the operational amplifier. The operational amplifier converts the negative voltage to a positive current, which current is transmitted to the galvanometer for biasing purposes. Since the rectified audio signal voltage and the negative DC voltage are in opposition, the biasing current on the galvanometer is at a maximum when the audio signal is zero. The components of the noise-reduction amplifier can be selected to permit the positive audio signal voltage to cancel the negative DC voltage at a predetermined modulation of approximately 60 percent, for instance, such that the biasing current on the galvanometer becomes zero at 60 percent modulation. Further increases in audio signal modulation beyond 60 percent cause the mixed voltage in the DC amplifier network to have a net positive value because the magnitude of the rectified audio signal will then exceed the magnitude of the DC voltage. However, if a net positive voltage were to pass through the operational amplifier it would be converted to a negative current, thereby effecting a reversal of bias on the galvanometer. Such reversal of galvanometer bias can undesirably distort the recorded modulation. To prevent positive voltage from entering the operational amplifier and effecting a bias reversal on the galvanometer a diode is connected across one of the input terminals and the output terminal of the operational amplifier. Consequently modulations exceeding 60 percent can be recorded without a reversal of galvanometer bias. Furthermore since the diode prevents positive voltage from entering the operational amplifier, the DC amplifier network provides no output to the galvanometer such that the galvanometer is essentially zero biased for modulations exceeding 60 percent. In this manner the DC amplifier network can operate as a switch to cut off the noise-reduction amplifier from the galvanometer. The DC amplifier network further includes a first resistor connected to the output terminal of the diode, and a second resistor and capacitor in series connected across the diode and first resistor. A third resistor is connected in parallel with the second resistor and capacitor.

The invention accordingly comprises the constructions hereinafter described, the scope of the invention being indicated in the following claims.

In the accompanying drawings, in which one of various possible embodiments of the invention is illustrated,

FIG. 1 is a simplified schematic wiring diagram of a noise-reduction amplifier including a DC amplifier network representing one embodiment of the present invention; and

FIG. 2 is a simplified representation of the cross-section of a light beam reflected onto a slit in an optical-sound recording system.

Referring now to the drawings for a detailed description of the present invention, a noise-reduction amplifier incorporating one embodiment of the present invention is generally indicated by 10. Noise-reduction amplifier 10 is broken down for convenience into three branches designated A, B, and C.

Branch A includes input terminals 12, 14, for receiving a portion of the AC audio signal that is being recorded by a conventional recording amplifier (not shown). Any suitable known manner of connecting terminals 12, 14, to the recording amplifier can be used. The audio signal passing through branch A is amplified and stepped up in voltage. The stepped up audio signal voltage which is variable in magnitude then enters branch B for full wave rectification through a rectifier comprising diodes CR1, CR2, CR3, and CR4. The rectified signal then passes through a conventional time delay and filter network comprising resistors R5, R6, and capacitors C9, C10, C11. After the audio signal has been rectified and filtered it enters branch C for mixing with a negative DC supply voltage provided by a DC source 16. The mixed DC voltage is fed through a DC amplifier network generally indicated by 18, which network includes output terminals 22, 24. Output terminals 22, 24, lead to a galvanometer coil (not shown) for providing biasing current thereto.

As seen in FIG. 2, 30 designates the cross-section of a triangular-shaped vibrating light beam reflected onto a fixed slit 32 by use of a known arrangement for optically recording a standard bilateral sound track. The optical paraphernalia for focusing beam 30 on slit 32 including the galvanometer and mirror are conventional and are not shown. When there is no modulation being recorded beam 30 does not vibrate and it is desirable to minimize the amount of light passing through slit 32. This is because ground noise can be reduced during periods of recorded silence by reducing the exposure of the light-sensitive sound track. Thus beam 30 is aligned to position an apex 34 thereof on slit 32, apex 34 being held at a reference level z by biasing current that noise-reduction amplifier 10 furnishes to the galvanometer.

When modulation begins beam 30 vibrates with respect to slit 32 from reference lever Z, the downward vibrating amplitude being designated y, the upward amplitude being designated x. It will be apparent that light from beam 30 can pass through slit 32 as apex 34 moves from z to y; but light cannot pass through slit 32 as apex 34 moves from z to x. Thus the portion of the sound signal represented by vibration amplitude x would not be optically recorded when beam 30 vibrates from reference level z. Because an increase in modulation causes a corresponding increase in amplitude vibrational amplitude of beam 30 it is desirable to lower the reference level of apex 34 by an amount that is substantially proportional to the modulation amplitude.

Reference levels should then be lowered according to the percentage of modulation, each reference level enabling light to pass through slit 32 for all vibratory positions of beam 30. This lowering of the reference level is accomplished by the noise-reduction amplifier, which serves to vary the magnitude of biasing current on the galvanometer mirror arrangement by predetermined amounts that correspond to the modulation percentage being recorded. The bias current magnitude should change in a substantially instantaneous manner in response to changes in modulation of the audio signal. Of course when the percentage of modulation is constant the bias remains constant. However, the reduction in bias current need not be in inverse proportion to the percentage increase of modulation. For example, the biasing current can be reduced to zero at modulations of approximately 60 percent. But a zero bias at a modulation of 60 percent is suitable only if the reference level of apex 34 at 60 percent modulation will permit light to pass through slit 32 for all vibratory cycle beam positions when modulation ranges from 60 percent to 100 percent.
Branch C of noise-reduction amplifier 10 plays a significant role in accomplishing a reduction of galvanometer bias as modulation increases. The negative voltage DC supply 16 of branch C feeds a series arrangement of potentiometers R₁₂, R₁₃, and a resistor R₀ connected to a junction point 26. The variable rectified filtered audio signal voltage from branch B of noise-reduction amplifier circuit 10 is mixed with the negative DC voltage at junction 26 prior to entering DC amplifier network 18. DC amplifier network 18 comprises a DC operational amplifier AR₂ having its own DC supply 28. Means for transmitting voltage to operational amplifier AR₂ include a diode CR₅ connected across the negative input terminal and the output terminal of operational amplifier AR₂. The positive input terminal of amplifier AR₂ is connected to a conductor 50 of noise-reduction amplifier 10. The voltage transmission means further include impedance means comprising a resistor R₇ connected to the output terminal of diode CR₅ and a series arrangement of a resistor R₁₀ and a capacitor C₀ connected across diode CR₅ and resistor R₇. A resistor R₈ is connected across resistor R₇ and capacitor C₀. Under this arrangement operational amplifier AR₂ is connected in DC amplifier network 18 as an inverting amplifier wherein AR₂ can convert negative voltage, for instance, to positive current. A two-position switch S₁ connected in series with DC amplifier network 18 has one switch position leading to a milliammeter MA and another switch position leading to a resistor R₄ that is connected to conductor 50.

In operation of the noise-reduction amplifier the components of branch C were rated at the following values:

\[
\begin{align*}
R₁ & = 330 \text{ ohms} \\
R₄ & = 470 \text{ kiloohms} \\
R₆ & = 1.5 \text{ megaohms} \\
R₆ & = 10 \text{ kiloohms} \\
R₂₁ & = 100 \text{ kiloohm potentiometer} \\
C₀ & = 100 \text{ p.F.} \\
\text{DC supply} & = -25 \text{ v.}
\end{align*}
\]

AR₂ is a standard high output voltage differential operational amplifier having the following characteristics:

Supply 28
Input voltage range (common mode voltage)
±8 volts for both inputs
Voltage range between inputs
±6 volts
Impedance between inputs
200 kiloohms
Negative input to common impedance
10 megaohms
Positive input to common impedance
10 megaohms
Output voltage
±20 volts
Output current
±200 milливamps
Voltage gain at rated load
50,000
Input noise at 10 K.C. bandwidth
0.5 microvolts R.M.S.
Input voltage offset
30 microvolts per day

When no audio signal voltage enters branches A and B of noise-reduction amplifier 10, R₁₂ and R₁₃ are set to provide a 30 milliamp reading on meter MA. Therefore, the galvanometer bias during periods of zero modulation is 30 milliamps. When sound modulation begins, the audio signal passing through branches A and B mixes at junction 26 with the DC voltage attributable to supply 16.

The variable rectified audio signal voltage in branch C can be considered positive and in opposition to the constant DC negative voltage attributable to supply 16.

Hence the 30 milliamp reading of milliammeter MA decreases as modulation increases due to the fact that increased modulations produce an increase in magnitude of the positive audio signal voltage.

Under this arrangement at approximately 60 percent modulation the positive audio signal voltage reaches a magnitude that is sufficient to cancel the magnitude of the negative DC voltage. Consequently milliammeter MA will read zero and no bias current is furnished to terminals 22, 24, of noise-reduction amplifier 10 for transmission to the galvanometer. For modulations in excess of approximately 60 percent, the positive audio signal voltage reaches magnitudes that exceed the magnitude of the constant negative DC voltage. Thus the net voltage in DC amplifier 18 becomes positive for modulations in excess of approximately 60 percent. As the net voltage in DC amplifier 18 changes sign when modulations exceed approximately 60 percent, it is possible to have a corresponding reversal of bias on the galvanometer in response to this change of sign. Such a consequence, however, can undesirably distort the recorded modulation. The arrangement of diode CR₅ in DC amplifier network 18 prevents this reversal of bias from occurring as it prevents a net positive voltage from going through operational amplifier AR₂. Since a net positive voltage cannot pass through AR₂, it will be apparent that for modulations in excess of approximately 60 percent the galvanometer bias remains constant at zero. DC amplifier network 18 has in effect cut off the galvanometer from noise-reduction amplifier 10 in the same manner as could be done by a switch. Although this switching effect takes place at a modulation of approximately 60 percent, it will be appreciated that the circuit components can be selected to permit a cut-off point of any predetermined modulation percentage.

Operational amplifier AR₂ also serves to attenuate any ripples in the audio signal from the rectifier so that the biasing current received by the galvanometer is substantially free of distortion. Resistor R₇ serves as a current limiting resistor for operational amplifier AR₂ and helps to prevent AR₂ from drawing maximum current while idling. Resistor R₈ serves as a feedback resistor for controlling gain of operational amplifier AR₂ and helps provide a fixed amplification factor. Resistor R₈ and capacitor C₀ serve to filter out unnecessary frequencies and to change the phase angle of operational amplifier AR₂. R₈ is used for test purposes when it is desired to disconnect the galvanometer from noise-reduction amplifier 10.

Some advantages of the novel noise-reduction amplifier circuit that are evident from the foregoing description include a DC amplifier network wherein a diode is used in combination with an operational amplifier to prevent a reversal of bias on the galvanometer, a DC amplifier network which can operate as a switch to cut off the noise-reduction amplifier from the galvanometer at a predetermined percentage of modulation, and a DC amplifier network which provides consistent operational stability.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying draw-
What is claimed is:

1. A noise-reduction amplifier in an optical sound recording system for furnishing a variable bias signal to a galvanometer to bias the galvanometer to corresponding variable predetermined positions comprising, audio signal generating means for producing a first audio signal of variable voltage magnitude, rectifying means connected to said audio signal generating means for rectifying said first audio signal, amplifying means comprising a D.C. amplifier network having an input side coupled to said rectifying means for receiving said first variable rectified audio signal, D.C. signal producing means connected to the input side of said D.C. amplifier network for providing a second D.C. signal of fixed voltage magnitude to said D.C. amplifier network, said D.C. amplifier network including a D.C. operational amplifier having an output terminal and at least one input terminal connected to the input side of said amplifier network, and a diode connected across said one input terminal and the output terminal of said D.C. operational amplifier, said diode permitting conduction across said one input terminal and the output terminal of said D.C. operational amplifier in a predetermined direction such that when the first variable rectified audio signal is opposed by the second D.C. signal of fixed magnitude and the net difference therebetween is a voltage of one sign, said D.C. amplifier network converts said first and second signals to the variable bias signal of the galvanometer, said D.C. amplifier network preventing conversion of said first and second signals to the variable bias signal when the net difference between the first and second signals is a voltage of a sign opposite said one sign.

2. A noise-reduction amplifier as claimed in claim 1 wherein said diode includes an input terminal and an output terminal, said input terminal being connected to said one input terminal of said D.C. operational amplifier, the output terminal of said diode being connected to the output side of said D.C. operational amplifier.

3. A noise-reduction amplifier as claimed in claim 2 wherein said D.C. operational amplifier includes positive and negative input terminals, the input side of said diode being connected to said positive input terminal.

4. A noise-reduction amplifier as claimed in claim 3 further comprising a first resistor having an input side and an output side, said input side being connected to the input terminal of said diode, a second resistor capacitor series combination connected across the input terminal of said diode and the output side of said first resistor, and a third resistor connected between the output side of said first resistor and the output terminal of said diode.

5. The noise-reduction amplifier of claim 1 wherein impedance means are connected across said diode, said impedance means including a first resistor.

6. The noise-reduction amplifier of claim 5 wherein one side of said first resistor is connected to one side of said diode, said impedance means further including a second resistor-capacitor series combination connected to the other side of said first resistor and to the other side of said diode.

7. The noise-reduction amplifier of claim 6 wherein said one side of said diode is the input side thereof, said other side of said diode being the output side thereof.

8. A noise-reduction amplifier as claimed in claim 1 wherein said D.C. operational amplifier is connected in said D.C. amplifier network as an inverting amplifier to convert net voltage of said one sign to current of the opposite sign.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,796,966 Dated March 12, 1974

Inventor(s) Otto A. Rauhut

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 25, "strip" should read -- stripe --.
Column 2, line 60, "network" should read -- network --.
Column 4, line 32, "levar" should read -- level --.
Column 4, line 32, "Z" should read -- z --.
Column 4, lines 41-42, "increase in amplitude vibrational amplitude" should read -- increase in the vibrational amplitude --.
Column 6, line 21, "consequence" should read -- consequence --.
Column 8, line 10, "moise" should read -- noise --.

Signed and sealed this 18th day of June 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents