Oct. 25, 1949. G. HOLST ET AL 2,485,829

APPARATUS FOR AND METHOD OF ELECTROOPTICALLY SCANNING AND REPRODUCING RECORDED OSCILLATIONS

Filed May 3, 1946 3 Sheets-Sheet 1

Fig. 1.

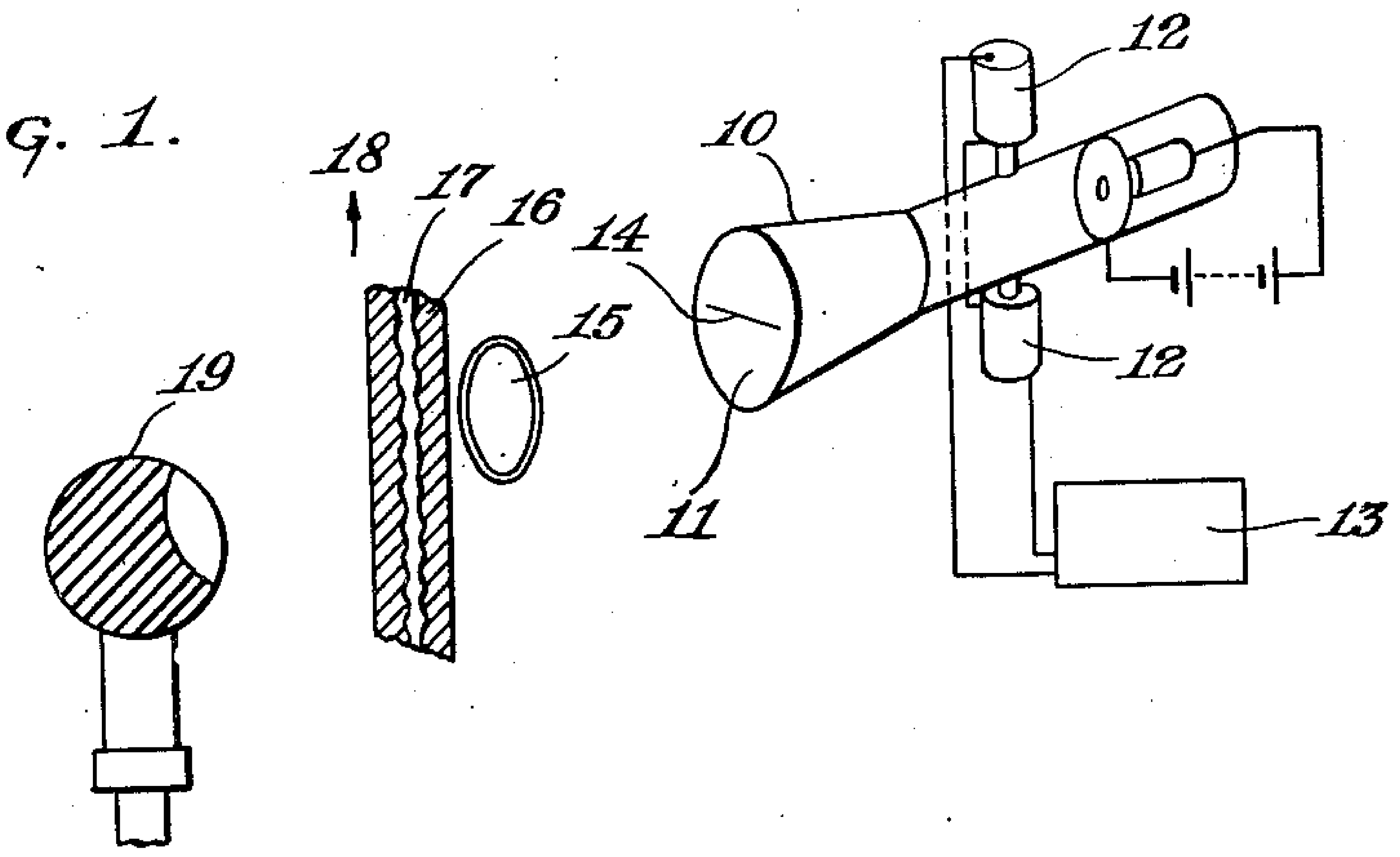

Fig. 2.

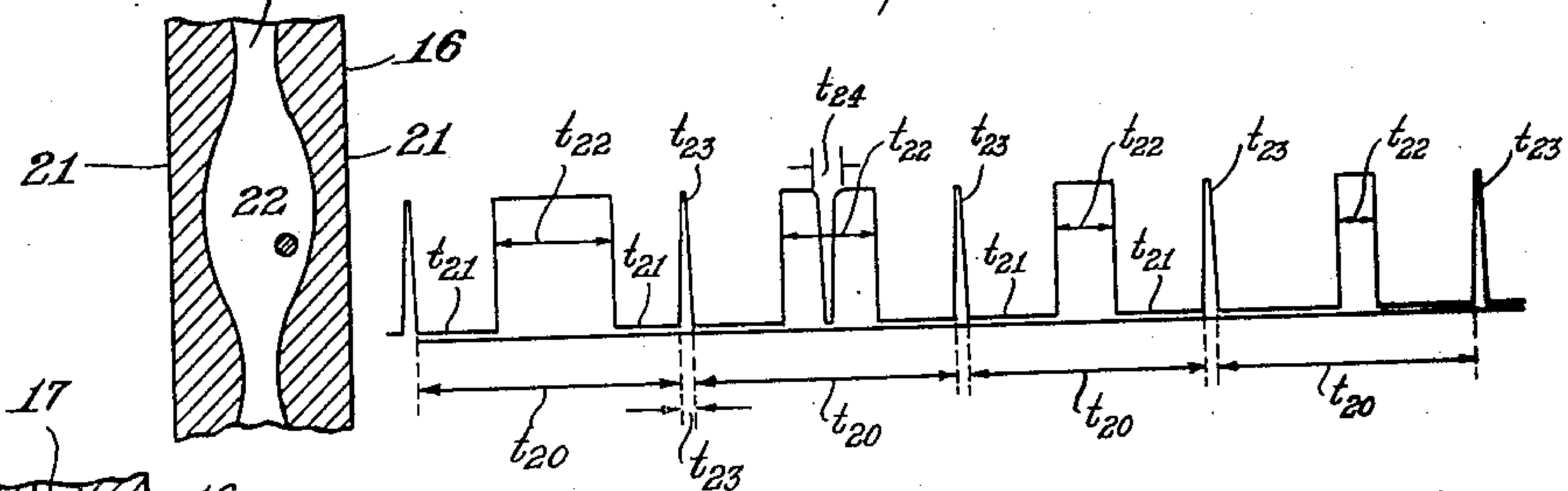

Fig. 2a.

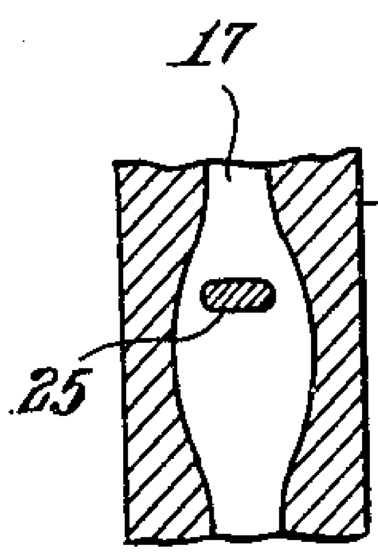

Fig. 2b.

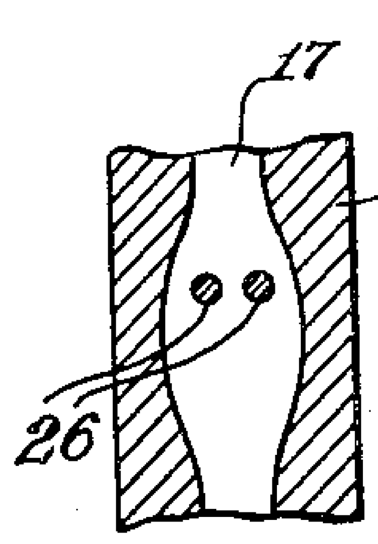

Fig. 3.

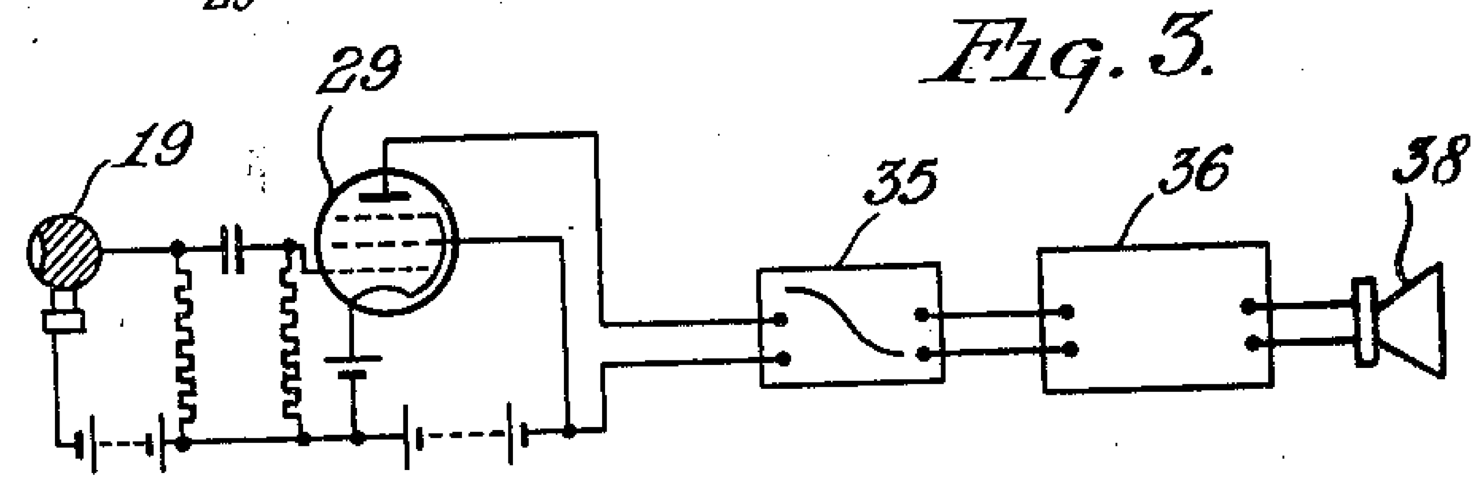

Fig. 4.

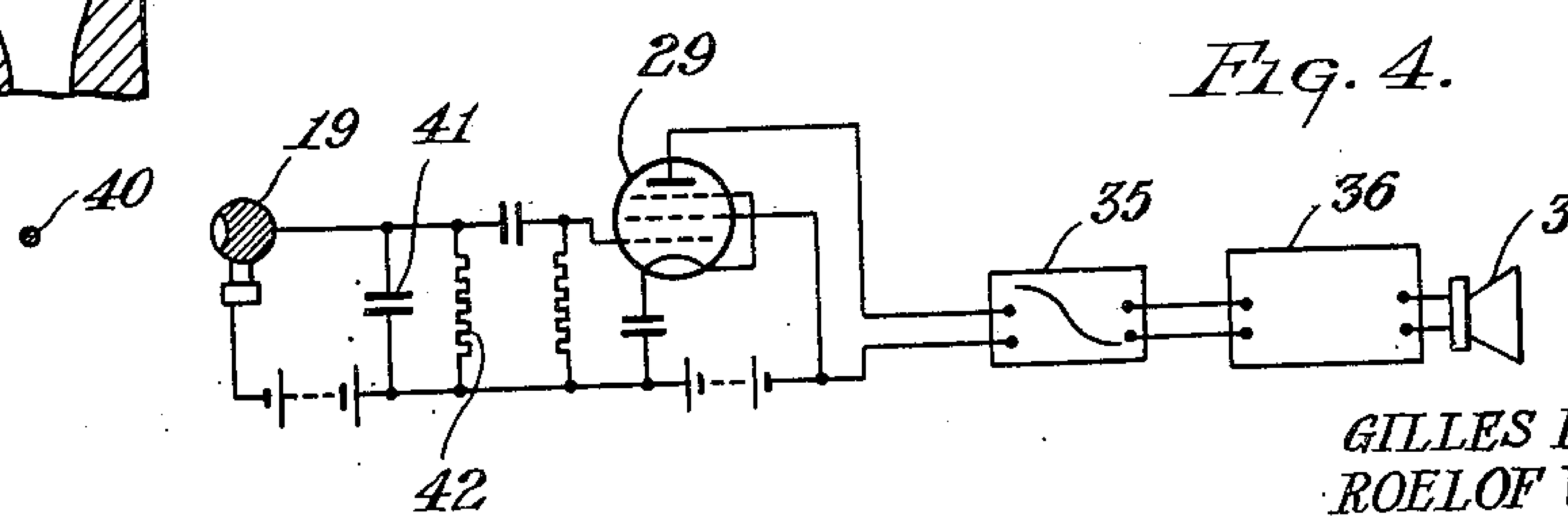

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Fig. 5.

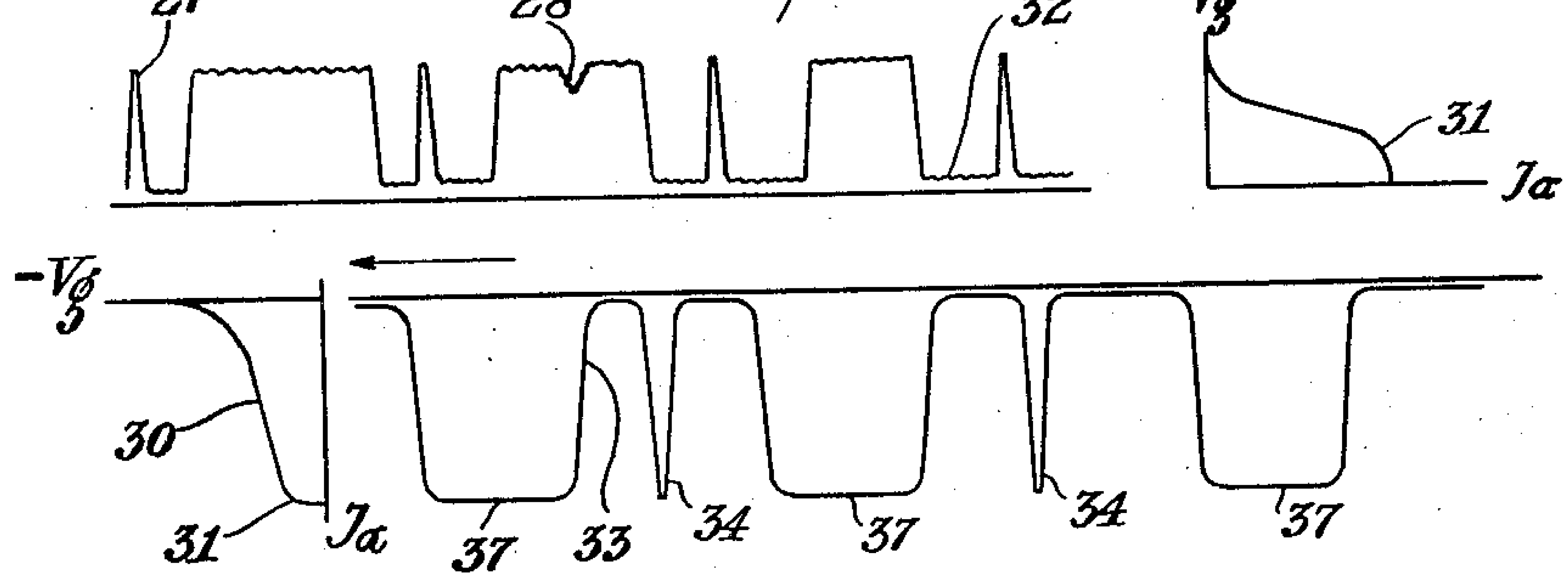

Fig. 6.

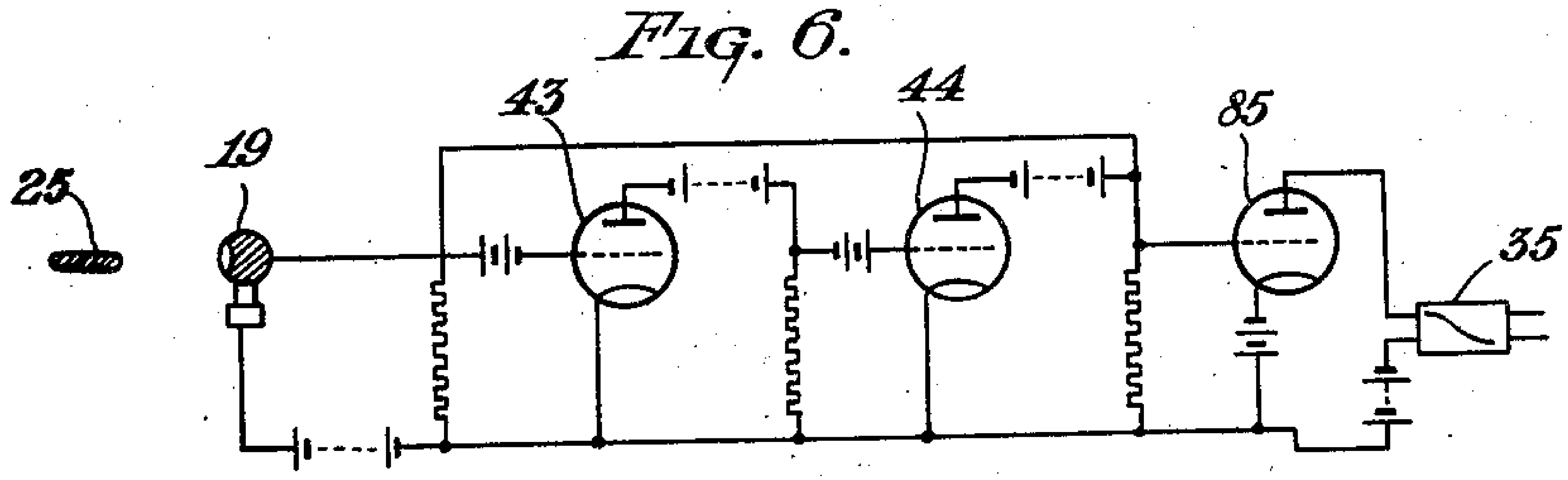

Fig. 7.

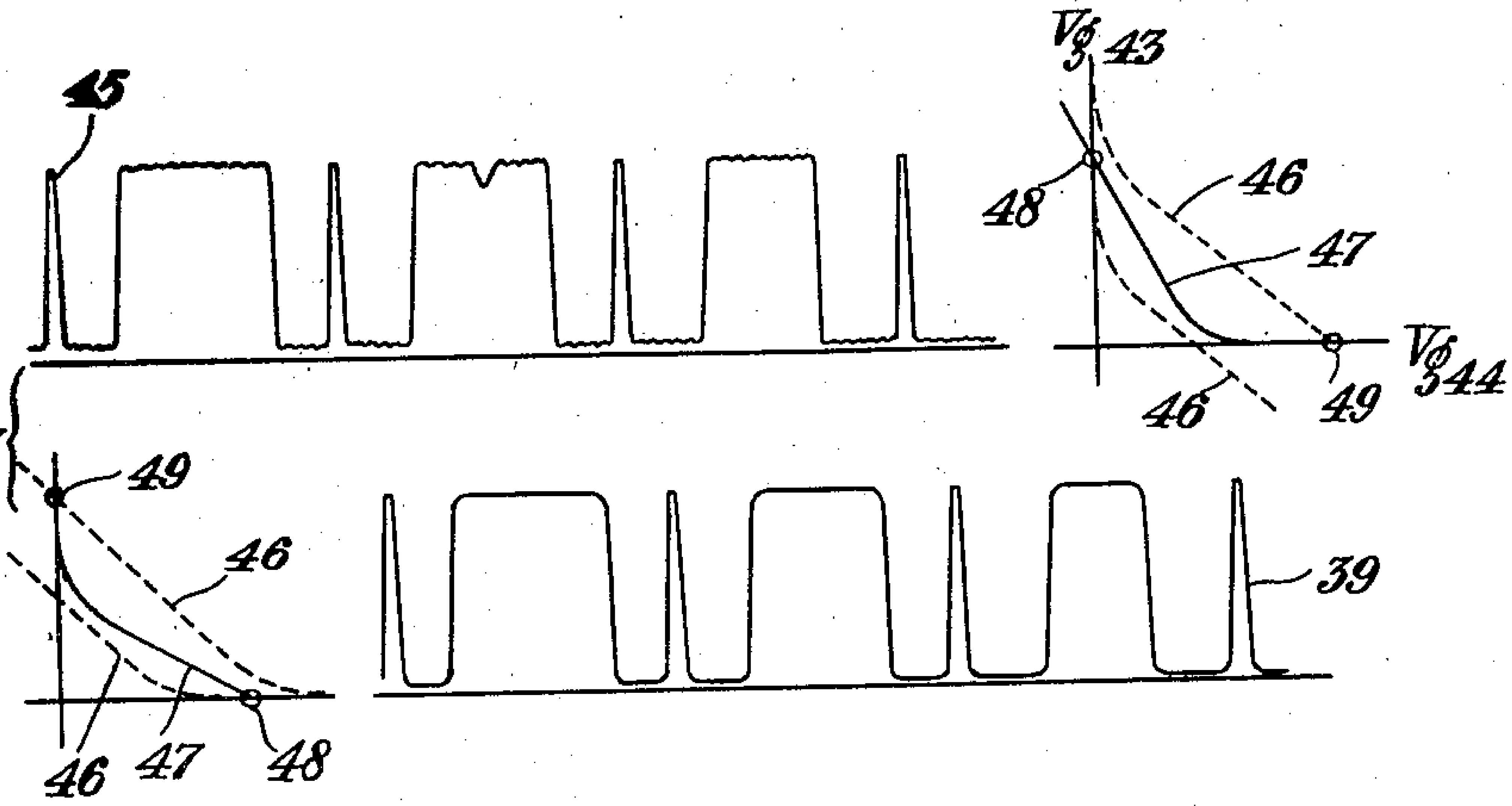

Fig. 8.

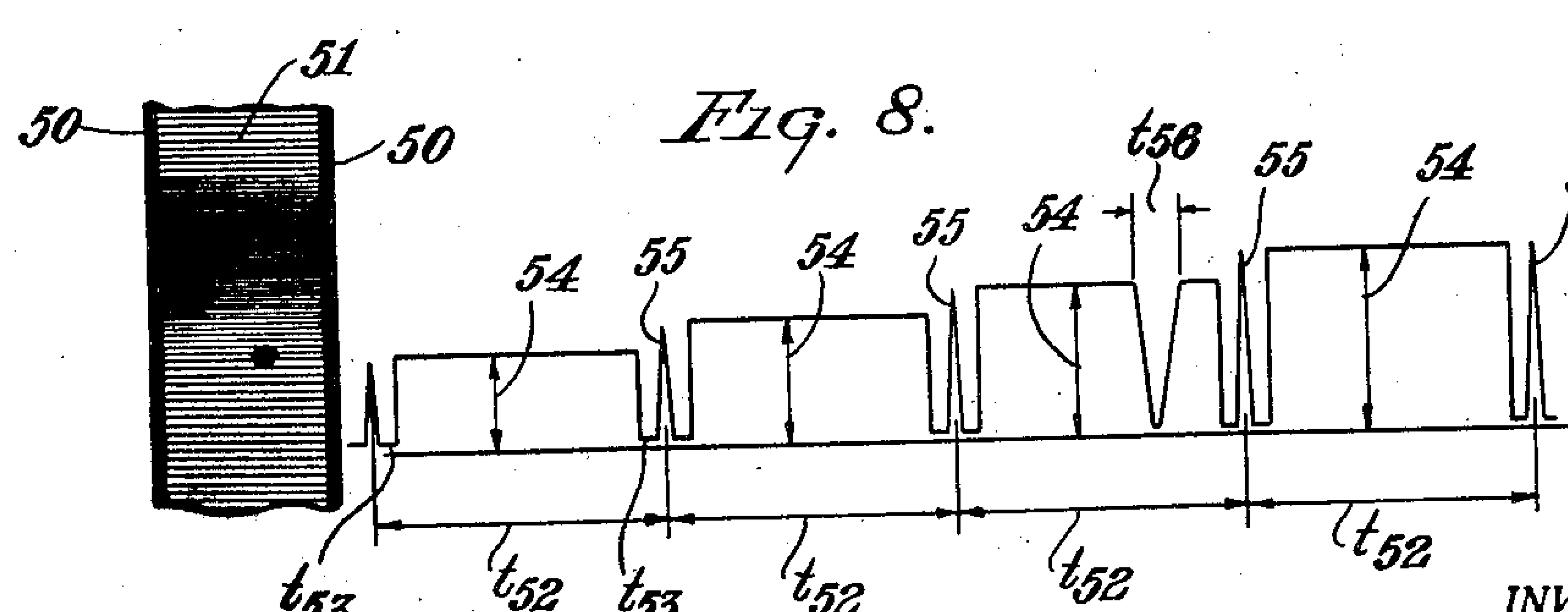

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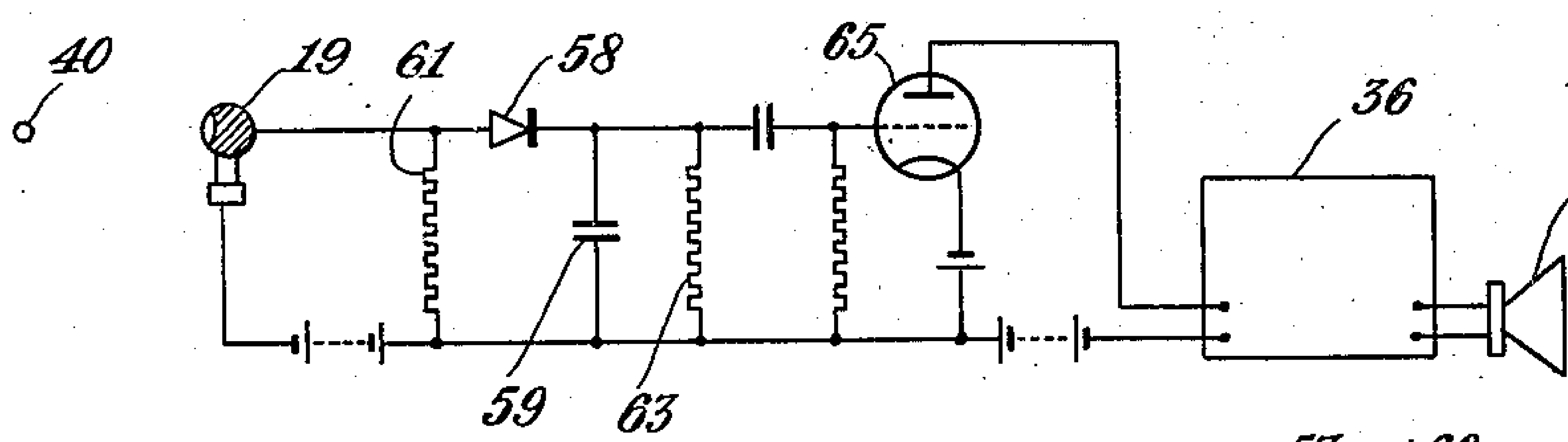
Fig. 9.



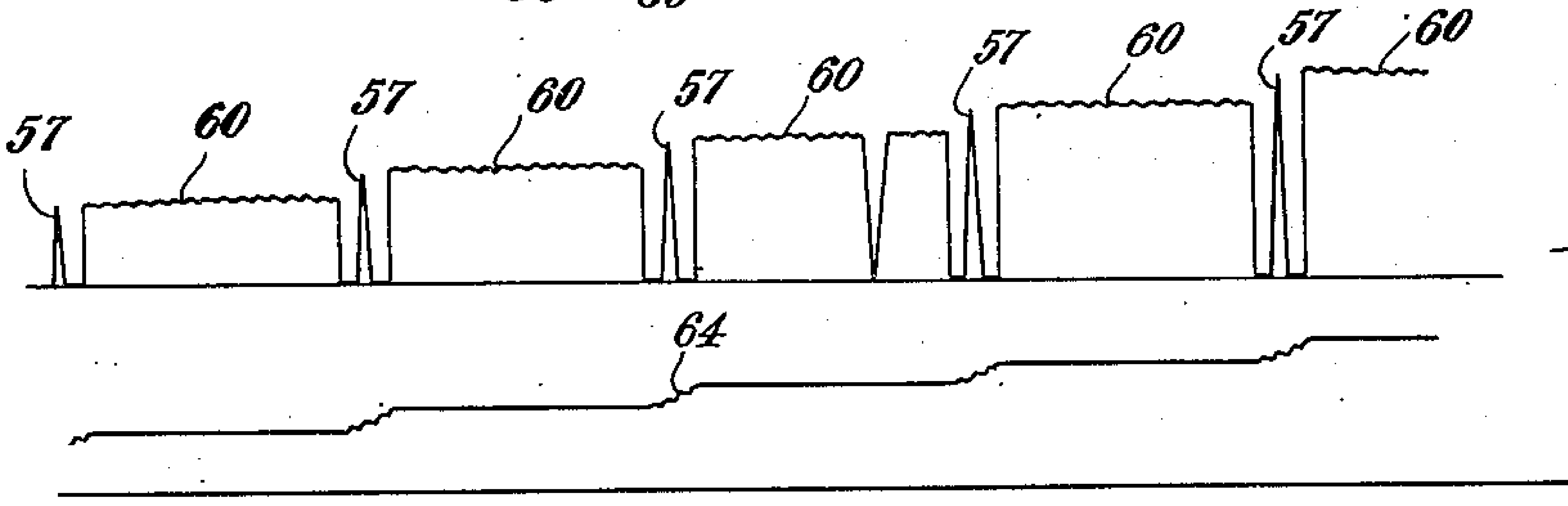


Fig. 10.

Fig. 11.

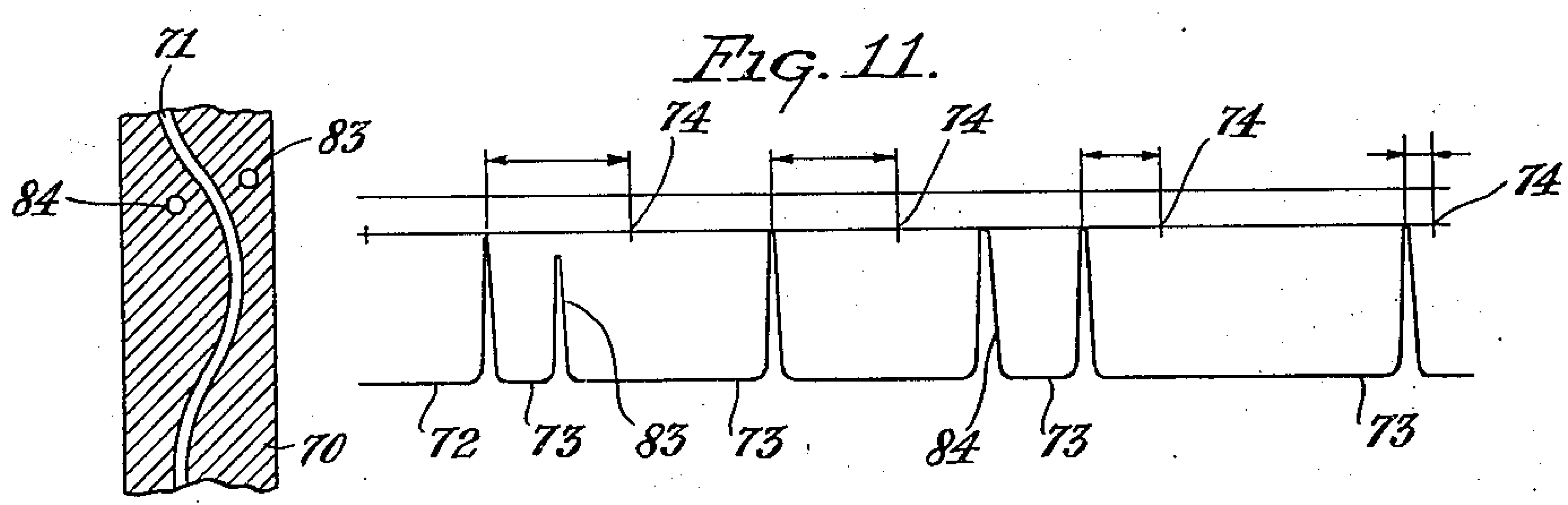


Fig. 12.

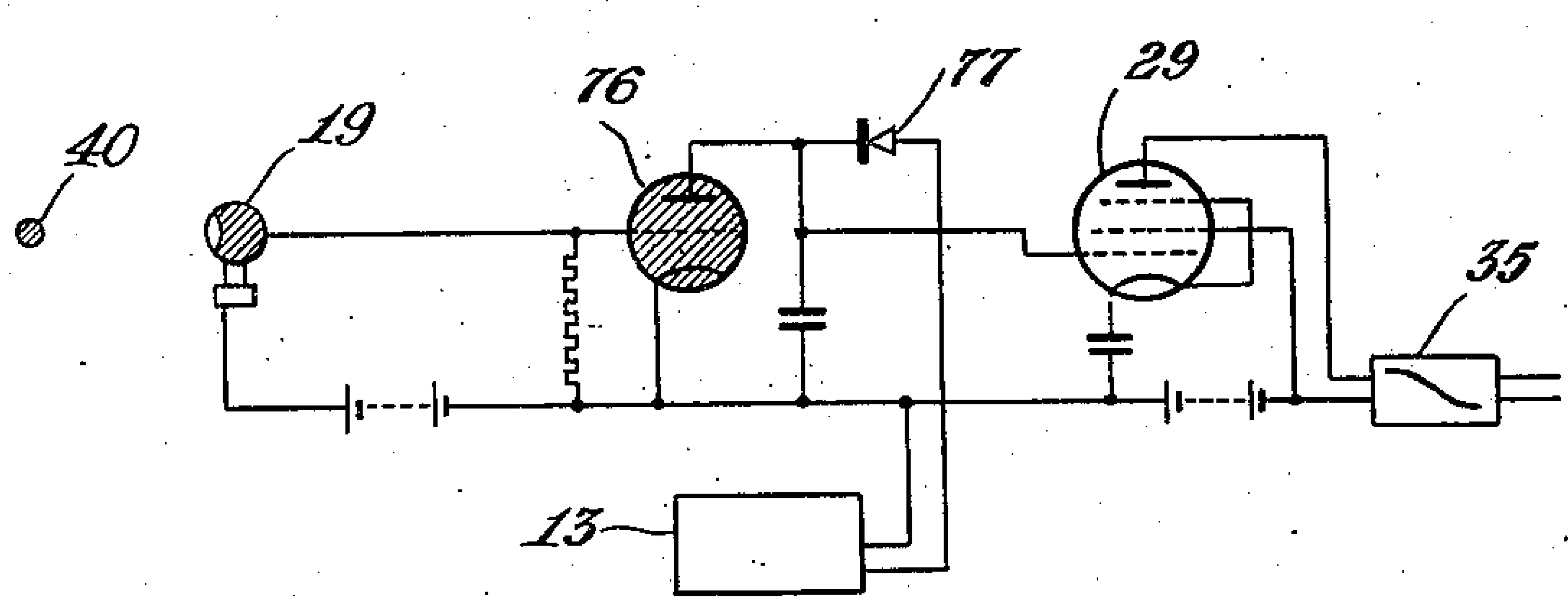
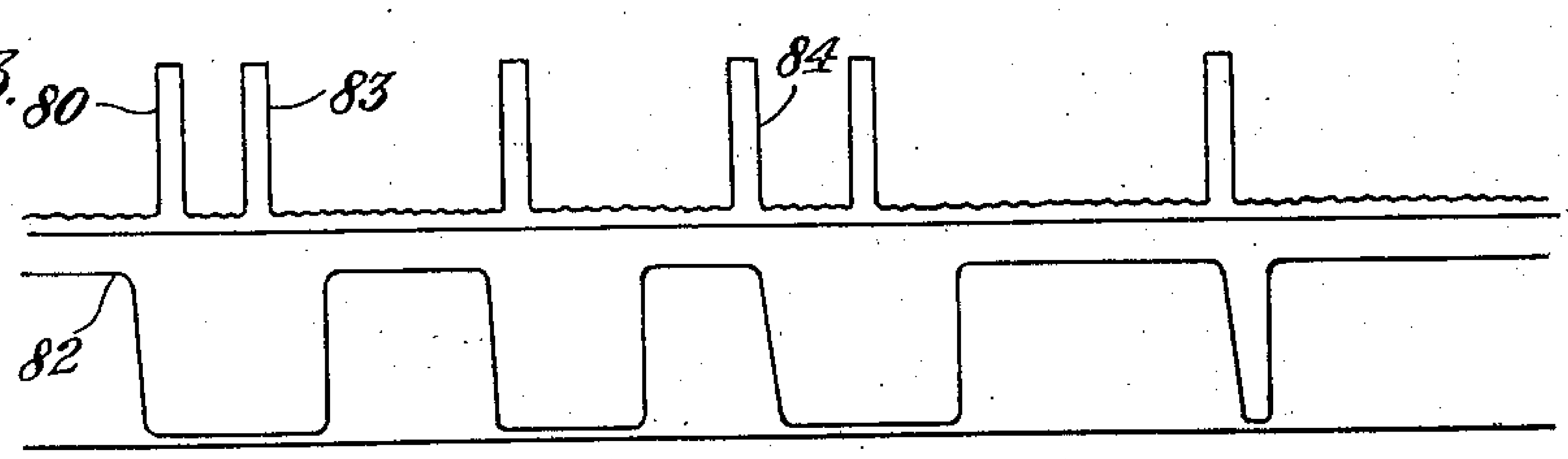


Fig. 13.



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Patented Oct. 25, 1949 2,485,829

UNITED STATES PATENT OFFICE

2,485,829

APPARATUS FOR AND METHOD OF ELECTROOPTICALLY SCANNING AND REPRODUCING RECORDED OSCILLATIONS

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Application May 3, 1946, Serial No. 666,875
In the Netherlands August 30, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires August 30, 1961

23 Claims. (Cl. 179—100.3)

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The invention relates to a method for electro-optically scanning and reproducing oscillation records, inter alia sound tracks. According to one of the known methods these records may be produced as amplitude records, i. e. records of variable width and constant transparency or again as intensity records of constant width. It is also possible to produce an oscillation record in the form of an oscillogram as a line of constant width and varying distance from the edge of the track. The invention does not relate, however, to combinations of the above-mentioned kinds of records.

It is known to scan the above-described oscillation records with the aid of a narrow slit through which passes the light of the oscillation track to reach a photo-electric cell. In this scanning method the light falling upon the photocell is also modulated by the dirt and the unevennesses present in the more or less transparent portion of the track. This modulation is also converted by the photocell into electric alternating voltage and made audible in the reproducing device as the known background noise. In order to suppress this troublesome noise, it is known to keep the transparent portion, already when the record is made or copied, as small as possible in amplitude recording or to keep the average transparency small in the case of intensity recording.

In the reproduction of sound tracks produced by amplitude recording it is furthermore known to cover the transparent portions as far as possible with the aid of a slidable diaphragm.

The reproduction of oscillation records according to the invention is based on principles quite different from those of the known methods of reproduction. It is in general possible to distinguish two elements in oscillation records, which elements jointly determine those properties of these records which are essential for the reproduction. These elements are the degree of transparency of the track and the width of the transparent track.

With records produced by amplitude recording the instantaneous width of the track is determined by the instantaneous value of the sound pressure to be recorded, this width being consequently decisive for the sound to be reproduced. The degree of transparency is only influenced by deterioration of the track and by dirt present on it.

With records produced by intensity recording and having the usual constant width of the track the instantaneous transparency should be determined by the course of the oscillations. The

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presence of dirt on the track always causes a local reduction of the transparency.

With records consisting of an oscillogram in the form of a transparent or opaque line of constant width in a surrounding which does not transmit or transmits light respectively, the amplitude to be reproduced determines the distance between this line and one of the sides of the track.

The invention has for its object to scan the oscillation records electro-optically and to reproduce them electrically in such manner that the dirt always present on the record and the deterioration of the track cannot contribute to the reproduction.

According to the invention, the oscillation record is scanned by a pencil of light which moves at a high frequency perpendicularly to the axis of the track. The light transmitted by the track or reflected in the case of tracks which are to be scanned episcopically, is supplied to a photo-electric element wherein the variations of the incident light are converted into variations of electric voltage. The latter variations are supplied to a device wherein only that out of the two properties of the record (degree of transparency and width of the transparent track) is selected and amplified which determines the oscillation to be reproduced whereas the element which comprises the irregularities in the sound track which give rise to the production of the background noise is eliminated or at least substantially eliminated.

By the pencil of light moving at a high frequency in a direction perpendicular to the axis of the track the two elements fixed by the record are measured with these high frequencies. The instantaneous intensity of the light falling upon the photocell is determined by the instantaneous transparency of the track whilst the width of the track is manifested by the direction of this luminous intensity. The two properties of the track may consequently be found back in the output circuit of the photocell in a determined current intensity and in the duration of the current. According to the known scanning methods both elements are jointly utilized in the reproduction. According to the invention, on the contrary, use is made of only one of the elements, that is to say of that which does not include the variations due to deterioration of the track but which is a measure for the amplitude to be reproduced.

The scanning of the track has to be effected at so high a frequency that during a single scanning the record is not displaced to an appreciable extent since otherwise there would be produced the same distortion which occurs in the case of an oblique scanning slit. If required, this distortion may be completely avoided by arranging that the scanning ray of light moves in a direction oblique to the axis of the track. In any case the scanning frequency must exceed the highest frequency of the oscillation record and it must be easy to separate it therefrom by electric means. For the scanning of sound tracks it is advisable to utilize a scanning frequency of at least 50,000 cycles per second. The maximum scanning frequency is determined by the properties of the scanning, reproducing and amplifying devices.

If a record produced by amplitude recording is scanned by means of the method according to the invention only the element width of the track, that is to say in every scanning period the duration of the transmitted light, is decisive for the instantaneous amplitude. The element degree of transparency includes all the deviations due to dirt present in the track and due to deterioration of the latter. According to the invention, the latter element is kept remote from the reproduction by means of a suitable electric blocking device.

According to the invention, variable density recording is characterized by a constant transparency, provided there are no irregularities present, and a constant time duration, fixed by the width of the path, for each scanning cycle. Deterioration of the track or the presence of dirt thereon is manifested by a local decrease of the transparency, that is to say by a decrease of short duration of the intensity of the scanning light, for dirt is nearly always opaque to light. It has been found in practice that scratches and the like cause such a refraction of light that the scanning light does not strike the photocell or strikes the latter to a lesser degree. According to the invention, in order to avoid these irregularities, in every scanning period the maximum luminous intensity of this period is measured and utilized for the reproduction.

According to the invention, in the case of an oscillogram the distance, i. e. the period of time, between the production of the light variation due to the oscillogram line and the end of the scanning period is measured by electric means. In this case dirt and the like may only give rise to troublesome parasitic noises if the dirt is located exactly on the narrow transparent line. The possibility thereof is considerably smaller than with an ordinary track, even when in the case of slight modulation the width of the track decreases.

The invention will be explained more fully with reference to the accompanying drawings which represent, by way of example, a few embodiments thereof.

Fig. 1 represents a device for scanning sound tracks with the use of the method according to the invention.

Fig. 2 graphically shows the variation of the intensity of the light falling on the photo electric element during the scanning of a sound track of varying width.

Figures 2*a* and 2*b* represent cross-sectional views of light beams employed according to the invention.

Figs. 3 and 4 represent a circuit-arrangement for amplifying the sound frequencies to be scanned and for making them audible.

Fig. 5 shows the variation of the electric voltages originating from the photo-electric element, in the different stages of the amplifying device.

Fig. 6 represents a further embodiment of a circuit-arrangement for making audible the oscillations to be scanned.

Fig. 7 graphically shows the course of the current curves in the circuit arrangement according to Fig. 6.

Fig. 8 graphically represents the variation of the luminous intensities on the photo-electric element during the scanning of a sound track produced by intensity recording.

Fig. 9 represents a circuit arrangement for amplifying the luminous intensities according to Fig. 8 and for making these intensities audible and

Fig. 10 graphically represents the variation of the alternating voltages in the different stages of this circuit arrangement.

Fig. 11 graphically represents the variation of the luminous intensities on the photo-electric element during the scanning of a sound track consisting of a transparent line of constant width but of varying position.

Fig. 12 represents a circuit arrangement for amplifying the oscillations according to Fig. 11 and for making them audible.

Fig. 13 graphically represents the current curves in the various parts of the circuit arrangement according to Fig. 12.

In Fig. 1, **10** denotes a cathode ray tube provided in the usual manner with the required electrodes and with a source of voltage for generating an electron beam in this tube. This electron beam impinges upon a luminescent screen **11** and forms a light spot thereon. The direction of this electron beam may be modified in a plane perpendicular to the axes of coils **12** by supplying electric currents to these coils so that the position of the light spot on the screen **11** is also variable. By means of a generator **13** which generates a high-frequency oscillation this electron beam is moved to and fro at a high frequency so that the light spot on the screen **11** also moves to and fro according to straight lines. On the said screen a luminous line **14** is visible to the eye.

The character of the movement of the light spot is determined by the shape of the current curve of the generator **13**. If the latter generates a sawtooth oscillation, the light spot moves uniformly from the one end to the other during a determined period of time. Then the return takes place in an extremely short time. It is also possible to cause the generator to produce a triangle oscillation. In this case the light spot is moved regularly to and fro.

Various other shapes of current curves are possible to satisfy the different requirements which have to be complied with by the movement of the light spot. It is also possible to make the return movement of the light spot invisible, that is to say to interrupt the electron beam during the period of return. For this purpose it is necessary that the generator **13** should be connected to the electrodes which generate this electron beam. This arrangement is already known from the photo-telegraphy technique in the line-scanning of pictures.

By means of a system of lenses **15** a reduced image of the light spot is formed on the sound track **17** of the film band **16**. This band moves uniformly in the direction of the arrow **18** so that the sound track **17** is regularly scanned by the light spot moving backwards and forwards. The light which passes through the transparent portion of the sound track is projected on to a photo-electric cell 19. The variations of the light falling thereon are converted into corresponding current variations which are supplied to an electric amplifying device which will hereinafter be described in detail.

Fig. 2 graphically represents the variation of the luminous intensity during the scanning of the sound track 17 of film band 16 produced by amplitude recording. The time has been plotted as the abscissa whereas the ordinate represents the intensity of the light falling upon the photocell.

In the present instance it is assumed that the cathode ray tube 10 is controlled by a sawtooth oscillation produced by the generator 13 so that the period of time during which the light spot returns from the one extreme position into the initial position is very short in comparison with the scanning time 20. During the first portion of the scanning path the image of the light spot passes over the blackened portion 21 of the sound track 17 so that substantially no light reaches the photocell t_{21}. Then the transparent portion 22 of the sound track is crossed t_{22}, during which movement all the light of the light spot falls upon the photocell. Then follows again a blackened portion 21 of the track with which no light reaches the photocell t_{21}. During the extremely short time wherein the light spot returns to the initial position t_{23}, a flash of light of short duration is transmitted towards the photocell. The above-described phenomenon is periodically repeated at a high frequency upon every passage of the light spot over the sound track. If dirt is present in the sound track or if the gelatine exhibits such a scratch that due to the refraction caused by this scratch no light or less light attains the photocell, an interruption t_{24} is perceptible during the exposure time t_{22}. If the sound track is scanned according to a known method this interruption would cause the background noise. However, by measuring and by utilizing only the period of time t_{22} between the beginning and the end of the scanning of the transparent track portion for reproduction instead of the total intensity of the transmitted light, any interruption of short duration such as is caused by the dirt in the sound track, for example t_{24}, which gives rise to the production of the known background noise, is not applied to the reproducing apparatus, this noise being thus eliminated in the reproduction.

A circuit arrangement by means of which such interruptions of short duration can be eliminated is described in detail with reference to Fig. 3. In this case use is made of a beam of light 25 as shown in Fig. 2*a* which has a silght length in the direction of the movement of the light spot over the sound track or of a light beam as shown in Fig. 2*b* which consists in this direction of two parts 26, 26. With either of these forms of light beams, the light intensity falling upon the photocell 19 never falls to the zero value so long as in the direction perpendicular to the axis of the sound track the light interruption is smaller than the length of the light spot 25 of Fig. 2*a* or than the joint lengths of the two light spots 26 of Fig. 2*b*. Owing to this the current curve of the photocell 19 acquires the character of curve 27 shown in Fig. 5. It is true that the light interruption of short duration t_{24} of Fig. 2 is perceptible as a decrease of current of short duration 28 but the current does not fall to the zero value.

The voltages originating from the photocell 19 are supplied, with the interposition of the usual coupling elements, to the control grid of a pentode electron tube 29 which operates with an anode voltage which is lower than the normal anode voltage. The anode-grid characteristic curve of such a tube is represented at 30 in Fig. 5. This characteristic curve is fairly steep and in the neighbourhood of the zero value of the grid voltage it exhibits a flat portion 31 wherein the anode current no longer varies even if the grid voltage were to vary slightly. This fact is utilized to ensure that the minimal alternating voltages 32 of the photocell 19, which are due to the minimal illumination through the blackened portion of the sound track and to the noise produced by the photocell, fall within this region. These undesired alternating voltages are not separately amplified in this case. The variations in the maximum alternating voltage of the photocell 19 such as the voltage variation 28 due to dirt in the track and to the photocell noise at full exposure are located in this case in the region of the negative grid voltage wherein the anode current is zero. Neither of these small current variations are consequently further transmitted. In the above-described circuit arrangement the pentode consequently acts as an amplitude filter with an "all or nothing" characteristic curve which passes a current of unvariable intensity only with amplitudes above a determined value and which stops the current with amplitudes below this value.

The variation of the current on the anode side of the tube is consequently that which is represented by curve 33 in Fig. 5. In this curve peaks 34 periodically occur at a frequency equal to the scanning frequency of the cathode ray tube 10. Beyond the pentode tube 29 is mounted a filter 35 which passes only those frequencies which are essential for the reproduction of sound, for example only the frequencies lower than 15,000 cycles per sec. The peaks 34, which occur at a high frequency of, say, 60,000 cycles per sec., consequently are not applied to the further low-frequency amplifying device 36. This filter does not transmit the electric waves 37 which correspond to the scanned transparent portions of the sound track, which waves also occur at a frequency of 60,000 cyles per sec. The variation of the area between every two successive waves 37 is, however, proportional to the variation in the scanning times t_{22} of the transparent portion of the sound track 17. The frequency of this variation is exactly the frequency of the scanned sound record 17, which is located in the range of the audible frequencies and which is consequently transmitted by the filter 35. The above-described circuit arrangement integrates, so to speak, the alternating voltages over the limited time. At the input of the amplifier 36 there consequently arrive only alternating voltages which are proportional to the oscillations recorded in the sound track 17. They are amplified in an amplifier 36 and supplied to a reproducing loudspeaker 38. The electric alternating voltages set up due to dirt on the track and to the noise in the photocell are consequently not reproduced.

Fig. 4 represents a circuit-arrangement with the aid of which likewise the light variations according to Fig. 2 can be made audible without the background noise of the sound track being also reproduced. Use may be made in this case of a beam of light 40, which is, in contradistinction to those beams shown in Figs. 2a and 2b, as small as is still compatible with the requirements of sufficient luminous intensity for the photocell. As such may be utilized, for example, a beam of light which has a diameter of 10 microns so that with a velocity of the film of 45.6 cms. per second oscillations of a frequency of 11,000 cycles per sec. can still be scanned. The smoothing of the unevennesses 24 in the light falling upon a photocell, which smoothing is obtained according to Fig. 3 owing to the shape of the light beam, is effected here by electrical agency, for beyond the photocell 19 is mounted a capacitor 41 which has a capacity such that the high-frequency scanning oscillation is not smoothed to an appreciable extent but that irregularities in these oscillations such as may occur, for example, due to an interruption 24, are partly eliminated. Capacitor 41 is connected in parallel with a resistor 42 through which the capacitor may discharge, the value of resistor 42 being so chosen with respect to the capacity of the capacitor 41 that the reactance of the capacitor at the scanning frequency is approximately equal to the resistance value of the resistor 42. Owing to this smoothing effect we obtain a voltage curve as is represented by curve 27 in Fig. 5. The further amplification of this alternating voltage takes place in this case completely in accordance with the method described with reference to Fig. 3.

Fig. 6 represents a circuit arrangement with the aid of which the result obtained is similar to that of the circuit arrangement according to Fig. 3, viz. amplification of the oscillations of comparatively large amplitude with elimination of the comparatively small alternating voltages set up by the noise of film and photocell. Instead of the pentode amplifying tube 29 there are present here two triodes 43 and 44 which are connected to one another in kallirotron arrangement (cf. the article by L. B. Turner in "Radio Review" I, 1920). The output of the tube 44 is retroactively coupled with the grid of the tube 43 so that the anode-grid characteristic curves 46 and 47 in Fig. 7 of the tubes 43 and 44 respectively must always have one common point in which the aggregate of these tubes operates. The smoothing effect is obtained by giving the beam of light a slight length in the direction of the movement as shown in Fig. 2a. The photocell 19 supplies to the grid of the tube 43 a voltage whose variation is graphically shown by curve 45 in Fig. 7. Owing to the application of this voltage the value of the grid voltage of the tube 43 varies so that the anode-grid characteristic curve 46 is displaced towards a smaller negative voltage. The operating point 48 of the tubes is fixed in the single common point between the characteristic curves 46 and 47. So long as the voltage applied decreases insufficiently to cause such a rise of the negative grid voltage that the characteristic curve 46 leaps over to the other common point 49, the tubes continue to operate in the point 48. The operating point can consequently be displaced from 48 to 49 only by voltage variations in curve 45 which exceed a determined value. At the grid of the triode 35 there consequently arrives a voltage according to curve 39. This triode is followed by a filter 35. Then the sound oscillations are further amplified in a manner analogous to that described with reference to Fig. 3 and converted into acoustic oscillations by a reproducing device. It is evident that other means which give a relay effect corresponding to the above mentioned method may also be used. More particularly relays which only respond after being excited during a determined period of time, would already eliminate interferences even without the effect of these interferences being reduced to that end by smoothing.

Fig. 8 represents the variation of the light intensity on the photocell if a sound track produced by intensity recording is scanned. The scanning time is plotted on the abscissa whereas the ordinate represents the intensity of the light falling upon the photocell. In the present instance the cathode ray tube 10 is assumed to be controlled by a sawtooth oscillation originating from the generator so that the period of time during which the light spot returns from the one extreme position to the initial position is very short in comparison with the scanning time t_{52}. During the first portion of the scanning path the image of the light spot passes over the black edges 50 of the sound track 51, which edges are always present in sound tracks produced by intensity recording for the purpose of limiting the track. During this time t_{53} substantially no light reaches the photocell. Then that portion of the track which carries the sound record and which is blackened to a greater or smaller extent is scanned so that depending on the local degree of blackening a larger or smaller quantity of light 54 falls upon the photocell. Since the width of the track is constant the period of time during which light falls upon the photocell is equal in every scanning period. In the case of intensity recording this time consequently cannot form a measure for the amplitude to be reproduced. After the sound record has been scanned the light spot encounters again the blackened edge 50 so that there follows anew a short time t_{53} of very low luminous intensity. During the accelerated return of the spot to the starting position light falls upon the photocell during a very short time t_{55}.

During the scanning of the sound track quantities of light of varying intensity consequently succeed one another, the short intermediate flashes of time t_{55} being disregarded. If at some point of the track there is a dust particle or a scratch in the layer of gelatine, there follows a short interruption of time t_{56} of the ordinarily uniform luminous intensity 54. In the known scanning method this interruption gives rise to the background noise. In practice it does not occur that the sound track 51 is deteriorated to such an extent that locally a higher transmissibility for light occurs.

The film particles which generally deposit on a sound track are nearly always opaque. Transparent particles and also superficial scratches in the film emulsion cause a refraction such that part of the incident light does not fall upon the photocell. These particles and scratches therefore may be considered as opaque with respect to the photocell.

In order to avoid that during the reproduction the background noise due to the presence of dirt on the sound track should be audible, it is necessary to eliminate local decreases of the luminous intensity 54 of time duration t_{56}. For this purpose the photocell currents are supplied to a circuit arrangement which only responds to the maximum intensities 54. Such a circuit arrangement for peak rectification is shown in Fig. 9. The light of the light beam 40 which passes through the sound track 51 and falls upon the photocell 19 sets up in the latter alternating voltages which are graphically represented by curve 57 in Fig. 10. These alternating voltages are supplied via a rectifier 58 to a capacitor 59. This capacitor is always charged via the rectifier 58 to the maximum instantaneous alternating voltage 60 which is set up by the maximum luminous intensity 54. Owing to the presence of the rectifier 58, which only allows the passage of current in one direction, it is impossible for this capacitor to discharge through a coupling resistor 61 in the photocell circuit. Abrupt decreases of current 62 due to the instantaneous interruption of light 56 can consequently not discharge the capacitor 59. These instantaneous interruptions of current consequently have no influence in the further amplification.

The capacitor 59 must be able, however, to discharge in the time interval between two successive oscillations of the highest sound frequency that is to be transmitted. For this purpose this capacitor has connected in parallel with it a resistor 63 which has a high value as compared with the reactance of the capacitor 59 at the scanning frequency, which amounts, for example, to 60,000 cycles per second. For the maximum sound frequency, for example of 15,000 cycles per second, this resistor 63 must, however, be of the same order of magnitude as the reactance of the capacitor 59.

Across the ends of the resistor 63 there consequently exists a voltage the variation of which is represented by curve 64 in Fig. 10. The high scanning frequency and the instantaneous interruptions due to dirt and scratches in the track are substantially eliminated therefrom. This voltage may be supplied directly to a triode 65 by which these low-frequency alternating voltages are further amplified and are supplied to the usual reproducing device (not shown).

In an analogous manner it is possible to utilize for the scanning the minimum transparency of the track if such should be advantageous in connection with the deteriorations which may occur.

Fig. 11 represents an oscillogram consisting of a bright line 71 of constant width in an opaque surrounding 70. This line is scanned by a light spot which moves to and fro at a high frequency in a direction perpendicular to the axis of the track 70. Curve 72 represents graphically the variation of the luminous intensity falling upon the photocell. When the light spot crosses the line 71, the luminous intensity increases during a short time 73 to a determined value. The lapse of time between the moment 73 at which the light spot crosses the line 71 and the moment 74 at which the scanning light spot has reached its final position, depends on the position of the line 71 on the track 70. The variation of the time interval 73—74 during a plurality of scanning periods is consequently the measure for the course of the line 71; that is to say for the amplitude and the frequency of the oscillogram. Fig. 12 represents a circuit arrangement with the aid of which the above-mentioned period of time 73—74 is measured and is made suitable for reproduction. A beam of light 40 of minimum dimensions, that is to say a beam having a diameter of about 10μ impinges upon the photocell 19 after having moved to and fro over the track 70. The cathode of the photocell 19 is directly coupled with the control grid of a gasfilled triode 76. The anode of this triode is fed by the voltage of the generator 13 which also controls the backward and forward movement of the light spot. In the branch between the generator and the anode is incorporated a rectifier 77 so that the voltage is allowed to pass only in one determined direction. The anode circuit of the gasfilled triode 76 has coupled in parallel with it a capacitor 78 which is charged at the beginning of every scanning period by the generator 13 via a rectifier 77. It is only possible for the capacitor to discharge through the gasfilled triode 76. So long as there is no voltage at the grid of this triode this circuit is, however, open so that the capacitor cannot be discharged.

When the scanning light beam passes a light interruption in the track 70 in the form of the oscillogram 71 a current circulates during a short time in the photocell circuit. The voltage at the grid of the triode 76 acquires a positive value and the gasfilled triode becomes conductive. Now the capacitor 78 can discharge. The variations of these currents are graphically shown in Fig. 13. Curve 80 shows the variation of the light falling upon the photocell and therefore also of the current in the photocell circuit and of the voltage at the grid of the gasfilled triode 76. Curve 82 represents the variation of the voltage at the capacitor 78. After the passage of a light impulse in the track 70 there follows a discharge of the capacitor 78 and at the end of every scanning period the capacitor is recharged. The voltage of the capacitor is supplied to the control grid of a pentode 29 which operates with an anode voltage lower than the normal anode voltage. The variation of the voltage is similar to that described with reference to Fig. 4. If at some places beside the oscillogram 71 there are holes in the opaque sound track 70, they become likewise perceptible on the photocell 19 as short transmissions of light 83 and 84. This light transmission is likewise manifested in the further circuit arrangement by a current variation of short duration. If, however, such a light transmission occurs in the track 70 between the oscillogram 71 and the end of the scanning period, as is the case with the hole 83, it is no longer perceptible at the capacitor 78 since the discharge of this capacitor has taken place already. Such deteriorations of the track are consequently not audible in the reproduction.

If, however, such a hole is located, in the direction of the scanning movement, before the oscillogram line 71, as is the case with the hole 84, a premature discharge of the capacitor 78 takes place, as is shown in Fig. 13.

In general, however, it rarely occurs that the blackened layer is deteriorated to such an extent that it becomes highly transparent to light. Dirt and slight deteriorations, however, can exert influence only then if they occur exactly at the place of the transparent line. Dirt on the filmband can consequently have only a slight influence on the reproduction of sound. A varying width and deterioration of the edges of the transparent line are neither audible or they are audible to a very slight extent. Thus we consequently also obtain a scanning of an oscillation record wherein the background noise is less than normally.

With reference to the above figures there has been described the reproduction of an oscillogram consisting of a bright line in an opaque surrounding. It is also possible to reproduce an oscillogram consisting of a black line in a transparent surrounding, in which event the output of the photocell 19 in the circuit arrangement of Fig. 12 is connected to the control grid of a triode whilst the anode of this triode is coupled with a grid of the gasfilled triode 76. In this case dirt particles present at the place of the deterioration 83 do no harm, dirt particles such as 84, on the contrary, are audible. By displacing the zero line of the oscillogram to the left it is possible to reduce the area where the dirt audible in the reproduction is located, with the result that the background noise decreases. A record wherein a bright line is present on a black background gives rise, however, to a greater decrease of the noise level.

Besides the above-described means and circuit arrangements for carrying the method according to the invention into effect, it is possible to suggest many other methods by means of which it is possible to amplify the electric currents obtained by scanning the track at a high frequency and to free them from undesired elements. The above-mentioned methods are only meant as examples. The movement of the pencil of light may also be obtained in other ways, for example, by optical means or rotary discs or gear-wheels (Nipkow-disc). These modes of realisation do not alter the essence of the invention.

What we claim is:

1. A method of reproducing an oscillation recorded on a carrier having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said carrier transversely of the axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the carrier, converting said collected light rays to produce electric current pulses having amplitude and duration variations proportional to the amplitude and duration of the collected light, selectively translating said current pulses having amplitude and duration variations corresponding to said oscillation and suppressing said current pulses having variations corresponding to said irregularities, and translating said translated current pulses to reproduce said oscillation free from background noise.

2. Apparatus for reproducing an oscillation recorded on a carrier having irregularities normally producing background noise in the reproduction of said oscillation, comprising means to scan said carrier transversely of the axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, a photo-electric element arranged to produce electric current pulses having amplitude and duration variations proportional to the amplitude and duration variations of the light rays impinging on said carrier, means to selectively translate said current pulses having amplitude and duration variations corresponding to said oscillation and to suppress said current pulses having variations corresponding to said irregularites, and means to convert said translated current pulses to reproduce said oscillation substantially free from background noise.

3. A method of reproducing an oscillation recorded on an optically reproducible oscillation record having width variations proportional to the amplitude variations of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said record across the width thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the record, converting said collected light rays to produce electric current pulses having amplitude and duration variations proportional to the width variations of said record and of said irregularities, selectively amplifying said current pulses having duration variations corresponding to said oscillation and suppressing said current pulses having variations corresponding to said irregularities, and translating said amplified current pulses to reproduce said oscillation free from background noise.

4. A method of reproducing an oscillation recordable on an optically reproducible recording medium having width variations proportional to the amplitude of said oscillation, said medium having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said medium across the width thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the medium, converting said collected light rays to produce electric current pulses having amplitude and duration variations proportional to the width variations of said oscillation and of said irregularities, selectively amplifying said current pulses having duration variations exceeding a predetermined value corresponding to said oscillation and suppressing said current pulses having variations corresponding to said irregularities, and translating said amplified pulses to reproduce said oscillation free from background noise.

5. A method of reproducing an oscillation the amplitude variations of which are recorded on an optically reproducible record as a function of the width of a transparent area of said record, said transparent area having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said record across the width thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the record, converting said collected light rays to produce electric current pulses having amplitude and duration variations proportional to the width of said transparent area and of said irregularities, selectively amplifying said current pulses having duration variations exceeding a predetermined value corresponding to said oscillation, filtering out current pulse having variations corresponding to said irregularities, and translating said amplified pulses to reproduce said oscillation free from background noise.

6. A method of reproducing an oscillation recorded on an optically reproducible record having width variations proportional to amplitude variations of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said record across the width thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, the cross-section of said pencil of light rays determined by the plane of said record being shaped to extend beyond edges of said irregularities in the direction of said scanning, collecting the light rays impinging on the record, converting said collected light rays to produce electric current pulses having amplitude and duration variations proportional to the width variations of said record and of said irregularities, selectively amplifying said current pulses having

duration variations exceeding a predetermined value corresponding to said oscillation, filtering out said current pulses having variations corresponding to said irregularities, and converting said amplified pulses to reproduce said oscillation free from background noise.

7. Apparatus for reproducing an oscillation recorded on an optically reproducible carrier having transparent and opaque areas, said areas having width variations proportional to amplitude variations of said oscillation, said transparent area having irregularities normally producing background noise in the reproduction of said oscillation, comprising means to generate a pencil of light rays having a cross-section extending beyond the edges of said irregularities in the direction of said scanning, means to scan said carrier transversely of the axis thereof with said pencil of light rays and at a frequency greater than frequency of said oscillation, means responsive to the light rays impinging on said carrier to produce electric current pulses having amplitude and duration variations proportional to the width variations of said transparent area and the width of said irregularities, means to selectively transmit said current pulses having duration variations exceeding a predetermined value corresponding to said oscillation, means to filter out said current pulses having variations corresponding to said irregularities, and means to convert said transmitted current pulses to reproduce said oscillation substantially free from background noise.

8. A method of reproducing an oscillation recorded on an optically reproducible record having transparency variations proportional to the amplitude of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said record transversely of the axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the record, converting said collected light rays to produce electric current pulses having amplitude and duration variations proportional to the transparency of said record; selectively amplifying said current pulses having amplitude and duration variations corresponding to the maximum and minimum transparency of said record and suppressing said current pulses having variations corresponding to said irregularities, and converting said amplified current pulses to reproduce said oscillation free from background noise.

9. Apparatus for reproducing an oscillation the amplitude of which is recorded on an optically reproducible record as a function of the transparency thereof, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising means to scan said record transversely of the axis thereof with a pencil of light rays and at a frequency greater than the frequency of said oscillation, means responsive to the light rays impinging on said carrier to produce electric current pulses having amplitude and duration variations proportional to the transparency of said carrier and said irregularities, means selectively to transmit said current pulses having amplitude and duration variations corresponding to the maximum and minimum transparency of said record to suppress current pulses having variations corresponding to said irregularities, and means to utilize said transmitted current pulses to reproduce said oscillation substantially free from background noise.

10. A method of reproducing an oscillation recorded on an optically reproducible record having density variations proportional to the amplitude of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said record transversely of the axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the record, converting said collected light rays to produce electric current pulses having amplitude variations proportional to the density of said record, selectively rectifying said pulses to produce a potential varying correspondingly to the maximum and minimum density of said record to suppress variations of said current corresponding to said irregularities, smoothing said rectified potential, and converting said smoothed potential variations to reproduce said oscillation free from background noise.

11. Apparatus for reproducing an oscillation recorded on an optically reproducible record having density variations proportional to the amplitude of said oscillation, comprising means to scan said record transversely of the recording axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, a photoelectric cell circuit responsive to the light rays impinging on said record to produce pulses having amplitude variations proportional to the density of said carrier, a rectifier circuit coupled to said photoelectric cell circuit to produce a direct potential corresponding to the maximum value of said pulses, and electric filter coupled to said rectifier circuit to smooth said direct potential, and means to employ said filtered potential to reproduce said oscillation.

12. A method of reproducing an oscillation recorded on an optically reproducible record having a line spaced from the edge of said record in proportion to the amplitude of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising the steps of scanning said record transversely of the axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, collecting the light rays impinging on the carrier, converting said collected light rays to produce electric current pulses having duration variations proportional to the distance variations of said line and said irregularities with respect to the edge of said record, selectively amplifying said current pulses having duration variations corresponding to the distance variations of said line with respect to the edge of said carrier and suppressing said current pulses having variations corresponding to the distance variations of said irregularities with respect to the edge of said record, and converting said amplified pulses to reproduce said oscillation free from background noise.

13. Apparatus for reproducing an oscillation recorded as an oscillogram on an optically reproducible record having opaque and transparent areas, the amplitude of said oscillation being proportional to the distance of said oscillogram from the edge of said record, comprising means to scan said record transversely of the axis thereof with a pencil of light rays and at a frequency greater than frequency of said oscillation, means responsive to the light rays impinging on said record to produce pulses having amplitude and

duration variations proportional to the transparency of said record, an amplifier circuit, means to apply said pulses to said amplifier circuit to produce in the output thereof a potential proportional to the distance variations of said oscillogram with respect to the edge of said record, and means to convert said potential to reproduce said oscillation.

14. Apparatus for reproducing an oscillation recorded on an optically reproducible record having transparency variations proportional to the amplitude variations of said oscillation, comprising a cathode-ray tube having means to generate an electron beam, a pair of deflection electrodes and a fluorescent screen upon which said beam impinges to form a light spot, a high frequency oscillation generator coupled to the deflection electrodes of said tube to oscillate said light spot across said screen at a rate higher than the frequency of said oscillation, means to project an optical image of said oscillating light spot upon said record normal to the reproducing axis thereof, a photoelectric cell arranged to intercept light rays from said oscillating light spot passing through said record to produce electric current pulses having amplitude and duration variations proportional to the transparency of said record, means to transmit said current pulses having amplitude and duration variations exceeding a predetermined value, and means to convert said transmitted current pulses to reproduce said oscillation.

15. Apparatus for reproducing an oscillation recorded on an optically reproducible record having width variations proportional to amplitude variations of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising a cathode-ray tube having means to generate an electron beam, a pair of deflection electrodes and a fluorescent screen upon which said beam impinges to form a light spot elongated in shape, a high frequency oscillation generator coupled to the deflection electrodes of said tube to oscillate said light spot across said screen in the direction of said elongation and at a rate higher than the frequency of said oscillation, means to project an optical image of said oscillating light spot upon said carrier normal to the axis thereof, a photo-electric cell arranged to intercept light rays from said oscillating light spot passing through the transparent area of said carrier to produce electric current pulses having amplitude and duration variations proportional to the width variations of said record and of said irregularities, means selectively to transmit said current pulses having duration variations exceeding a predetermined value corresponding to said oscillation and to suppress said current pulses having variations corresponding to said irregularities, and means to convert said transmitted current pulses to reproduce said oscillation substantially free from background noise.

16. Apparatus for reproducing an oscillation recorded on a carrier having a transparent area the width of which is proportional to the amplitude of said oscillation, said transparent area having irregularities normally producing background noise in the reproduction of said oscillation, comprising a cathode-ray tube having means to generate an electron beam, a pair of deflection electrodes and a fluorescent screen upon which said beam impinges to form a pair of light spots, a high frequency oscillation generator coupled to the deflection electrodes of said tube to oscillate

said light spots across said screen in the direction connecting said spots and at a rate higher than the frequency of said oscillation, means to project an optical image of said oscillating light spots upon said carrier normal to the axis thereof, a photo-electric cell arranged to intercept light rays from said oscillating light spots passing through the transparent area of said carrier to produce electric current pulses having amplitude and duration variations proportional to the width of said transparent area and said irregularities, means selectively to transmit said current pulses having amplitude and duration variations exceeding a predetermined value corresponding to said oscillation and to suppress said current pulses having variations corresponding to said irregularities, and means to convert said transmitted current pulses to reproduce said oscillation substantially free from background noise.

17. Apparatus for reproducing an oscillation recorded on an optically reproducible record having width variations proportional to the amplitude variations of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising a cathode-ray tube having means to generate an electron beam, a pair of deflection electrodes and a fluorescent screen upon which said beam impinges to form a light spot, a high frequency oscillation generator coupled to the deflection electrodes of said tube to oscillate said light spot across said screen at a rate higher than the frequency of said oscillation, means to project an optical image of said oscillating light spot upon said record normal to the axis thereof, a photo-electric cell arranged to intercept light rays from said oscillating light spot impinging on said record to produce pulses having amplitude and duration variations proportional to the width variations of said record and of said irregularities, a filter circuit coupled to said photo-electric cell and having a time constant at which frequencies higher than the oscillation of said high frequency oscillations are eliminated, means selectively to transmit said current pulses having duration variations exceeding a predetermined value corresponding to said oscillation and to suppress said current pulses having variations corresponding to said irregularities, and means to convert said transmitted pulses to reproduce said oscillation substantially free from background noise.

18. Apparatus for reproducing an oscillation recorded on an optically reproducible record having transparency variations proportional to the amplitude of said oscillation, said record having irregularities normally producing background noise in the reproduction of said oscillation, comprising a cathode-ray tube having means to generate an electron beam, a pair of deflection electrodes and a fluorescent screen upon which said beam impinges to form a light spot, a high frequency oscillation generator coupled to the deflection electrodes of said tube to deflect said light spot across said screen at a rate higher than the frequency of said oscillation, means coupled to said generator to blank out said spot on the return deflection thereof, means to project an optical image of said oscillating light spot upon said record normal to the reproduction axis thereof, a photoelectric cell arranged to intercept light rays from said oscillating light spot impinging on said record to produce pulses having amplitude and duration variations proportional to the width variations of said record and said

irregularities, a peak rectifier element coupled to said photoelectric cell to produce a direct potential proportional to the maximum photoelectric cell current, a resistance-capacity filter circuit coupled to said rectifier element selectively to transmit amplitude variations of said photoelectric cell current exceeding the frequency of audible sound corresponding to said oscillation and to suppress variations of said current corresponding to said irregularities, and means to convert said transmitted current variations to reproduce said oscillation substantially free from background noise.

19. A method of reproducing sound from a sound track on a record which comprises scanning the sound track in elementary paths transversely of its length, establishing a current pulse for each scanning path, the amplitude of each pulse being dependent upon the transparency of an elementary area of the scanning path at any instant, translating said pulses into pulses of limited uniform amplitude, integrating said translated pulses into a variable current, and translating said variable current into sound.

20. A method of reproducing sound from a sound track on a record which comprises establishing a series of current impulses varying in amplitude in accordance with the transparency of successive elementary areas in transverse paths across said sound track, one pulse being established for each transverse path in said sound track, limiting the amplitude of said pulses to a predetermined value, integrating said limited pulses to produce a variable current, and translating said variable current into sound.

21. A method of reproducing sound from a sound track on a record which comprises scanning the sound track according to elementary paths transversely of its length, establishing a current pulse for each scanning path, the value of each pulse varying in accordance with variations in transparency of successive elementary areas of the respective scanning path, and the length of each pulse corresponding to the width of the clear portion of the sound track at the point of scanning, transmitting said pulses through a current limiter to limit the amplitude thereof, translating said amplitude limited pulses into a variable current, and translating said variable current into sound.

22. A method of reproducing sound from a sound track on a record which comprises scanning the sound track according to elementary paths transversely of its length, establishing a current pulse for each scanning path, the value of each pulse varying in accordance with variations in transparency of successive elementary areas of the respective scanning path, and the length of each pulse corresponding to the width of the clear portion of the sound track at the point of scanning, transmitting said pulses through a current limiter to limit the amplitude thereof, translating said limited pulses into pulses having amplitudes proportional to the lengths of the corresponding scanning pulses, translating said variable amplitude pulses into a variable current, and translating said variable current into sound.

23. Apparatus for reproducing sound from a sound track on a record comprising, in combination, means for scanning a sound track in elementary paths transversely of its length and establishing a current pulse for each scanning path which varies in amplitude in accordance with the transparency of the successive elementary areas in the corresponding path, a current limiter, means for transmitting said variable pulses through said limiter whereby the amplitudes thereof are limited to a predetermined value, means for integrating said limited pulses into a variable current, and means for translating said variable current into sound variations.

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