Fig. 1

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METHOD OF AND AN APPARATUS FOR RECORDING A VARIABLE VOLTAGE

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Fig. 2

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METHOD OF AND AN APPARATUS FOR RECORDING A VARIABLE VOLTAGE

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The present invention relates to a method of recording a variable voltage and to apparatus for recording such voltages, more particularly the invention relates to a recording by photographic means.

Methods and apparatus of the general kind above referred to, have many useful fields of application. The recorded variable voltage or voltages may be representative of mechanical movement such as the speed, acceleration or movement of a fast moving object or of a physical magnitude such as variations in temperature or moisture with respect to time or distance.

It is already known to record variable voltages photographically by means of a cathode ray oscillograph, the beam of which traces the variations on a film by the agency of an interposed suitable optical system.

In arrangements as heretofore known, the voltage is caused continually to deflect the beam whereby the deviations of the deflections and the variations of the voltage are in approximate coincidence, the time deflection of the tracing being obtained by moving the film at a right angle to the direction of the voltage controlled deflection. The graphs traced on the moving film are interpreted by appropriate measurements and calculations.

The required evaluations of the tracings are rather complex, and it is time consuming to carry out the required measurements by manual operations. Attempts to devise automatic measuring operations were not successful, or at least too complicated, especially when several variable voltages are traced on the same film.

Accordingly, one of the objects of the present invention is to provide a novel and improved method of and an apparatus for simultaneously recording several voltages.

Another object of the invention is to provide a novel and improved apparatus for carrying out several recordings by means of a single cathode ray oscillograph.

The basic concept of the invention resides in recording the one or several variable voltages as a plurality of the momentary values traced on the film in the form of lines, the time deflection of the film, generally straight lines, each line representing a momentary value and the length of each line being indicative of the respective momentary value.

Other and further objects, features and advantages of the invention will be more fully appreciated from the appended claims forming part of the application.

In the accompanying drawings, several preferred embodiments of the invention are shown by way of illustration and not by way of limitation.

In the drawing:

FIG. 1 is a diagrammatic view of a recording apparatus according to the invention.

FIG. 2 is a block diagram showing the components included in the electronic control system of the apparatus of FIG. 1.

FIGS. 3 to 9 are graphs of wave forms as they appear at different measuring positions in the apparatus of FIGS. 1 and 2.

FIG. 10 is a diagrammatic view of an apparatus by means of which variable voltages traced on a film in the apparatus of FIG. 1 are converted into graphs suitable for evaluating and computing the variations of the voltages.

FIG. 11 is a block diagram of the components of the control system used in the apparatus of FIG. 10, and FIGS. 12 to 29 are graphs of wave forms as they appear at different measuring positions in the apparatus according to FIGS. 10 and 11.

Before describing the figures in detail, some of the terminology used in this specification will be defined. The term "cathode mixer" or "mixer" refers to a device comprising two or more triodes, one for each input, the tubes having a common cathode resistance. The anodes are connected each to a grid and the output is connected to the cathodes which in turn are connected together. In a mixer of this kind, the output voltages have the same value as the highest of the input voltages.

The "Schmitt trigger circuit" is a trigger in the nature of a multi-vibrator with two stable positions. The position which is assumed by the trigger circuit depends upon the input level. If this level is higher than the so-called upper switch-over level, the trigger circuit assumes a position hereinafter referred to as the first position. When the input level is below the so-called lower switch-over level, the trigger circuit assumes its other, or second position. In the event the input level is between the upper and the lower switch-over levels, the first position is assumed by the trigger circuit if the upper switch-over level has been last passed and the second position if the lower switch-over level was last passed. As is now apparent, triggers of the kind herein referred to, show a hysteresis similar to that of a relay. Schmitt trigger circuits are described, for instance, by Buckle O.S., Time Bases, Chapman and Hall Ltd., 1944.

The "integrators" hereinafter referred to, are controlled by the triggers so that the trigger in the first position locks the voltages at the grid of the integrator and at its output at fixed values. When the trigger changes to its second position these voltages are released and the integrator begins to integrate a constant negative voltage and at the output a voltage appears rising linearly in time. As soon as the trigger returns to its first position, the integrator rapidly returns to its locked position. Integrators controlled in such a manner are described for instance in Chapter 7, Part 19, of Radiation Laboratories Series, McGraw-Hill Book Company Inc., 1949.

Referring now to the figures in detail, there is shown in FIG. 1, a cathode ray tube K controlled by a recording circuit system IK, to which is fed the magnitude to be measured or supervised in the form of an electric current. The beam of the tube is focused upon a film F by means of an objective O of suitable design. The direction of movement of the film which is driven at a selected rate of speed by any suitable drive means is indicated by an arrow x, and the direction transverse of the film movement by an arrow y. The electron beam of tube K is deflected in transverse direction, but as evident the lines traced on the film and shown as a train of parallel straight lines deviate at a small angle from the transverse direction due to movement of the film in the direction of the x axis. This angle of deflection will be hereinafter referred to as angle α. The dashed line from which the lines traced on the film originate is hereinafter designated as α=0 in the system of coordinates formed by the x and y axes.

In the period of time in which the recording is carried out, a rectangular negative pulse 1 is fed to a mixer B. This mixer is shown as a block in FIG. 2 which also shows...
all the other components comprised in the control system IK of FIG. 1. The shape of pulse 1 is shown in FIG. 3. Negative pulses of the shape shown in FIG. 4, are also continuously fed to the mixer BL1 at its input. The reference level for the wave forms when they do not coincide with the actual levels are shown as dashed lines in FIGS. 3 and 4 and also in the subsequent figures. Pulses 2 are generated by a pulse generator PG at an accurately maintained frequency. Each pulse of the wave form 2, starts a sweep on the screen of the cathode ray tube K through mixer BL1, a trigger TR1, an integrator Ig1, a mixer BL3, and a y-amplifier y-F. At the same time, the necessary beam intensity is supplied to tube K by means of trigger TR1. The output voltage 6 of the integrator, the shape of which is shown in FIG. 5, is fed to a comparator KP. The second input of the comparator is supplied with the voltage 5 which is to be measured or recorded. Comparators of the kind suitable for the purpose are described on page 340, Part 19, of the aforementioned Radiation Laboratories Series. The comparator KP produces a positive pulse of the waveform 3 shown in FIG. 6, each time the voltage 6 equals voltage 5. The voltage which reaches trigger TR1 from mixer BL1 is shown in FIG. 7, as voltage 4. In this figure the upper and the lower switch-over levels of the trigger are shown by chain-link lines. As is apparent, the switch-over levels are passed by pulses generated by the pulse generator and the pulses generated by the comparator. The positive voltage fed from the trigger to the cathode ray tube is shown in FIG. 8 as having the wave form 7, and the voltage supplied from the trigger to the integrator is shown in FIG. 9 as having the wave form 8.

A recording by means of the apparatus, as hereinbefore described, is carried out as follows. The voltage 4 which fed from mixer BL1 to trigger TR1 is a composite of the wave forms 1, 2 and 3 due to a selection of each of the voltage peaks. As can be seen in FIG. 7, the wave form 4 is initially above the upper chain-linked line which represents the upper switch-over level of the trigger. Consequently, the trigger assumes its first position. When voltage 4 passes the lower switch-over level of the trigger for the first time, a pulse of the voltage 2 is generated after voltage 1 has decreased to its lower level. As a result, the trigger moves into its second position. Integrator Ig1 now begins to integrate a constant voltage whereby a voltage is generated rising linearly in time. This voltage is designated as voltage 6 in FIG. 5. Voltage 6 is fed to comparator KP which, when the voltage has reached the same value as voltage 5, generates a pulse having the wave form 3 in FIG. 6. The pulse of wave form 3 causes trigger TR1 to return to its first position and the integrator ceases to integrate and moves rapidly into its locked position. This cycle is repeated for each pulse generator by pulse generator PG. The linearly rising voltages 6 pass to the y-amplifier y-F and from this amplifier to the cathode ray tube K. As a result, this tube effects sweeps having a length corresponding to voltages 6.

A second mixer BL3 is interposed between integrator Ig1 and y-amplifier y-F. The second input to mixer BL3 is fed with a constant and low voltage which does not materially affect the recording. The mixer BL3 is used for analysing only but is also included in the recording system hereinafter described to obtain the same conditions of linearity for both operations.

The lines produced by the sweep of the cathode ray tube are traced on film F as is shown in FIG. 1.

After the film has been developed and fixed, a negative is obtained in which momentary values of the variable voltage appear as transparent lines on a more or less opaque background.

To obtain an analysis or number registration of the variable voltage suitable for measuring, the film of FIG. 1 may be played back by the apparatus shown in FIGS. 10 and 11.

The apparatus of FIG. 10 comprises film F bearing the lines to be measured and obtained as previously explained, the objective O, the cathode ray tube K and a photo-amplifier FM including a photo-sensitive cathode FK. On the side of the film facing the photo-amplifier, a mixer B including a slot extending transversely of the film is interposed. The apparatus of FIG. 10 further comprises a playback circuit system AK, a computer RV, and a number or figures registering apparatus SF.

The blockers BL1 and BL2 determine the time's range over which the time components as the block diagram of FIG. 2, to wit; mixer BL1, trigger TR1, integrator Ig1, mixer BL3, y-amplifier y-F, cathode ray tube K and camera Kam. Pulse generator PG of FIG. 11 generates a train of fast negative pulses having the wave form 11 of FIG. 12. These pulses are fed to a mixer BL2, to which is also fed from an integrator Ig2 the saw-toothed voltage 12 shown in FIG. 13. The voltage output of mixer BL2 has the wave form 13 of FIG. 14 which figure also shows the upper and the lower switch-over levels for a trigger TR2 as chain link lines. The output side of mixer BL3 is connected to trigger TR2 which generates the wave form 14 of FIG. 15. The second integrator Ig2 integrates during the time trigger TR2 is in its second position, that is, for the period of time in which a pulse is delivered by pulse generator PG until the voltage delivered by integrator Ig2 to mixer BL2 reaches the upper switch-over level of trigger TR2. As a result, the wave form 12 of FIG. 13 is generated. Integrator Ig2 through mixer BL3 and the y-amplifier y-F deflects the beam of the cathode ray tube in the direction of the y-axis shown in FIG. 10. During these sweeps, the so-called "feeler sweeps," the intensity of the beam is maintained by the square wave form 14 of FIG. 15.

When one of the lines of film F is moved into registry with the slot of mixer B, the sweeping beam impinges upon the line in registry and the photo-amplifier FM is excited by light impulses of increasing amplitude. These impulses are amplified in an amplifier Fa, and are shown as three rectangular voltage pulses included in the wave form 15 of FIG. 16. The wave form 17 of FIG. 18 shows the output pulses of mixer BL1. The presence of three rectangular pulses has been arbitrarily selected and it is further assumed that the fourth pulse is so high that the lower switch-over level of the subsequent trigger TR1 is passed. The upper and the lower switch-over levels of this trigger are indicated in FIG. 17 by the chain linked lines. As a result of the fourth pulse passing the lower switch-over level of trigger TR1, the trigger releases a slow sweep, the so-called "play-back sweep," from integrator Ig1, through mixer BL3 and y-amplifier y-F. The trigger TR1 also produces the negative step voltage 16 of FIG. 17 fed to a mixer BL3 which produces the input voltage 18 of FIG. 20. This voltage is fed to a trigger TR3, which is now activated by the impulses coming from the photo-amplifier FM. The negative stepped voltage shown as wave form 16 in FIG. 17 reduces the level of the voltage 22 fed to mixer BL3 so that the voltage 23 now controls mixer BL3 and its output voltage 24. As a result, the sweep can no longer reach the screen of the cathode ray tube. The play-back sweep starts at a somewhat lower level than the feeder sweep which corresponds to the feeder sweep across film F, commencing at a slightly negative y-value, that is, to the left of the dashed line on the film in FIG. 10. Integrator Ig2 further produces a pulsating voltage 26 shown in FIG. 27. This voltage serves to generate registering sweeps of the electron beam in the direction of the x-axis during the play-back sweep. In the embodiment shown, the pulsating voltage is obtained from the same source as the feeder sweeps but it can also be generated by an independent source.

The pulses are transmitted to the cathode ray tube K through a mixer BL5 and an x-differential amplifier x-F.
Prior to the release of the registering sweeps, the two inputs of the x-differential amplifier X-F were fed with voltage 16 through the mixer BL5 and a mixer BL4. Furthermore, there was no voltage differential between the deflection plates of tube K for deflecting the beam in the direction of the x-axis as the tube was controlled by x-amplifier X-F, see wave form 28 on FIG. 29. Consequently, the electron beam was not deflected in the direction of the x-axis. As a result of the negative stopped voltage of the wave form 16, the wave form 25 obtained on the output side of mixer BL4 has a lower level due to a voltage 25 fed to the second input of the mixer. This lower level is the mean level for the voltage 26 which at the same time controls the output voltage 27 of mixer BL5. Consequently, the spot of the beam is deflected during the play-back sweep symmetrically about the line defined by the feeder sweep as shown by wave form 28 in FIG. 29. For each measuring sweep in the direction of the x-axis, there is fed, when the spot of the beam impinges upon the line in a registral, a pulse to a computer R1 through photo amplifier FM, amplifier Fa, a mixer BL7, and a trigger T3 connected to mixer BL7. The switch-over levels for trigger T3 are close to each other. Consequently, the short voltage pulses from amplifier Fa shown in the form of pulses having the wave forms 15 and 18 produce on the output side of the trigger equally short output pulses having the wave form 19.

The length of the play-back sweep is greater than the longest of the lines on film F. Part of the voltage 23 delivered by integrator I21 to mixer BL6 is attenuated in an attenuator A1. Mixer BL6 has a comparatively short cathode resistance connected in parallel with a condenser. A constant voltage 20 is fed to mixer BL6 as shown in FIG. 19. The voltage output of the attenuator is increased until it has a wave form 20 of FIG. 19 and when it reaches the upper-switch-over level of trigger T1, the trigger switches over, the play-back sweep is discontinued and the voltage 23 rapidly returns to the output value it had prior to the integration. Voltage 20 decreases slowly to the level of voltage 20 but retains control over the output voltage 17 from mixer BL1. Consequently, any pulses originating in amplifier Fa can not start a new play-back sweep until voltage 20 has dropped below the lower-switch-over level for trigger T1. During this period of time all the other voltage changes have returned to the values they had prior to the release of the play-back sweep.

A new play-back sweep is released by the feeder sweep when the next line on film F moves into registry with the slot of mixer B. As a result the voltage from B is fed to a second computer R2 which is energized for each negative step of voltage 16. The same voltage is also fed to a number registering apparatus R-reg which for each positive step of the voltage 16 registers the setting of the two computers R1 and R2. After completion of the registration, the computer R1 is set back to zero.

It is not necessary to maintain proportionality between the momentary values of the variable voltages and the length of the corresponding line on film F. The same cathode ray tube is used for both, recording and play-back, and as the recording circuits are also included in the play-back circuits, proportionality will always be observed between the registry pulses and the voltage values.

While the invention has been described in detail with respect to certain now preferred examples and embodiments of the invention it will be understood by those skilled in the art after understanding the invention, that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended, therefore, to cover all such changes and modifications in the appended claims.

The apparatus above described can be used for the simultaneous registration of a plurality of varying voltages, these voltages being fed in turn cyclically to the apparatus by a commutator device.

What is claimed as new and desired to be secured by Letters Patent is:

1. A method of recording variable voltages which comprises generating pulses each representing a momentary value of a variable voltage, feeding said pulses to a cathode ray tube to deflect the beam thereof, tracing the deflections of the beam in the form of lines of uniform thickness on a photo-sensitive film, the length of each line representing the momentary digital value of the variable voltage, developing said film, moving the developed film longitudinally in front of the screen of an oscillograph, deflecting the beam of the oscillograph by a voltage varying with time as the voltage that has caused said lines on the developed film and controlled the length thereof simultaneously deflecting the beam in a direction perpendicular to said lines at a predetermined frequency thereby generating pulses, feeding said generated pulses to photo-multiplying means and then to counting means counting said pulses.

2. In the method according to claim 1, the step of tracing said momentary values of the voltage in the form of single short voltage pulses.

3. In the method according to claim 1, the step of moving said film longitudinally at a substantially uniform rate of speed and deflecting the beam in a direction forming an angle of 90° to the movement of the film.

4. The method according to claim 1, wherein the beam is deflected to trace in a given interval of time a line proportional to the momentary value of the voltage corresponding to the respective line.

5. A method according to claim 1, wherein a single cathode ray oscillograph is used for tracing said lines on the film and sweeping the lines on the developed film whereby the momentary values of the variable voltages and the number of pulses obtained during play-back are proportional.

6. The method according to claim 1, wherein the total of the oscillograph is deflected to make first repeated fast feeder sweeps transversely of the direction of movement of the film, said sweeps being sweeps upon reaching the photo-multiplying means with sufficient intensity causing the said means to release a second sweep transversely of the direction of the film movement and also several registration sweeps in the direction of the movement of the film, said registration sweeps crossing said lines on the film in transverse direction and actuating said computing means, the permutation of said lines by the incident light caused by said feeder sweeps controlling the release of said second sweep.

7. The method according to claim 1, wherein the variable voltage to be recorded is composed of several variable voltages.

8. An apparatus for recording a variable voltage, comprising cathode ray oscillograph means having a screen, a film, means for moving said film in longitudinal direction, control means controlling said oscillograph means so as to cause the beam thereof to trace parallel transverse lines on said film for recording said lines thereon, each line representing a momentary variable voltage and the length of each line being indicative of the digital value of the respective momentary voltage, and play-back means including means for moving the film, after development, in front of the screen of said oscillograph means, means for sweeping the beam transversely across said film while being moved, photo-multiplying means for producing pulses indicative of a line in registry with the sweep of the beam, and computing means for counting the pulses.

9. An apparatus according to claim 8 wherein said oscillograph means comprises a single oscillograph for recording lines on the film and playing back the developed film.
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