

[54] **INTEGRATOR CONTROL CIRCUIT**
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[58] Field of Search..... 307/229; 328/127;
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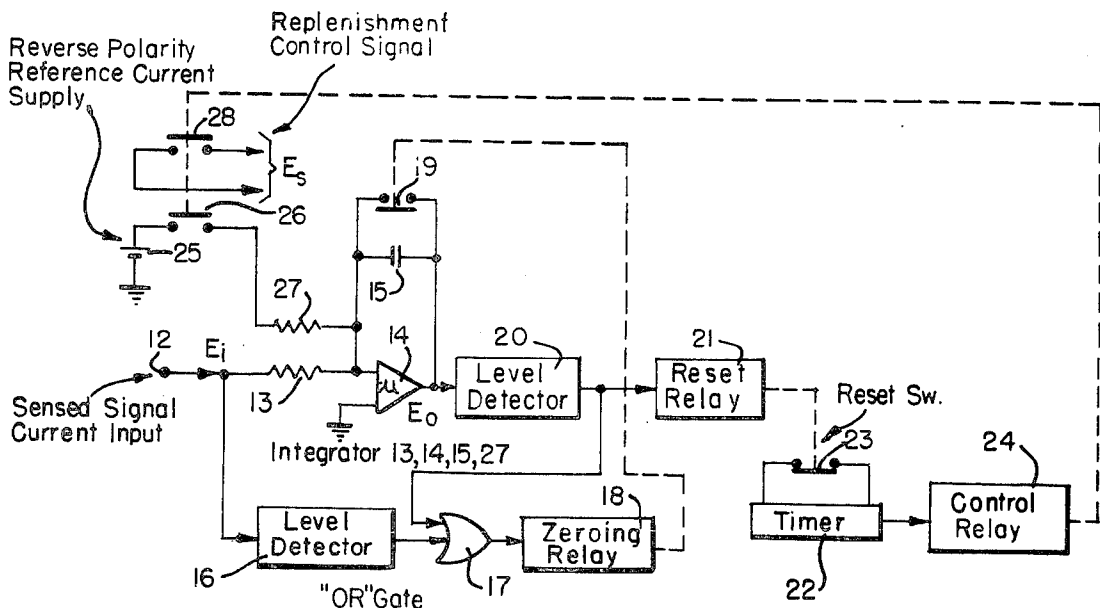
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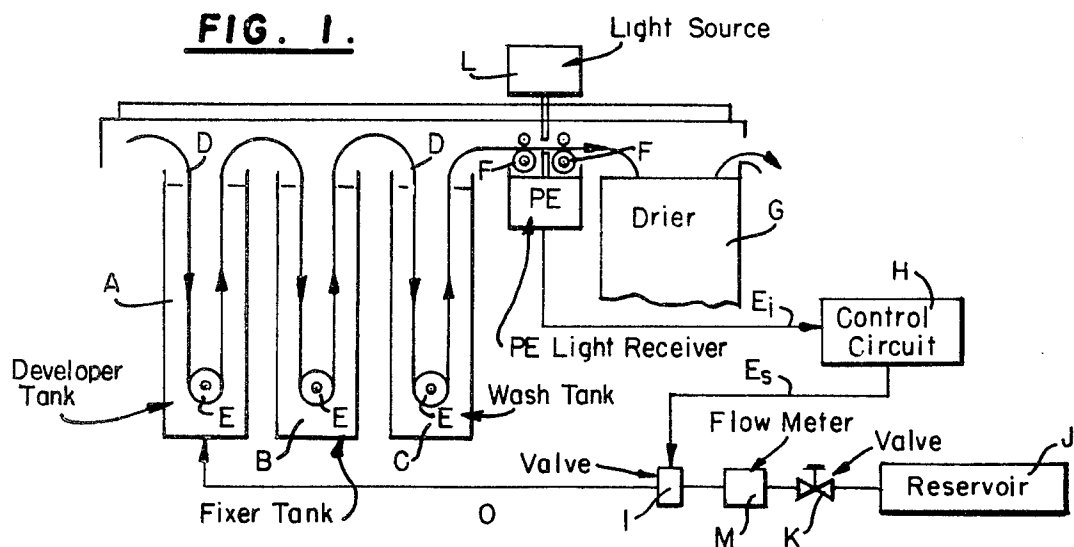
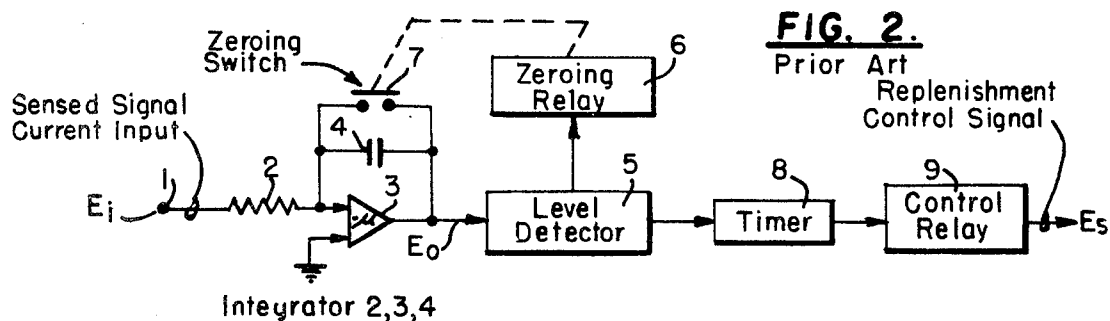
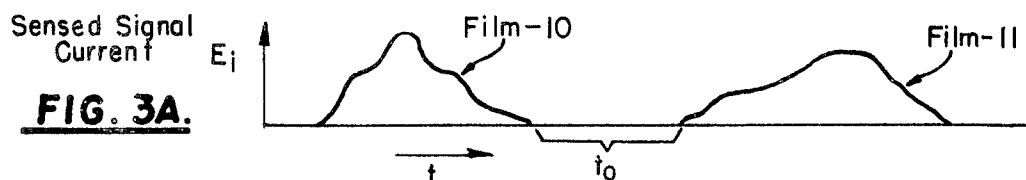
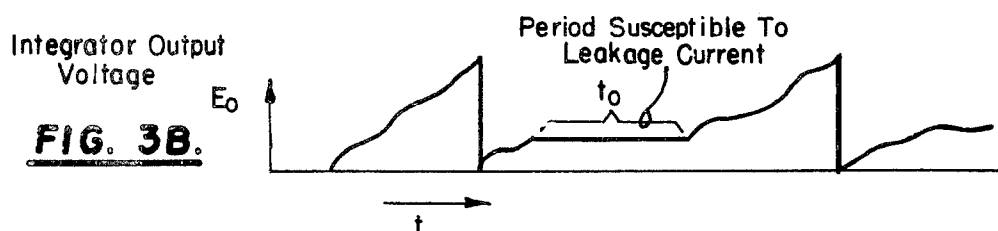
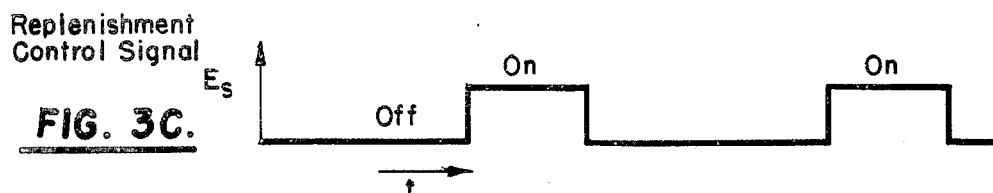
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[57] **ABSTRACT**

A control circuit, for automatically controlling chemical replenishment in a chemical-containing automatic film processor, includes an integrator circuit which receives signals related to the image density in a sheet of image bearing material being transported through the processor. The signal currents are integrated for a predetermined time interval, and upon elapse of said predetermined time interval a reference current source having a polarity opposite to that of the signal current is coupled to the input of the integrator to reduce the output of the integrator toward a reference level. A circuit is provided for generating a control signal which effects replenishment throughout the time period required to reduce the output of the integrator to the reference level.

7 Claims, 9 Drawing Figures





INTEGRATOR CONTROL CIRCUIT

This is a division, of application Ser. No. 412,516, filed Nov. 2, 1973.

BACKGROUND OF THE INVENTION

This invention relates to a method of replenishing the processing liquid in an automatic film processor to compensate for the lowered activity of the developer and fixer fluids which would otherwise result from the processing of exposed film.

Automatic film processors convey exposed films by appropriate transport means through a sequence of developing fixing and washing baths. However, processing results are affected by at least four factors: developing time, developing temperature, degree of fluid agitation, and chemical activity of the processing liquid. Of these four factors, the developing time, temperature and degree of agitation can be controlled relatively easily by the incorporation of appropriate design features associated with the mechanical construction of the automatic film processor. Therefore, if the remaining factor, i.e., chemical activity of the processing liquid, can be maintained constant, then the overall film processing performance can be stabilized. The concentration and activity of the processing liquid decrease as a result of depletion caused by film development action and by chemical oxidation and, in order to restore the concentration and activity, it is common practice to add appropriate amounts of replenishing fluid from time to time.

One commonly employed method of controlling replenishment depends upon the establishment of a constant rate of flow of replenishing fluid, and control of the duration of time during which the fluid is introduced into the developing liquid. To practice this method a variety of means have been disclosed in the prior art. For example, one approach employs a sensing means at an appropriate position along the film transport path to detect the physical passage of the length of film, thereby enabling replenishment to be performed during travel of the film through the sensing station. This method delivers replenishing fluid to the processing liquid in an amount proportional to the length of film being conveyed and is best suited to a situation where films of a definite width and average exposure are being processed because, when such a system is used in the processing of sheet films of different sizes, even those films which are of equal area may result in different amounts of replenishment depending upon whether the minor dimension or the major dimension of the film sheet is sensed. Accurate replenishment rarely results from the use of such length-sensing systems.

An alternate method is designated "dial-type replenishing" wherein a dial similar to that of a telephone set is provided and an appropriate number, selected from a tabular chart depicting the size of the film to be processed and its estimated degree of exposed area, is dialed in to set a synchronous timer, thereby allowing replenishment fluid to flow at a constant rate until the dial returns to its initial position. This method is of practical utility, but the selection of numbers and dial operations often tends to be inconvenient. In addition, certain modern process cameras for the graphic arts allow the film to be removed from the camera back automatically after exposure operations have been completed and then convey the film, by mechanical means,

to the automatic film processor. If the dial-type method is applied to such a system, manual operation of the replenishing dial will be required for each sheet of film to be processed, eliminating many of the benefits of automation.

To eliminate such drawbacks inherent in replenishment systems of the prior art an alternative technique has been developed wherein the blackened areas of the processed film are measured photoelectrically, and this information is then used to replenish the processing liquid according to the measured values. This approach employs a photoelectric means which views the entire width of the path through which the processed film passes, and which senses the interruption of measuring light flux resulting from the passage of the blackened areas of the film, using this information to control the replenishing device. Systems of this general type are disclosed, for example, in Street et al. U.S. Pat. No. 3,554,109, and Street U.S. Pat. No. 3,559,555. The present invention relates to an improvement of this type of replenishing technique, and has as an objective the elimination of disadvantages inherent in the control circuits used heretofore, in order to provide a practical, accurate replenishing method.

SUMMARY OF THE INVENTION

The replenishment system of the present invention is operative to automatically control chemical replenishment in a chemical-containing automatic film processor. As film sheets are transported through the processor, the varying image densities in each of said sheets are optically monitored throughout substantially the entire width and length of each sheet. The sensor employed to effect this monitoring produces a signal which is coupled as one input to an integrator circuit, and the integrator circuit is in turn associated with a timer operative to permit the integrator to accumulate and integrate the sensing signal currents during a predetermined time interval. At the end of the predetermined time interval, the timer operates to connect, to the input of the integrator circuit, a reference current source having a polarity opposite to that of the sensing signal current, and the reference source accordingly reduces the output of the integrator circuit toward a reference voltage level. The time required to reduce the integrator circuit output voltage to the reference level is jointly dependent upon the output level of the integrator circuit at the time the reference source is connected to its input, and upon the magnitude of any sensing signal present at the input of the integrator circuit during the time that the reference source is attempting to reduce the integrator circuit output to said reference voltage level. A replenishment control signal is generated for a period of time which corresponds to the time required to effect reduction of the integrator circuit output to the reference level.

The integrator circuit, in its preferred form, includes an integrating capacitor which is charged by the sensing signal input current, and which is differentially discharged by connecting the reference current source to a second input of the integrator. Since the improved system of the present invention contemplates that the capacitor of the integrating circuit be periodically discharged to a reference voltage level, such as ground potential, proper operation does not require the integrating circuit capacitor to maintain a charge for any significant period of time. The system operation is accord-

ingly rendered independent of any leakage of charge from the capacitor, thus providing for more accurate control and replenishment than has been possible heretofore.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of an automatic film processor incorporating the automatic replenishment control system of the present invention;

FIG. 2 is a schematic block diagram of a prior art control circuit employed in automatic replenishment control systems of the general type shown in FIG. 1;

FIGS. 3A, 3B and 3C graphically illustrate the operation of the prior art control system of FIG. 2;

FIG. 4 is a schematic block diagram of the control circuit of the present invention; and

FIGS. 5A, 5B and 5C graphically depict the operation of the circuit shown in FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to FIG. 1, an automatic film processor incorporating the automatic replenishment control of the present invention may comprise a plurality of processor tanks comprising at least one developer tank A, at least one fixer tank B, and at least one wash tank C. Exposed sensitized material to be developed is fed in sequence through the tanks A, B, and C along a path of the type generally designated D by means of an appropriate transport system diagrammatically illustrated by rollers E. Squeegee rollers F are located downstream of the wash tank C; and the developed film is caused to pass through said squeegee rollers for partial drying, whereafter the film is fed through a drier G for final drying and subsequent collection. Apparatuses of this general type are in themselves well known.

A sensor arrangement, comprising a light source L and a photoelectric light receiver PE, disposed respectively on opposing sides of the film transport path, is provided at a position between wash tank C and dryer G to determine the different image densities developed in different areal portions of the film by the processor action, thereby to provide a measure of the amount of chemical which has been used up in the course of the development process. Such sensor arrangements may take various forms, some of which are described and illustrated in Street et al. U.S. Pat. No. 3,554,109 and Street U.S. Pat. No. 3,559,555 and, in its preferred embodiment, the sensing system is adapted to substantially completely inspect each sheet of film throughout both its width and length. The sensing signal produced by the sensor is coupled to a control circuit H (with which the present invention is primarily concerned), and the output of the control circuit selectively operates a solenoid controlled valve I adapted to permit the feeding of replenishment chemical from a reservoir or tank J via a manual shut-off valve K, flowmeter M and a line O to the developer tank. A similar arrangement may be provided to effect controlled replenishment of the fixer solution in tank B but, to simplify the drawings, this has not been shown in FIG. 1.

FIG. 2 is a block diagram showing the control circuit H of one replenishment system of the prior art. The signal current E_i , obtained from the photoelectric means PE (FIG. 1) in proportion to the blackened areas of the film, is coupled to input terminal 1 and is accumulated in an integration circuit composed of resistor 2, DC

amplifier 3 and capacitor 4. When the output voltage E_o of the integration circuit reaches a predetermined magnitude, the level detector 5 operates and causes contacts 7 of zeroing relay 6 to close, thereby dissipating the charge accumulated in capacitor 4 of the integration circuit. Simultaneously, timer 8 is actuated and, via control relay 9, generates a solenoid-valve control signal E_s to initiate replenishment of the liquid. It can be seen, therefore, that the control circuit of FIG. 2, when used in the system of FIG. 1, causes a flow of replenishing fluid at a predetermined constant rate set by flowmeter M, for a predetermined period of time established by timer 8, whenever the accumulated voltage E_o resulting from sensing signal E_i , reaches the aforementioned predetermined magnitude.

FIG. 3 is a chart showing the operating relationships between various waveforms associated with the device of FIG. 2. FIG. 3A shows typical sensing signals E_i , FIG. 3B shows resultant integration circuit outputs E_o ; and FIG. 3C shows the related replenishment control signals E_s . Due to the input sensing signal E_i , the output E_o increases gradually and, after a definite integrated voltage level is reached, output E_o is returned to zero and, at the same time, a replenishment control signal E_s is produced for a predetermined period of time. Accordingly, the circuit of FIG. 2 enables replenishment to be carried out automatically in proportion to the blackened areas of the film, and is generally very effective. However, a disadvantage is presented by the fact that, when the value of output voltage E_o accumulated in response to signals from individual films fails to reach said definite voltage level, replenishment of the liquid may be inaccurate. Such a condition could exist in some photographic facilities where an automatic film processor is used under conditions where film processing operations are not carried out continuously, e.g., as a result of variations in work load and scheduling, resulting in periods of inactivity of the device shown in FIGS. 1 and 2; and this can cause instability in the strength of the developing liquid in tank A.

To illustrate this problem, which characterizes the prior art, FIG. 3 depicts a situation where two processed film sheets (FIG. 3A) pass the photoelectric sensor in succession with and intervening time interval t_0 , and two time-spaced sensing signals E_i , depicted respectively by curve 10 and curve 11, accordingly enter the integrator in sequence. The integration circuit output voltage E_o resulting from the first film sheet increases in an amount depicted by curve 10 and, upon reaching the predetermined value, results in zeroing of the integrator and actuation of timer 8 to initiate a replenishment period (FIG. 3C), as previously described. If we assume, however, that the sensing signal E_i resulting from the first film sheet has not ceased at this moment in time (e.g., because the film sheet has not yet passed completely through the photoelectric sensor L-PE) the integrator output voltage E_o again rises while the replenishment control signal E_s is being generated. The new increase in integrated output voltage E_o resulting from signal current represented by the remainder of curve 10 ceases when input signal E_i terminates, and the value of output voltage E_o should thereafter remain unchanged until the second film sheet (curve 11 in FIG. 3A) reaches the photoelectric sensor, whereupon output voltage E_o will again increase further.

No problem will be presented if output voltage E_o is not subject to change during the interval t_o between passage of the two films. In practice, however, the value of output voltage E_o tends to decrease gradually during interval t_o due to unavoidable leakage of charge from capacitor 4, and the effect is particularly pronounced if interval t_o is comparatively long, e.g., due to intermittent operation of the processor. Accordingly, the value of additional output voltage E_o integrated as a result of the sensing signal 11 generated by the second film sheet will be lower than that which would be obtained if the second film sheet had been transported without any intervening time interval, and the amount of replenishing liquid added will be less than the quantity actually required. Thus, in small graphic arts establishments, where films are processed relatively infrequently, the processing liquid is not necessarily replenished in the amounts actually required, and its activity gradually decreases, resulting in unstable processing conditions. To prevent this, manual testing and corrective control operations may be required, despite their undesirability in an automated system.

The present invention provides a novel automatic integrator circuit and replenishment system which eliminates the aforementioned disadvantages resulting from possible leakage of charge from the integrator capacitor. FIG. 4 is a block diagram of one embodiment of the invention, and FIG. 5 is a chart showing the operating relationships between various waveforms of the apparatus of FIG. 4.

The sensing signal E_i , developed by the blacked portion of the film as it passes through the photoelectric sensor, enters input terminal 12 and is coupled to an integration circuit consisting of resistor 13 DC, amplifier 14 and capacitor 15, as described in relation to the prior art device of FIG. 2. According to this embodiment of the present invention, however, a reference current supplied by a separate reference current source 25 is selectively connected, via normally-open relay contacts 26, to the summing junction formed between resistors 13 and 27 at the input of integration amplifier 14. This reference current is of opposite polarity to that of the sensing signal input and acts arithmetically, when applied via switch 26, to decrease the integrated value of the sensing signal current.

The sensing signal E_i is also applied to a level detector circuit 16 which produces an output signal whenever E_i is present at input terminal 12, and this signal is coupled through "or" circuit 17 to open the normally closed relay contacts 19 of said integrator zeroing circuit, via relay 18, thereby removing a short circuit across capacitor 15 and the enabling signal integration to commence.

The voltage output E_o of the integration circuit constitutes the input signal to level detector 20, which is similar to level detector 16 mentioned previously, and detector 20 produces an output signal (when voltage E_o exceeds a reference level) which, via relay 21, causes the reset switch contacts 23 of timer circuit 22 to open. Timer circuit 22 is adjusted to produce a control signal when a definite time period T_o has elapsed subsequent to the opening of reset switch 23, and this timer signal is used, through relay 24, to close switch 26 so as to connect reference current source 25 to the input of the integration circuit; and to close switch 28 which turns on the flow of replenishing fluid by coupling signal E_s to solenoid valve I (see FIG. 1).

FIG. 5A depicts a typical sensing signal input current E_i ; FIG. 5B is the resulting integration circuit output voltage E_o ; and FIG. 5C depicts the replenishment control signal E_s . The sensing signal E_i is produced as the blackened portions of the film pass through the photoelectric sensor, and FIG. 5A shows sensing signals resulting from the passage of two such films, identified by curves 29 and 30. When the sensing signal E_i shown by curve 29 first enters the system via level detector 16, it opens reset switch 19 of the integration circuit after passing through "or" circuit 17 and actuating relay 18; sensing signals E_i are then accumulated and integrated output E_o commences. As output E_o appears, the reset switch contacts 23 of timer circuit 22 open due to actuation of level detector 20 and relay 21; the timer commences and, after a definite time period T_o has passed, the timer 22 causes reference current switch 26, and replenishment signal switch 28, to close via relay 24. When the reference current switch 26 closes, a reference current of opposite polarity to that of the sensing signal input E_i is produced, as previously mentioned, and is differentially integrated so that the value of output E_o gradually decreases.

Because the time required to transport the relatively short-length film depicted by curve 29 through the photoelectric sensor is less than the time interval T_o established by timer 22, the sensing signal current shown by curve 29 falls to zero before time T_o has elapsed and, due to the differential integration action, the value of voltage E_o commences to decrease linearly throughout time period T_1 , reaching zero when time period T_1 , determined by the constant discharge current flowing through resistor 27 and the magnitude of voltage E_o at the instant when switch 28 was closed, elapses. During the period T_1 throughout which the inverted-polarity reference current is applied to the integrator, switch 28 remains closed, producing replenishment signal E_s , as shown in FIG. 5C, and the processing liquid is replenished during the time period T_1 .

When output voltage E_o decreases to a predetermined reference level, e.g., ground potential, the timer reset switch 23 closes via level detector 20 and relay 21, and the timer is reset, opening switches 26 and 28 via relay 24. At the same time switch 19 in the integration circuit closes via "or" circuit 17 and relay 18, due to the absence of output from level detector 20 discharging capacitor 15 to reset the integration circuit to its initial condition. The differential integration results from the constant current derived from the reference supply 25 (and the term "differential integration" is employed herein to reflect this concept, even though a signal current E_i may not be present simultaneously with the constant reference current at the integrator input). The replenishment time T_1 is proportional to the integrated value of E_o , and the amount of chemical replenishment is precisely proportional to the accumulated value of sensing signal E_i , i.e., is proportional to the blackened area of the processed film.

The foregoing example discusses the circuit action when the film being processed is of a relatively short length and the input period of the sensing signal E_i is of a shorter duration than the set period T_o of timer 22. Let us now consider the case in which the film being processed is of a considerably greater length, i.e., the sensing signal input shown in curve 30 extends over a longer time period than the set period T_o of timer 22.

The device of this invention is equally applicable to the maintenance of accuracy under either circumstance.

In the latter case, even if the set time T_0 of timer 22 has elapsed and the inverted-polarity reference current differential integration has commenced, the sensing signals E_i will continue to enter the system and, hence, the value of output voltage E_o will become the difference between the integrated value of E_i and the integrated value of the inverted-polarity reference current. In other words, if there were no sensing signal E_i subsequent to elapse of time period T_0 , the output E_o would decrease at a constant rate, as shown by the inclined dotted line in FIG. 5B, resulting in a replenishment period of duration T_2 . But, due to the accumulation of a succession of sensing signals E_i subsequent to elapse of time period T_0 , output voltage E_o decreases as shown by the solid line in FIG. 5B, resulting in a modified and extended replenishing period T_3 . Moreover, when sensing signal E_i continues to be produced even after time period T_3 has elapsed (as shown in FIG. 5B), the integration of signal E_i will be resumed from the moment at which the period T_3 terminates, and the integrator output voltage E_o will commence to rise again during time period T_4 , at the end of which sensing signal input E_i ceases. Then, when the preset time period T_0 again elapses, a further replenishment period T_5 will result, in response to the signal acquired during period T_4 .

As described above, and in accordance with the method of replenishment disclosed by this invention, the processing liquid is replenished in precise proportion to the exposed areas of the processed films. Furthermore, the time period T_0 set by the timer circuit is selected to be so short that the natural discharge of capacitor 15 in the integrator circuit can be neglected, resulting in precise replenishment. In this way the disadvantages associated with conventional replenishing devices of the prior art are eliminated, thereby contributing to a marked increase in the utilization of automatic film processors.

Many variations will be apparent to those skilled in the art, and it must therefore be understood that the foregoing description is intended to be illustrative only and not limitative of the present invention. Moreover, it will be appreciated that the integrator control circuit which characterizes the present invention can be used in the performance of control functions other than automatic replenishment.

Having thus described my invention, I claim:

1. An integrator control circuit comprising signal integrator means, means coupling a signal to be integrated to the input of said integrator means, a reference source having a polarity opposite to that of said signal, timer means operative, upon elapse of a predetermined time interval subsequent to commencement of said sig-

nal integration, for connecting said reference source to the input of said integrator means to reduce the output of said integrator means toward a reference level, and means for generating a control signal during the time period between the elapse of said predetermined time interval and the subsequent reduction of said integrator means output to said reference level, whereby the duration of said control signal is dependent upon the output level of said integrator means when said predetermined time interval elapses, and is also dependent upon the magnitude of any signal present at the input of said integrator means subsequent to elapse of said predetermined time interval.

2. The circuit of claim 1 including control means responsive to the coupling of said signal to the input of said integrator means for rendering said integrator means operative.

3. The circuit of claim 2 wherein said integrator means includes an integrating capacitor, said control means including a shorting switch connected across said capacitor, and signal detector means responsive to the presence of said signal at the input of said integrator means for opening said shorting switch.

4. The control circuit of claim 1 including control means jointly responsive to the absence of said signal at the input of said integrator means and to the presence of said reference level at the output of said integrator for rendering said integrator means inoperative.

5. The control circuit of claim 4 wherein said integrator means including an integrating capacitor, said control means comprising a first level detector having its input connected to the input of said integrator means, a second level detector having its input connected to the output of said integrator means, an OR circuit having inputs connected to the outputs of said first and second level detectors, and a relay connected to the output of said OR circuit, said relay including a pair of contacts connected across said integrating capacitor for selectively shorting said capacitor to render said integrator means inoperative.

6. The control circuit of claim 1 including means responsive to the presence of a signal in excess of said reference level at the output of said integrator means for activating said timer means, and a control relay coupled to the output of said timer means operative, upon elapse of said predetermined time interval, to close a circuit connecting said reference source to the input of said integrator means.

7. The control circuit of claim 6 wherein said control means is further operative, upon elapse of said predetermined time interval, to close a further circuit operative to initiate an external control function.

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