

June 27, 1972

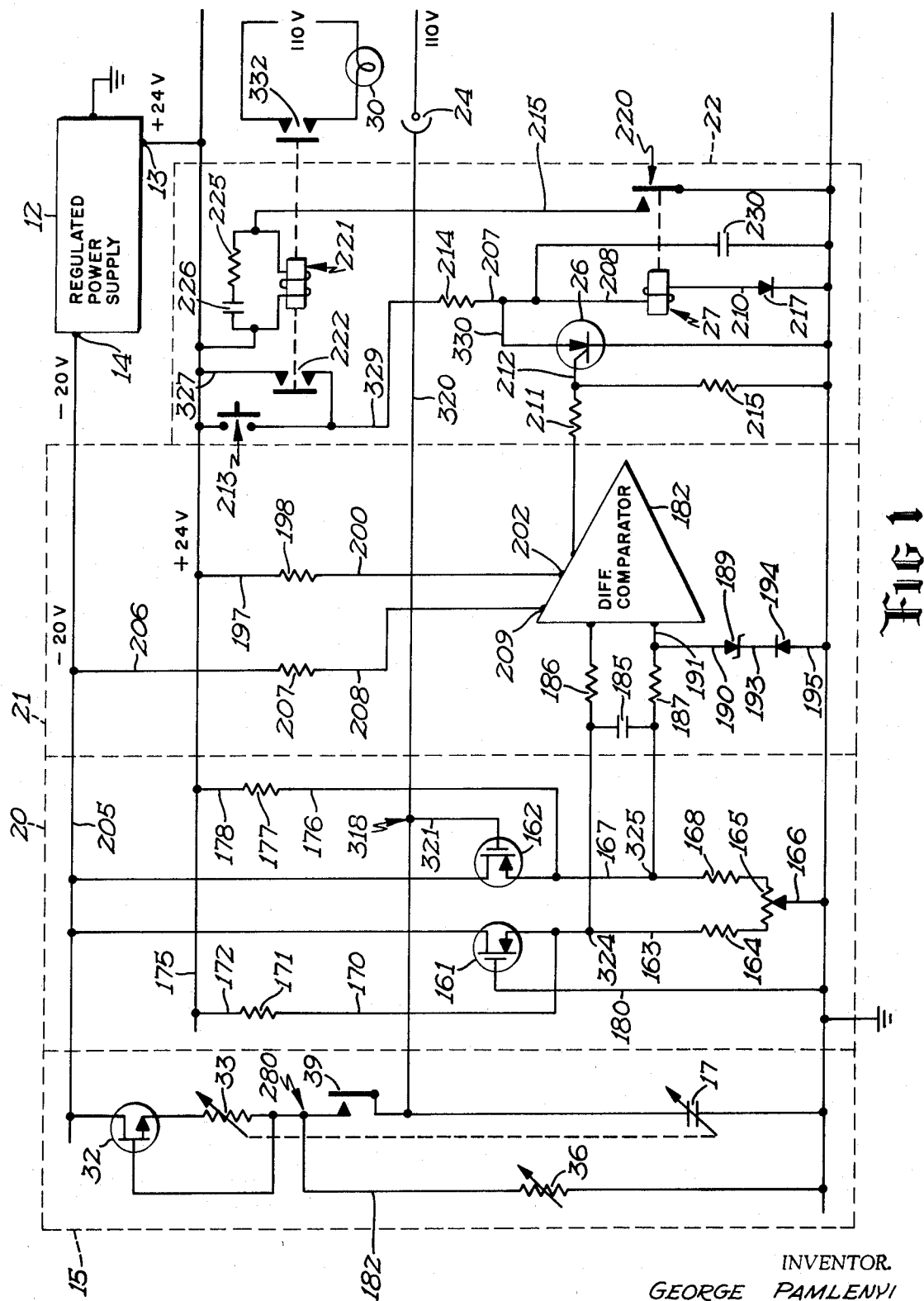
G. PAMLENYI

3,672,767

PHOTO PROCESS TIMER

Filed July 15, 1970

4 Sheets-Sheet 1



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PHOTO PROCESS TIMER

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4 Sheets-Sheet 2

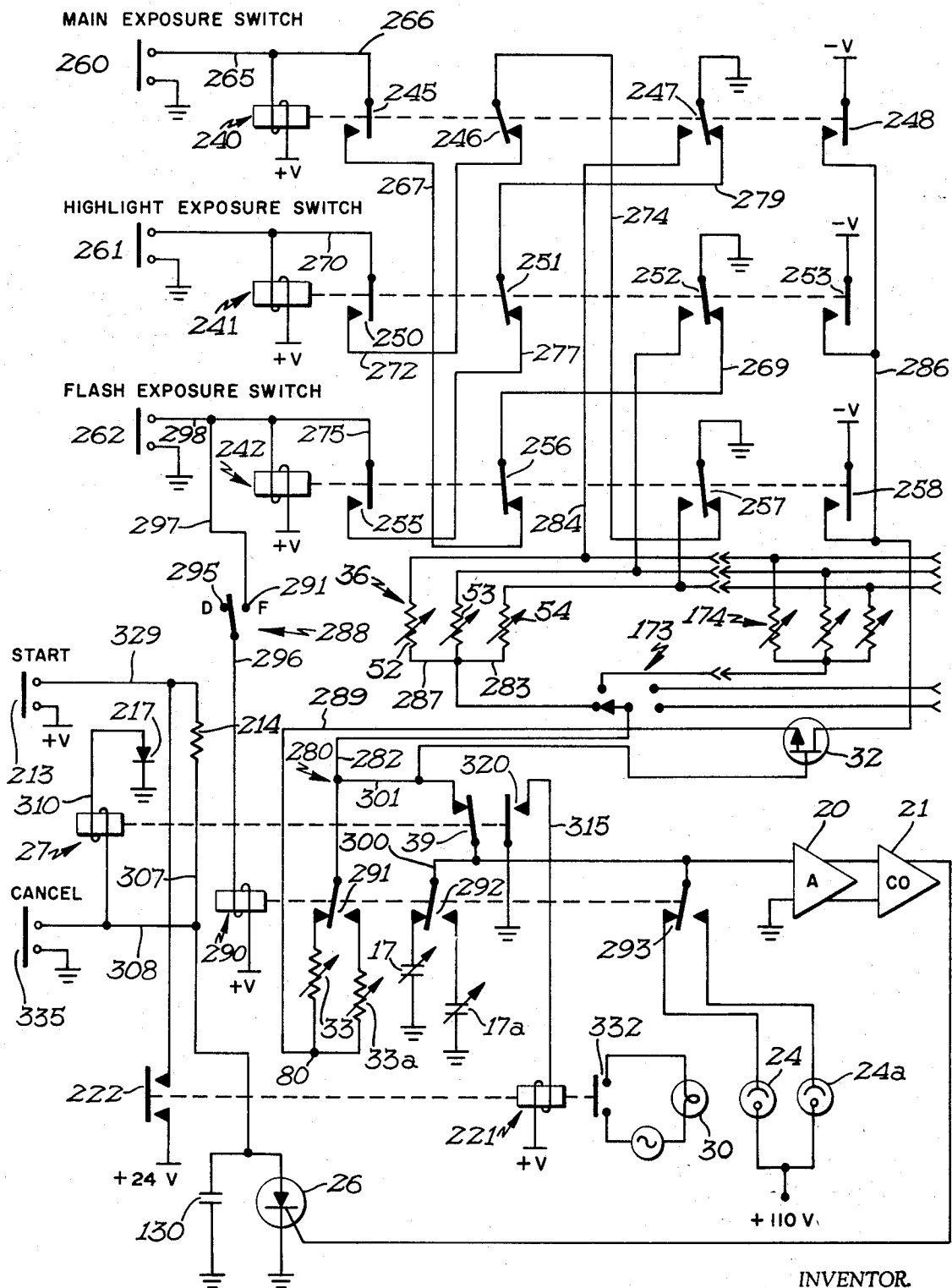


FIG 2

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PHOTO PROCESS TIMER

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4 Sheets-Sheet 3

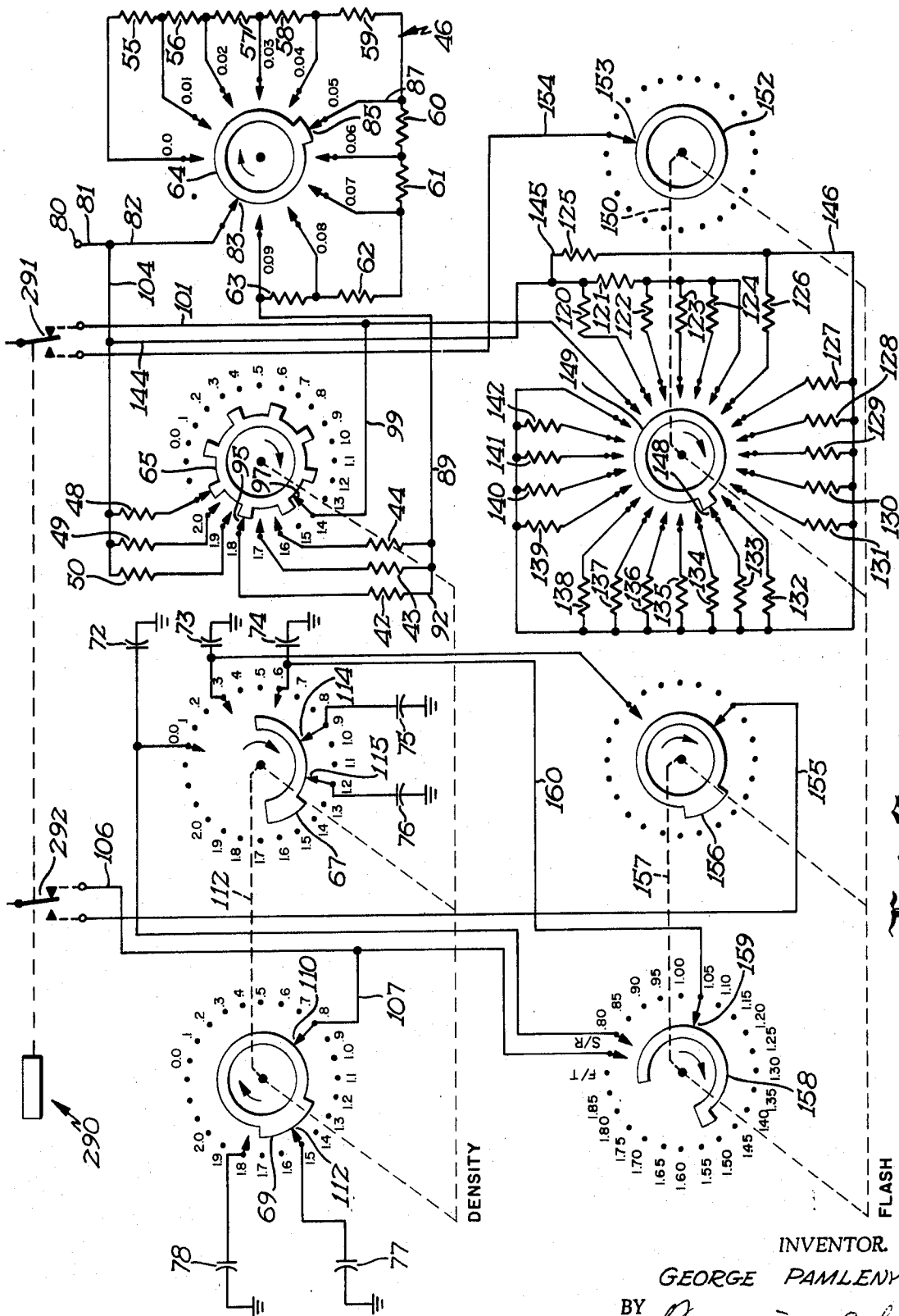


FIG 3

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4 Sheets-Sheet 4

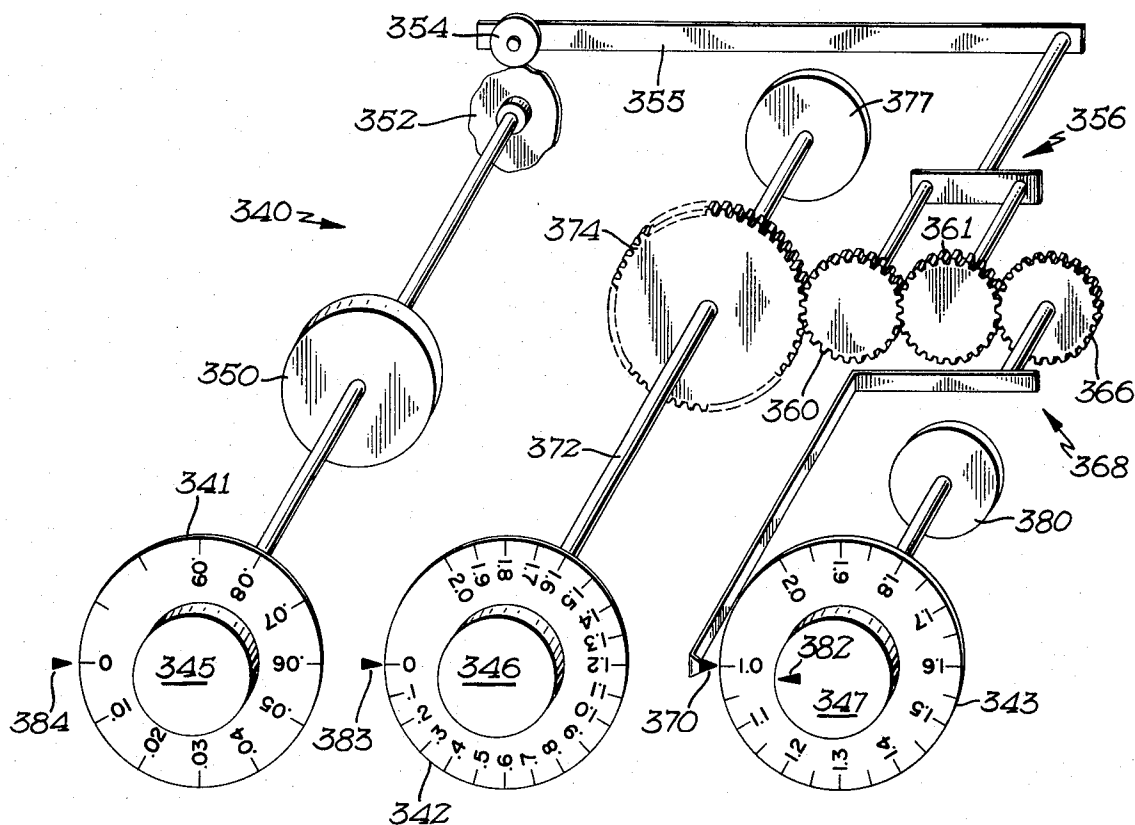


FIG 4

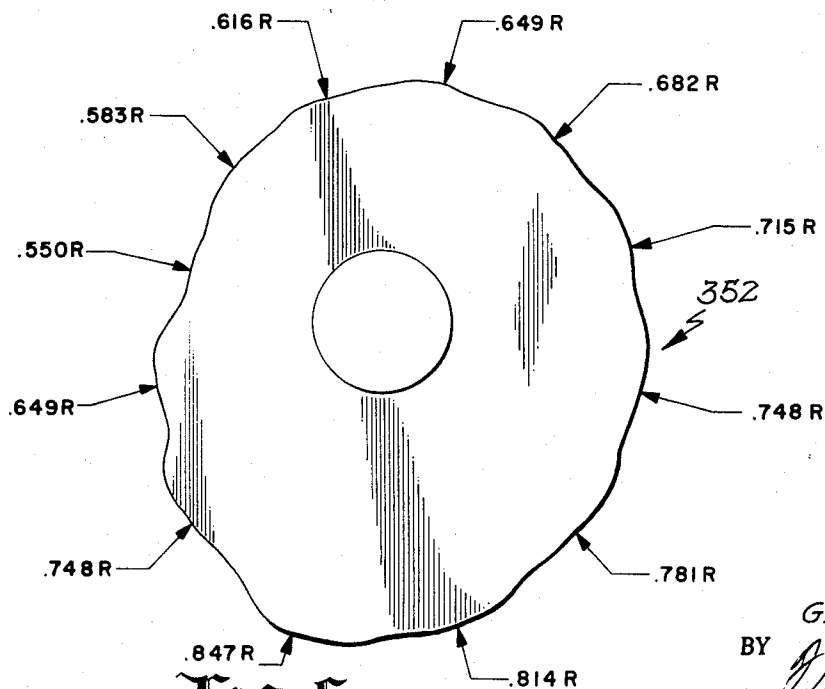


FIG 5

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3,672,767

PHOTO PROCESS TIMER

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U.S. Cl. 355—37 10 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for determining the elapse of a timing cycle utilized in high production photographic process. Dials connected to variable resistors and capacitors have indicia thereon calibrated to provide values of time units and density. Manipulation of the density dials preselects resistance and capacitance values to control the potential to which a capacitor is charged. Momentary depression of a start switch energizes the lighting to be utilized and initiates discharge of the capacitor through a phototube which is exposed to the lighting utilized so that the discharge of the capacitor through the phototube is dependent upon the light intensity. The discharge of the capacitor is monitored and when the capacitor has discharged to a predetermined value, the lighting is terminated to complete the cycle. Means are provided to preset the timing cycle for all lighting normally utilized in high production photographic processes as well as means for converting the circuit for color work. In the latter case different exposure and density values for each of the various colors can be preselected before the circuit is initially energized.

The apparatus may also include a mechanical computer which allows density readings to be fed into the dials and automatically calculates and enters additional compensating values of density.

BACKGROUND OF THE INVENTION

This invention is concerned with circuitry for controlling the main, highlight and flash exposure times of the lamps which are conventionally used in continuous tone and halftone photographic processes. It has become increasingly important in the photographic arts to be able to produce high quality work at a high rate of production. To meet this need, the industry is moving to electronic circuitry to provide the speed necessary for high production. Various circuits have been advanced utilizing an RC timing cycle to energize and de-energize the various lamps used in continuous tone and halftone photographic processes. The circuits, however, are complicated by the utilization of alternating current voltages and by monitoring the charging of the capacitor so that additional circuitry is necessary to assure that random noise pulses do not provide a false indication of the maximum potential which indicates the end of the timing cycle. In addition, some of the circuits are limited to variation of either time units (seconds) or relative illumination (density). However, standard values of density vary as exposure time varies and practitioners in the art using standard nonelectronic equipment consider both the exposure time and density when attempting to produce high quality work. Also due to the range of timing cycles desired and the nonlinearity of the effect on film of standard lighting most circuits currently utilized employ a relatively substantial large number of resistive and capacitive elements.

SUMMARY OF THE INVENTION

The present invention by utilizing regulated DC voltages and monitoring the discharge of the capacitor, al-

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lows construction of a simple noncomplex circuit which is highly accurate in reproducing successive work of the same high quality. Due to improved electronic design, particularly in the area of resolution of the log and linear relationships of voltage and current responses, the number of capacitive and resistive elements necessary to achieve the desired time responses has been substantially reduced.

An additional feature of the present invention includes phototubes for monitoring and compensating for variations in line voltage and deterioration of the various lamps employed. These phototubes modify the timing cycle selected.

Additionally, due to the present invention, standard photographic techniques may be utilized in that the invention provides both variable exposure time in addition to variable density provision. To achieve these results relays are associated with each of the lamps to allow variation of exposure time and density values preselected according to the halftone screen and density values of the original to be used. Selection of the lamp to be utilized, accomplished by momentarily pressing a button, engages a relay which charges a timing capacitor to a potential dependent upon the exposure time and density desired. The particular capacitor to be charged and the potential to which it is charged is dependent upon the density and the time unit values indicated above. Circuit design allows a linear variation of voltage, the voltage being generated by a current which is logarithmically variable. By employing this technique the multitude of resistive and capacitive elements that are normally employed in a circuit of this nature are substantially reduced.

Depression of the start button disengages the charging circuit and energizes the selected lamp which initiates discharge of the capacitor through a light sensitive phototube. Since discharging is accomplished through the light sensitive phototube any variation in line voltage or deterioration of a lamp being utilized will cause a variation in the conduction of the phototube and therefore compensate for line voltage variation or the deterioration of the lamp. The discharge of the timing capacitor is monitored by a differential amplifier and differential comparator to determine when the capacitor is discharged to a small predetermined value. When that small potential has been reached the output of the differential comparator increases to a relatively large positive output within nanoseconds. This output is applied to the gate of a silicon controlled rectifier which, when it conducts, discharges the relay which controls the lighting circuit. As the relay is de-energized its switch accomplishes de-energization of the lamp being utilized and thus ends the timing cycle for that lamp.

Momentary depression of the switch associated with the next lamp to be utilized de-energizes the relay associated with the first lamp and begins charging the timing capacitor to the predetermined value for the second lamp to be used. As before, depression of the start button again disengages the charging circuit and times the exposure of the second lamp. This process is repeated until the photographic process is complete. It should be noted that, alternatively, instead of the various lamps used for black and white photographic processes, each of the individual lamps can be replaced with color for color work and a switch is provided to accommodate this design.

A variation of the present invention includes a mechanical computer which allows density readings to be fed into the dials and automatically calculates and enters additional compensating values of density. In the past those values have been calculated by hand with the

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inherent error and time delay associated therewith. This computer is based on principle of the slide rule and calculates and enters automatically the value of excess density upon entering the values of shadow density, highlight density and halftone screen range into the computer dials. To accomplish this, a cam and cam follower as well as gearing is provided to mechanically calculate and calibrate the photoprocess timer according to standard photographic formulas.

Various objects of the invention will be apparent from a consideration of the accompanying specification, claims and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of my timing circuit;

FIG. 2 is a schematic diagram showing the associated relays and circuitry which allows the utilization of my timing circuit with the various lighting used in halftone photographic processes;

FIG. 3 is a schematic diagram showing the relationship of the resistive and capacitive elements which allow me to vary the current magnitude and consequently the timing cycle in a logarithmic progression;

FIG. 4 is a schematic diagram of the mechanical computer utilized to calculate and enter excess density; and

FIG. 5 is the cam utilized in my mechanical computer to obtain the values desired.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, I have shown my photo process timer which is designed to be connected to a suitable source of commercial power. A conventional, regulated power supply 12 is designed to convert alternating current power to direct current voltages of opposite polarity. For example, power supply 12 may be designed to provide a positive 24 volt voltage at one ungrounded output terminal 13 and a negative 20 volt voltage at its other ungrounded output terminal 14.

Circuit section 15 is a charging circuit for a variable density capacitor 17. The discharge circuit for the capacitor 17 comprises circuit sections 20, 21 and 22 and includes external phototube 24. Circuit section 20 is a conventional, commercially available, differential amplifier which monitors the voltage potential of capacitor 17 and feeds the differential to circuit section 21. Circuit section 21 is a conventional, commercially available differential comparator which produces a step increase output when its input decreases to a small negative potential. This step output is fed to circuit section 22 which signals the end of the timing cycle by firing a silicon controlled rectifier 26 which de-energizes a relay 27 to de-energize the lamps 30. While monitored by the above-mentioned circuit sections 20, 21 and 22, actual discharge of the capacitor 17 is accomplished through a phototube 24 which remains conductive only so long as lights 30 are energized.

Still referring to FIG. 1, charging circuit 15 utilizes a constant current source which is shown as a field effect transistor 32. Connected in series with the source-drain path of this transistor 32 is a variable resistor 33. The lower end of this resistor 33 is connected to the gate of the field effect transistor 32 and thus variations of the resistor adjust the current through the field effect transistor 32. Also connected in series with the transistor 32 and resistor 33 is a variable resistor 36 across which the charging capacitor 17 is connected through normally closed relay bar 39. It can be seen from the above that the magnitude of the voltage on the capacitor is determined by the setting of variable resistor 36 across which the capacitor 17 is connected, and the current through the field effect transistor 32 which is a function of the setting of the variable resistor 33. Variable resistor 33 and variable capacitor 17 are designed to allow

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logarithmic changes in illumination (density scale) while variable resistor 36 is designed to permit linear changes in time (time-unit scale).

FIG. 2 shows how my timing circuit, shown in the lower left hand side of FIG. 2, can be utilized to selectively perform the timing of the various lamps which are used in continuous tone and halftone processes which utilize sensitized emulsions responsive to light. The operational functions of the main, highlight and flash circuits will be discussed under the section entitled operation below. Each is utilized to obtain a high quality, continuous tone or halftone reproduction of the original which is to be copied. In each circuit variable resistor 36, which is preferably a series of standard decade resistors, is designed to permit linear changes in time units. Thus, a voltage, directly proportional to the current flowing through the constant current source 32 is impressed across the timing capacitor 17 and this permits linear changes in exposure time due to uniform adjustments of the impedance device 36 associated with the time unit dials.

The balance of charging circuit section 15 is designed to obtain uniform changes in illumination due to uniform changes of the impedance devices 33 and 17 associated with the density dials. Since illumination varies logarithmically with exposure time, variable resistor 33 and variable capacitor 17 are designed to produce logarithmic variations in exposure time. There are two methods utilized to obtain this result. Discharge time is dependent on the size of a capacitor and the voltage to which it is charged. Since the antilogarithms of 0.1, 0.2 and 0.3 (the desired density steps) are 1.259, 1.585 and 1.995, respectively, and since 1.995 is approximately two, it will be apparent that the discharge time must double for each 0.3 density step. It is known that the RC time constant for discharge of a capacitor is directly proportional to the capacitor value. Therefore, doubling of discharge time, and consequently exposure time, can be achieved by doubling capacitor size 17 for each 0.3 increase in density. In order to get uniform density steps with uniform adjustments of the impedance device within the range between capacitors, it is necessary to have the current increased logarithmically. With the resistance network discussed below, designed generally as 33 in FIG. 1, the current is increased within each 0.3 density interval in a logarithmic progression. The capacitor value 17 is doubled after each 0.3 density step and the resistance value 33 is returned to the value calculated for 0.0 density. In this manner a logarithmic increase in illumination is established for the desired range of 0.0 to 2.0 in 0.01 steps of the density dials.

FIG. 3 shows schematically how the logarithmic changes in current obtained by variable resistor 33 and variable capacitor 17 are achieved with the utilization of as few impedance elements as possible. Variable resistor 33 is comprised of rotary switch 65 and associated resistors 42-44 and 48-50 and rotary switch 64 and resistors 55-63. The parallel combination of resistors 42-44 and 48-50 respectively provide density steps of 0.1. Density steps 0.01 are achieved with resistors 55-61, which are serially connected with the parallel branch containing resistors 42, 43 and 44. The number of resistors and the magnitude of each resistor is obtained as follows.

From the characteristic curves of the field effect transistor 32 the highest current desired can be chosen along with the resistance value 33 necessary to produce that current. Applying the ratios previously derived (i.e., 1.259, 1.585 and 1.995) to the maximum current value, suitable current values are obtained which, when applied to the characteristic curve of the field effect transistor 32, yield the desired resistance values for 0.1 density steps. Since the ratio doubles for every 0.3 density step, instead of increasing the resistance, the capacitor value 17 is doubled after each 0.3 step and the circuit resistance is returned to its initial value. This method provides a simple and

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economic circuit design for the basic logarithmic increases desired.

Density steps of 0.01 are achieved with the use of a resistance 42, 43 or 44 in series with a variable resistance 46, both of which are in parallel with a second resistance 48, 49, 50 as shown by schematic in FIG. 3. The total resistance of these parallel networks is selected so that at decade density steps (i.e., 0.00, 0.10, 0.20 density) the equivalent resistance (designated by the numeral 33 in FIG. 1) is that calculated above. For a given resistor (R_3) variable from 0 to a positive value, designated by the numeral 46 in FIG. 3, the following formulas for R_1 and R_2 provide the values of the resistances 43 and 49 respectively, to be employed between .1 and .2 density.

$$R_1 = \frac{-R_3 + \sqrt{R_3^2 + (4)(A)R_3}}{2}$$

where $A = \frac{(R_2 \text{ density})(R_1 \text{ density})}{(R_2 \text{ density}) - (R_1 \text{ density})}$

$$R_2 = \frac{(R_1)(R_1 \text{ density})}{(R_1) - (R_1 \text{ density})}$$

Utilizing the same formulas, values can be obtained for the resistance 42, 44, 48 and 50 employed between 0 and .1 density steps and .2 and .3 density steps.

The equivalent circuit, therefore, is that shown in FIG. 3 with every 0.3 density step requiring a doubled capacitor and a return to the first contact positions on rotary switch 65.

Doubling of the capacitor 17 for each 0.3 step in density is similarly achieved with the use of interconnected rotary switches 67 and 69. Capacitors 72-78 (collectively designated as 17 in FIG. 1) are connected to the rotary switches to achieve this result. It should be noted that for the first four steps in capacitance size, individually larger capacitors are used, 72 through 75. Thereafter, successively larger capacitors are connected in parallel to achieve at the last capacitive step a total capacitive value twice the magnitude of the last capacitor 78.

To give an example of the operation positioning of this network, a main density of 1.55 will be used. As shown in FIG. 2, when relay 240 is energized current flow (assuming conventional current flow) from ground through relay switch 247, conductor 284, time unit resistor 52, conductor 287, conductor 282, relay switch 291, density resistor 33, conductor 289, field effect transistor 32, conductor 286, relay switch 248, to the negative source of voltage. The timing capacitor 17 is connected from point 280, conductor 301, relay switch 39, conductor 300, relay switch 292, timing capacitor 17, and ground. It should be noted that the time unit resistor 52 is connected to ground as traced above and therefore the time unit resistor 52 and the timing capacitor 17 are effectively in parallel.

The apparatus shown in FIG. 3 is the detailed apparatus represented in FIG. 2 by the variable density resistors 33 and 33a and the variable timing capacitors 17 and 17a connected between relays 291 and 292 and point 80 and ground respectively. Referring to FIG. 3, for a density of 1.55, current would flow from point 80, through conductor 82, contact 83, rotary switch 64, contact 85, conductor 87, resistors 58, 59, 60 and 61, conductor 89, conductor 92, resistor 42, contact 95, rotary switch 65, contact 97, conductor 99, conductor 101 to switch 291. A parallel current would flow from point 80, conductor 81, conductor 104, resistor 48, contact 107, rotary switch 65, contact 97, conductor 99, conductor 101 to relay switch 291. Similarly, variable capacitor 17 would comprise capacitors 75, 76 and 77 in parallel, with the connection being from switch 292, conductor 106, conductor 107, contact 110, rotary switch 69, contact 112, capacitor 77 to ground; common connection 112, rotary switch 67, contact 114, capacitor 75 to ground; and contact 115, capacitor 76 to ground. Similar circuits can be traced for any density between 0.00 to 2.0.

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Also shown in FIG. 3 are the resistive and capacitive elements required for the flash lamp exposure time. As is known in the art, when flash lighting is utilized it produces different characteristic results during processing than the balance of the lighting techniques. Design valves for the flash dial parameters are obtained from the following formula:

$$\Delta T = 100 = \frac{100}{10^{\Delta D}}$$

where ΔT is the flash exposure time required for a given change in flash density. Time values are obtained for 0.05 density changes and ratios are established between successive time value. In the same manner as indicated above these ratios are applied to the maximum desirable field effect transistor 32 current to obtain appropriate resistance 33a and capacitance 17a values.

As shown in FIG. 3, the flash density parameters (designated 33a and 17a in FIG. 2) are arranged much the same as the density elements 17 and 33. Note, however, that economy of design is achieved by utilization of the same capacitors that are employed for the main and highlight density circuits. Resistive elements included in the flash density circuit comprise resistors 120-142. Tracing the circuit for a 1.50 flash density, relay 290 would be energized and the relay switches 291 and 292 would be in the position opposite to that shown in FIG. 3. Current would flow (in a conventional manner) from point 80, through conductors 81, 104, 144, 145, resistor 125, conductor 146, resistor 133, contact 148, rotary switch 149, common connection 150, rotary switch 152, contact 153, conductor 154 through relay switch 291. Variable capacitor 17a would comprise capacitor 74 and would be connected into the circuit through relay switch 292, conductor 155, rotary switch 156, common connection 157, rotary switch 158, contact 159, conductor 160, capacitor 74 to ground.

As indicated above, the time unit resistors 52, 53 and 54 (collectively referred to as 36 in FIG. 1) are serially connected across the timing capacitor 17 to receive the current from the field effect transistor 32. Due to the density circuitry discussed above (shown in FIG. 3), a current of constant magnitude flows through the time unit resistors 36 regardless of what the total resistance is. It can thus be seen that the voltage drop across the resistance 36 is linearly proportional to the resistance value because current is held constant for any given density. The timing capacitor 17 is therefore charged to a negative voltage which is proportional to the numerical value set on the time unit switch.

Rotary switch 173 provides an additional feature to the invention. Shown in its normal position in FIG. 2, the normal time unit resistor banks 36 are connected into the circuit. However, if, for example color separation work is to be performed or various halftone screens are to be used provision is made for additional banks of time unit resistors through the use of jacks 174 all of which can be preset. With these additional banks the time units for each color can be preset prior to initiating the reproduction. Thereafter, to switch colors all that is necessary is to rotate the rotary switch 173 to bring the preset time unit valves into the circuit.

Referring back to FIG. 1, circuit section is a differential amplifier which monitors the discharge of the capacitor 17 through phototube 24. While any conventional differential amplifier may be utilized, the design depicted is commercially available being a General Instrument Corporation MEM 550 C. It comprises two matched field effect transistors 161 and 162 in parallel, both connected to a source of voltage 14 negative with respect to ground. The source of electrode of transistor 161 is connected through a conductor 163 and a resistor 164 to one side of potentiometer 165. The shaft 166 of the potentiometer is connected to ground. The source electrode of transistor

162 is similarly connected through conductor 167 and resistor 168 to the other side of the potentiometer 165. Both field effect transistors 161 and 162 are forward biased, transistor 161 from the source electrode through conductor 170, resistor 171, conductor 172, to the positive bus 175 and transistor 162 from the source electrode through conductor 176, resistor 177, conductor 178 to the positive bus 175.

Temperature stabilization of the set of field effect transistors is accomplished with resistors 164 and 168, each connected in series with the source electrode of transistors 161 and 162, respectively, to opposing ends of zeroing potentiometer 165. From the specification sheet, the point is chosen where the field effect transistors 161 and 162 have zero temperature coefficient. Since the gate of transistor 161 is grounded through conductor 180, the set is balanced by setting resistor 36 to zero, resistor 36 being connected to the gate of the second transistor 162. The forward biasing resistors 171 and 177 are then chosen to maintain through the device the current necessary to achieve a zero temperature coefficient. The respective currents are then balanced with the use of potentiometer 165. Thereafter, any increase or decrease in temperature will affect both field effect transistors 161 and 162 equally and will not upset the differential between the two.

Circuit section 21, shown by schematic, includes a conventional solid state high speed differential voltage comparator 182, for example a Fairchild u A 710 C. Connected across the output terminals of circuit 20 is a transient suppression capacitor 185. Dropping resistors 186 and 187 are connected between the output terminals of circuit 20 and the input terminals of circuit 21 to meet the input design specifications of the commercial unit 182. In addition, overvoltage protection is assured by Zenner diode 189 connected to the input of the differential comparator 182 through conductors 190 and 191 and to ground through conductor 193, diode 194 and conductor 195.

Positive supply voltage to the differential comparator is supplied from the positive bus bar 175 through conductor 197, dropping resistor 198 chosen to meet design specifications, conductor 200 to terminal 202. Negative supply voltage is supplied from negative bus 205, conductor 206, dropping resistor 207, and conductor 208 to negative terminal 209.

The voltage transfer characteristics of the differential comparator 182 are such that the output of the comparator 182 remains slightly negative for large negative inputs until the input voltage decreases to a small negative millivolt value. Thereafter, as conventionally occurs, any additional decrease causes the output to step, within nanoseconds, to a relatively large positive voltage. For example, with the Fairchild u A 710 C. the output steps from approximately -5 v. to 3 volts.

Circuit section 22, which is essentially comprised of dropping resistor 211, silicon controlled rectifier 26 and relay 27, serves to signal the end of the timing cycle. The output of the differential comparator 182 is connected to the gate of a silicon controlled rectifier 26 through a dropping resistor 211, and a conductor 212. A resistor 215, connected between the gate of the rectifier 26 and ground is utilized to assure that the gate voltage is maintained at near ground potential until the step input from circuit 21 occurs. The relay 27 is energized initially from the positive bus 175, through a manual switch 213, a series dropping resistor 214, the coil of relay 27 and a diode 217 to ground. Energization of the relay 27 closes a normally open relay switch 220 which energizes a relay 221 which through its relay switch 222, maintains the above mentioned relay 27 in an energized state. A resistor 225 and capacitor 226 are connected in parallel across the relay 221 for spark suppression. A transient suppression capacitor 230 is connected across the rectifier 26 and relay 27. When the input voltage from circuit 21 increases, the rectifier 26 is fired and becomes conductive. Current

through circuit section 22 then flows from the positive bus 175, through the resistor 214, and the rectifier 26 to ground. Rapid de-energization of the relay is accomplished with a diode 217 which discharges the counter-electromotive force built up across the relay 27 when it is shorted out by the rectifier 26.

As shown by schematic in FIG. 1, the selected lighting is also energized and de-energized by switches associated with relay 221.

Referring now to FIG. 2, I have shown by timing circuit connected to various relays which allow me to attain the high quality photographic result which is an objective of this invention. For black and white photographic processes, resistors 33, 33a, 52, 53 and 54 and capacitors 17 and 17a are individually preset and relays 240, 241 and 242 are sequentially actuated to obtain the particularly desired composition. Each of the relays 240, 241 and 242 actuate four relay switches. Relay switches 245, 246, 247 and 248 for relay 240; switches 250, 251, 252 and 253 for relay 241; and switches 255, 256, 257 and 258 for relay 242. Note that switches 247, 252 and 257 have two sets of contacts and thus are utilized both in their normal position, as shown, as well as when each associated relay, 240, 241 and 242, respectively, are energized.

The first switch on each relay, 245, 250 and 255 respectively, provides self-latching of the relays after momentary closing of the associated manual switches 260, 261 and 262. Upon closing the manual switch 260, relay 240 is energized from the positive source of voltage through the coil of relay 240, conductor 265, switch 260 to ground. Energization of the relay 240 closes switch 245 and thereafter relay 240 is energized from the positive source of voltage, through conductor 266, switch 245, conductor 267, switch 256, conductor 269, switch 252 in its normal position as shown in FIG. 2, to ground. Relay switch 246 de-energizes relay 241. Assuming relay 241 is energized prior to depression of switch 260, it would be energized from its positive source of voltage, through the coil of relay 241, conductor 270, switch 250, conductor 272, switch 246, conductor 274, switch 257 in its normal position to ground. Energization of relay 240 opens switch 246 and thus de-energizes relay 241. Similarly, switch 247 de-energizes relay 242 which is normally energized from its positive source of voltage, through the coil of relay 242, conductor 275, switch 255, conductor 277, switch 251, conductor 279, switch 247 in its normal position to ground.

Switch 247, in its activated position also connects the proper time unit resistor 52 into the circuit, connection being from input terminal 280 through conductor 282, rotary switch 173, conductor 287, time unit resistor 52, conductor 284, switch 247, to ground. The fourth switch 248 of relay 240 connects negative potential to the field effect transistor 32, connection being from the negative source of voltage, through switch 248, conductor 286, to the drain electrode of transistor 32. It can be seen from FIG. 2, that each of the associated relay switches interconnects the respective relays 241 and 242 in the same manner. Designations for the manual switches 260, 261 and 262 in a commercial unit would be main exposure, highlight exposure and flash exposure respectively.

It should be noted, as indicated earlier, that when flash lighting is utilized it produces different characteristic results during processing than the balance of the lighting techniques. Therefore, additional circuitry is provided, being essentially switch 288, relay 290 and relay switches 291, 292 and 293, which allow presetting the desired density values, as derived above, for flash purposes.

Manual switch 28 is provided to allow the unit to be easily convertible for single exposure color work. If single exposure color work is to be performed switch 288 is set to position 295. As this is a free contact, the normal circuitry is utilized and each color is controlled by the separate circuits designated main, highlight and flash. If flash lighting is to be used, as with black and white work,

switch 288 is set to position 291 and relay 290 is energized from the positive source of voltage through conductor 296, switch 288, conductors 297 and 298, through push button 262 to ground. Energizing relay 290 causes relay switches 291, 292 and 293 to move from their normal positions (shown in FIG. 2) to the positions which intersect the combination values discussed earlier for flash density into the circuit. It should be noted that during flash operations an internal phototube 24a is utilized and is actuated from a small incandescent bulb (not shown) in the flash circuit.

The additional aspect of the present invention, the mechanical computer, is designated by the numeral 340 and is shown in FIGS. 4 and 5.

The computer is used to compute and enter data necessary for photographic processes. For example, the value of excess density (D_e) is presently computed by hand utilizing the following equations.

$$D_c = D_s - (0.1D_h + 0.01D_{sc})$$

$$D_e = D_c - D_{sc}$$

Where

D_s = Shadow density

D_h = Highlight density

D_c = Copy range

D_{sc} = Screen range

D_e = Excess density

In the embodiment shown by schematic in FIG. 4 three dials are employed 341, 342 and 343, each with a control knob, 345, 346 and 347 respectively, rotatably fixed to the dials. For operational ease, dials 341 and 342 can be made coaxial but for ease of discussion they have been disclosed as separate dials. As shown in FIG. 4 each of the dials 341, 342 and 343 have indicia on the outer edge thereof. The indicia on dial 341 corresponds to 0.01 density values, the indicia on dial 342 corresponds to 0.1 density values, and the indicia on dial 343 corresponds to flash density values.

Rotatably connected to control knob 341 is rotary switch 350, designated 64 in FIG. 3, which adjusts resistor 46 (shown in FIG. 3) and cam 352. Cam 352, shown in detail in FIG. 5, is constructed so that the radial movement of the cam follower 354 is transmitted through lever 355 and shaft assembly 356 to cant gears 360 and 361. The tangential movement of gear 361 relative to gear 366 rotates gear 366 and this rotation is transmitted through shaft assembly 368 to pointer 370. As is obvious from FIG. 4, rotational movement of dial 342 is transmitted through shaft assembly 372, gear 374, gears 360, 361 and 366, and shaft assembly 368 to move pointer 370. In this manner the summation of D_h indicated in the formula is accomplished as movement of dial 341, cam 352, cam follower 354, lever 355, shaft assembly 356, gears 360 and 361, gear 366 and shaft assembly 368 is only one tenth as effective to move pointer 370 as dial 342. Rotary switch 377 as shown in FIG. 4 comprises switches 65, 67 and 69 in FIG. 3 and is operatively connected to and selects resistors 42 and 48, 43 and 49, or 44 and 50 (as indicated in FIG. 3) and adjusts variable capacitor 17. Switch 380 comprises switches 149, 152, 156 and 158 and is operatively connected to and adjusts resistors 33a and capacitors 17a.

OPERATION

Initially, in the operation of this invention the proper time unit values are derived. Proper values are dependent on the film, chemistry, and halftone screen being used as well as the personal preference of the operator as to the dot size preferred along the gray scale. Normally sufficient is utilization of only the main and flash circuitry. The main exposure time is based on the dot size the photographer prefers for the highlight portion of the

original and the flash time units are set to give the photographer the shadow dot size he prefers. The highlight circuitry and hence the highlight time unit values are utilized to modify the normal procedure. Both the highlight and shadow dot size remain the same while the highlight circuitry controls the placement of the 50% halftone dot and consequently the middletones. This technique is known in the art as the "no-screen bump."

After the proper time unit values are derived for a particular film, chemistry and halftone screen no further time unit calibration is necessary. Thereafter, the same time unit settings are maintained and only density differences, depending on the respective densities of the piece of work to be reproduced, are varied.

Density variations are as follows. If the normal procedure is to be used, the measured highlight density value is set on the main density dials. This adjusts variable resistor 33 and variable capacitor 17 as shown in FIG. 2. A calculated value for excess density is then set on the flash density dial, adjusting resistor 33a and 17a as shown in FIG. 2. Excess density is the difference between the copy density range and the halftone screen range. The copy density range is the difference, as measured on the original to be used, between the main dot size (highlight density) and the shadow dot size (shadow density). An alternative mechanism can be used whereby screen range can be referenced as a zero point with a slip clutch. Then by turning the dial to the copy range, as defined above, the dial, and consequent adjustment of resistor 33a and capacitor 17a, is rotated an amount equivalent to excess density.

If the no-screen bump technique is to be utilized, density adjustments are initially obtained by trial and error. A suggested starting point is to subtract 0.3 density from the main exposure (thereby cutting the main exposure time in half) and adding .06 density prior to initiating the highlight exposure time.

Electrical operation of the invention can be understood with reference to FIG. 2. Density and time unit settings are obtained as discussed above. Main exposure switch 260 is momentarily depressed manually thereby energizing relay 240. Relay 240 is maintained in its energized state by relay switch 245. Relay switches 246 and 247 de-energize relays 261 and 262. Switch 247 connects the preset time unit resistor 52 across the timing capacitor 17, connection being made from capacitor 17, switch 292, conductor 300, switch 39, conductor 301, conductor 282, conductor 287, resistor 52, conductor 284, switch 247 to ground. A potential source negative with respect to ground, is applied to the constant current source, field effect transistor 32, with the magnitude of the current being determined by the setting of variable resistor 33. Since the lamps 30 have not as yet been energized, the phototube 24 is non-conductive and therefore does not draw current. The timing capacitor 17 has now been charged to a predetermined value dependent upon the values of resistors 33 and 52 and is ready to initiate the timing cycle.

Momentary depression of switch 213, designated the "start switch," energizes relay 27 from the positive source of voltage through switch 213, conductor 329, resistor 214, conductor 307, conductor 308, the coil of relay 27, conductor 310, diode 217 to ground. This initiates the timing cycle by disconnecting the charging circuit by opening normally closed relay bar 39 and energizing relay 221 which in turn energizes the selected lamp (shown by schematic at 30). Relay 221 is energized from the positive potential source through the coil of relay 221, conductor 315, switch 320 to ground. As the lamp is energized phototube 24 becomes conductive and timing begins. Referring to FIG. 1, discharge of the capacitor 17 occurs through phototube 24 which is conventionally connected to a rectified source of commercial voltage of a polarity opposite to that to which the capacitor 17 is charged. The phototube 24 therefore acts as a constant current

source with the current dependent only on the high resistance of the phototube 24.

As current flow through the phototube 24 continues the potential at point 318 becomes increasingly less negative. This potential is applied to the gate of transistor 162 through conductor 321. Since the current through field effect transistor 161, and therefore through resistor 186, is maintained at a constant value due to its forward biasing and grounded gate, the potential differential between output terminals 324 and 325 decreases proportionally to the decrease in capacitor voltage. As the differential voltage approaches a small negative value (in the millivolt range) this signals discharge of the capacitor 17 and thus the end of the timing cycle. This condition is detected by the differential comparator 182, which is connected to the output terminals of the differential amplifier circuit through dropping resistors 186 and 187. As discussed earlier, the differential comparator 182 responds to the small negative differential by a step voltage output within nanoseconds. This voltage is applied to the gate of silicon controlled rectifier 26 through dropping resistor 211. When the silicon controlled rectifier is fired, relay 27 is de-energized as current flows from the positive bus 175, through conductor 327, relay contact 222, conductor 329, resistor 214, conductor 330, silicon controlled rectifier 26 to ground. De-energization of relay 27 opens switch 220, which de-energizes relay 221. This opens relay switches 222 and 332 which terminates current flow through the silicon controlled rectifier 26 and de-energizes the selected lamp 30.

Since separate time-unit switches are provided for each of the lamps and all have been preset, to accomplish exposure for the next lamp, all that is necessary is momentary depression of the switch associated with the lamp. For example, to initiate highlight exposure, highlight exposure switch 261 is depressed. Referring to FIG. 2, relay switch 250 would then latch the relay 241 to ground through the circuit traced earlier, relay switch 251 de-energizes relay 242, relay switch 252 assures that relay 260 remains de-energized and connects the highlight time unit resistor 53 into the circuit and relay switch 253 applies the negative potential to the charging circuit through field effect transistor 32. Thereafter, momentary depression of the start switch 213 repeats the timing cycle as discussed above. Operation of the flash lamp is accomplished in the same manner with additional relay 290 energized from the positive bus, through the coil of relay 290, switch 288, conductor 297, switch 262 to ground. Energization of this relay switches relay switches 291, 292 and 293 to the position for flash density discussed earlier and connects internal phototube 24a into the discharge circuit.

It should be noted that the timing cycle can be terminated manually at any time. This is accomplished with "cancel" switch 335, which when depressed shorts the positive potential on conductor 308 to ground, therefore de-energizing relay 27, which in turn de-energizes relay 221 through the circuit traced earlier. De-energization of relay 221 opens relay switch 332 and thus extinguishes the lamp 30.

Operation of the mechanical computer is as follows. Referring to FIG. 4, the value of D_{sc} is set between pointer 370 and pointer 382 on control knob 347. There is a slip clutch (not shown) between the knob 347 and dial 343 for this purpose. Control knob 346 is rotated until the proper value of $0.1 D_h$ appears opposite the pointer 383 associated with the dial 342. This adjusts resistors 33 and capacitors 17 and transmits the value of $0.1 D_h$ to pointer 370. Control knob 345 is then rotated until the value of $0.01 D_h$ appears opposite the pointer 384 associated with dial 341. This sets switch 350 and thus adjusts resistor 46, and transmits the value of $0.01 D_h$ to pointer 370. The addition $0.1 D_h$ and $0.01 D_h$ has taken place because of the 1:10 relationship of the relative movement of the dials 341 and 342. Control knob 347

is then rotated, as well as associated dial 343, so that the value of D_s is opposite pointer 370. With the rotation of control knob 347, switch 380 has been rotated, adjusting resistors 33a and capacitors 17a and the value of D_s has been entered into switch 380, that value being the difference between D_s and $(D_{sc} + 0.1 D_h + 0.01 D_h)$. While the mechanical computer is disclosed as being integrally connected with the timing circuit in my photo process timer, there is no intent to so limit it. It should be understood that the computer can be constructed as a separate apparatus and the values calculated entered manually on dials operatively attached to a timing circuit as described and disclosed earlier.

In general, while I have described a specific embodiment of my invention, it is to be understood that this is for purposes of illustration only and that various modifications can be made within the scope of my invention.

I claim as my invention:

1. A photo process timer for use in continuous tone and halftone processes which utilizes sensitized emulsions responsive to light comprising, in combination:

at least one timing capacitor;

a charging circuit for said timing capacitor including a source of voltage connected in series with said capacitor;

an adjustable impedance connected in series with said source of voltage and in parallel with said capacitor to establish the voltage to which said capacitor is charged;

means connected in series with said source of voltage for maintaining the current through said adjustable impedance constant despite the effect that adjustment thereof has on the overall impedance of the charging circuit;

means for disconnecting said timing capacitor from said charging circuit and for establishing a discharge circuit therefor; and

means for indicating when said timing capacitor has discharged to a predetermined voltage, including an electrically responsive element connected in circuit with said timing capacitor.

2. The photo process timer of claim 1 wherein said means for indicating when said timing capacitor has discharged to a predetermined voltage comprise:

a differential amplifier connected to said timing capacitor to monitor the discharge of said capacitor;

a differential comparator connected to said differential amplifier to indicate when said capacitor has been substantially discharged; and

an electronic switching device connected to said differential comparator which de-energizes a relay to signal the end of the timing cycle.

3. The photo process timer of claim 1 wherein said means in series with said source of voltage for maintaining a constant current through said adjustable impedance comprises a field effect transistor.

4. The photo process timer of claim 1 wherein said adjustable impedance is linearly variable for varying the potential across said capacitor in direct proportion to any adjustment made and wherein said timer further comprises:

a second adjustable impedance electrically connected to said means to maintain a constant current for varying the current therethrough in logarithmic steps; a plurality of additional timing capacitors; and

means for selectively connecting said additional timing capacitors across said second adjustable impedance, individually and in parallel, whereby the potential to which said capacitors are charged, in combination with the selected total capacitance value, produces a timing cycle of desired duration.

5. The photo process timer of claim 1 further comprising:

a plurality of lamps utilized in photographic processes; a plurality of relay switching means operatively con-

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nected to said lamps and said timing capacitor for energizing said lamps and for initiating discharge of said timing capacitor;

a plurality of manual switches operatively connected to said relay switching means for selectively activating said relays and thereby selectively energizing said lamps; and

wherein said electrically responsive element operates to de-energize said relay switching means when said capacitor has discharged to a predetermined value.

6. A photo process timer comprising, in combination: at least one timing capacitor;

a charging circuit for said timing capacitor including a source of voltage connected in series with said capacitor;

a first impedance connected in series with said source of voltage and connected in parallel with said capacitor;

an adjustable second impedance connected in series with said first impedance and said source of voltage for varying the current through said first named impedance to establish the voltage to which said timing capacitor is charged;

means for disconnecting said timing capacitor from said charging circuit and for establishing a discharge circuit therefor; and

means for indicating when said timing capacitor has discharged to a predetermined voltage, including an electrically responsive element connected in circuit with said timing capacitor.

7. The photo process timer of claim 6 further comprising means in series with said source for maintaining a constant current through said first impedance, and wherein said adjustable second impedance comprises a resistance network electrically connected to said means for maintaining a constant current whereby adjustment of said second impedance causes the constant current through said first impedance to vary logarithmically.

8. The photo process timer of claim 6 wherein said

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first impedance connected in parallel with said capacitance is an adjustable resistor whereby adjustment of said resistor increases or reduces the voltage across said timing capacitor in direct proportion to the magnitude of the adjustment.

9. The photo process timer of claim 8 further comprising a plurality of additional adjustable resistors and means for selectively connecting any one of said additional resistors in parallel with said timing capacitor and for disconnecting said first named adjustable resistor.

10. The photo process timer of claim 6 further comprising mechanical means for calculating values of density and for adjusting said second adjustable impedance, said means comprising:

- 15 a plurality of input shafts;
- control knobs affixed to each of said input shafts;
- switching means for adjusting said adjustable impedance operatively connected to each of said input shafts; and
- 20 connecting means for translating density information derived from rotation of said control knobs, said connecting means comprising:
- at least one set of gears operatively fixed to one of said input shafts; and
- 25 at least one cam follower assembly operatively fixed to another of said input shafts.

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