

[54] **EXPOSURE CONTROL IN ELECTROSTATIC PHOTOCOPYING PROCESSES**

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[51] Int. Cl. **G03g 15/00**

[58] Field of Search **355/3, 8, 14, 17, 355/68, 69; 324/32**

[56] **References Cited**

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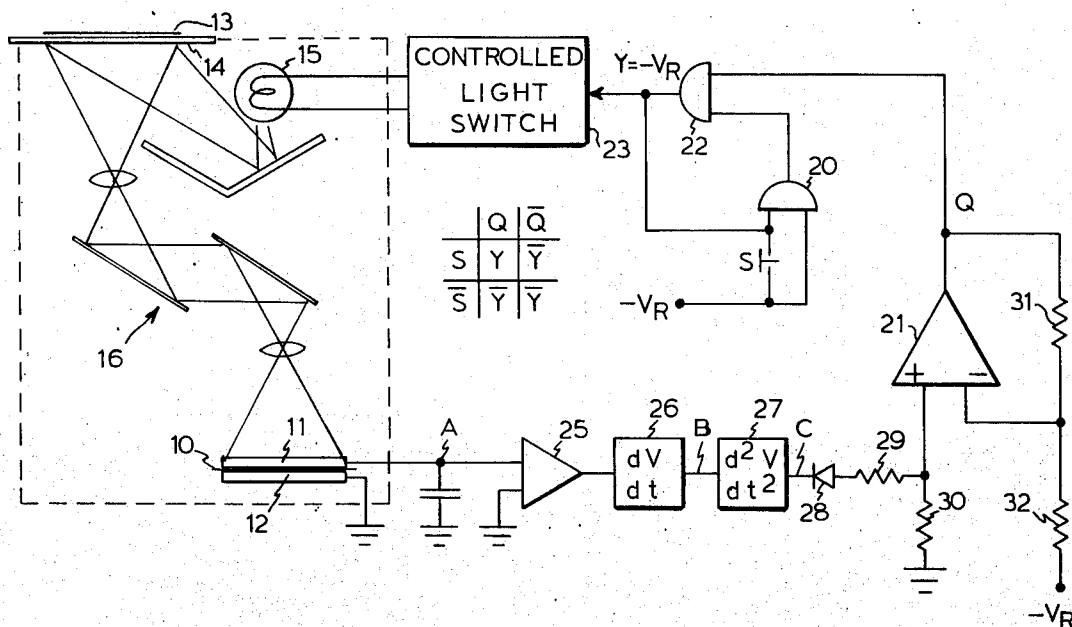
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[57] **ABSTRACT**

Automatic exposure control for optimum contrast in an electrostatic photocopying process is disclosed using an electrometer to detect average charge of a photoconductive film during exposure, and detecting a change in the rate of discharge from a high rate during the initial period of under-exposure to a low rate of over-exposure. Exposure is then terminated upon detecting that change.

5 Claims, 2 Drawing Figures



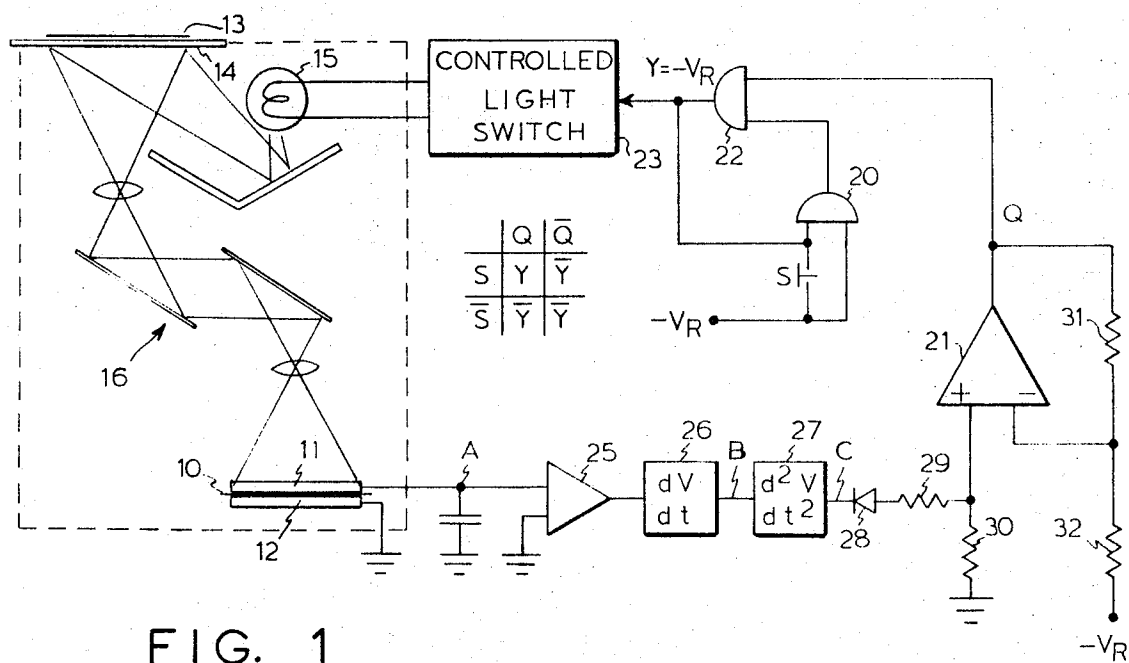


FIG. 1

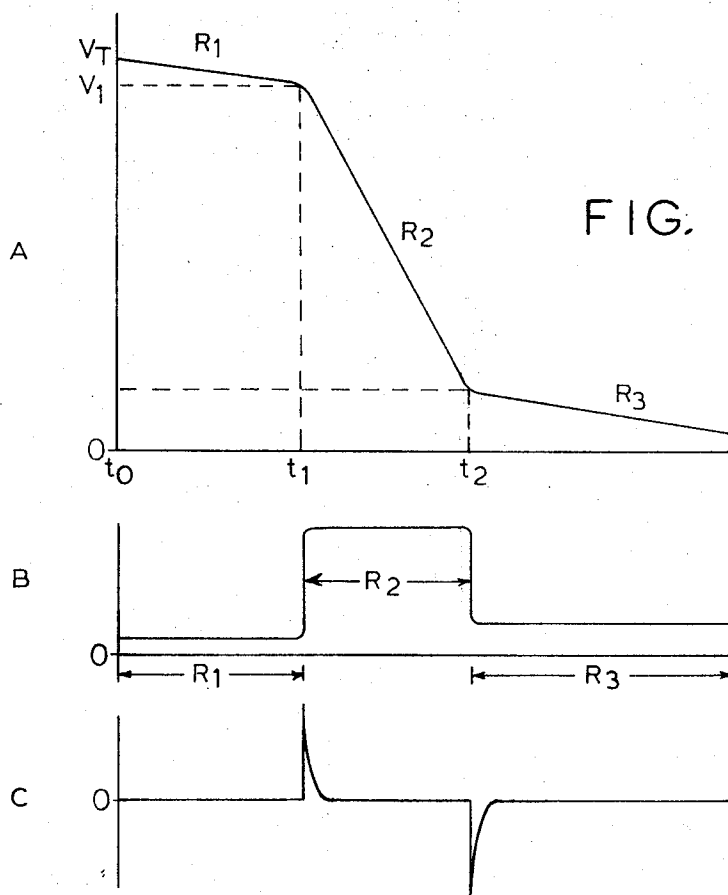


FIG. 2

EXPOSURE CONTROL IN ELECTROSTATIC PHOTOCOPYING PROCESSES

BACKGROUND OF THE INVENTION

This invention relates to an improvement in electrostatic photographic or photocopying processes of the types in which a photoconductive film, such as zinc oxide in a transparent insulating binder, is first uniformly charged and then discharged by a light image (pattern of light and shadow). The latent electrostatic image left on the photoconductive film is developed by a "toner" comprised of comminuted, triboelectric material in either a dry powder form or a liquid dispersion form.

In photocopying processes of the type to which this invention relates, it is customary to charge the photoconductive film to a predetermined and fixed electrostatic potential of several hundred volts. Contrast in the copy is then set by exposure control. This control must take into consideration not only the desired level of contrast but also the average density of the light image. The desired level of contrast can be empirically set for a wide class of items to be photocopied, such as printed or typed documents, but because the average density can vary widely from one item to the next, it is not practical to rely on manual adjustment of the exposure for variations in average density.

It is conceivably possible to maintain the exposure constant and to control contrast in the resulting copy by control of the development process. However, to control the development, it is necessary to know the charge remaining in the light areas of the photoconductive film after exposure. For reasonably fast copying of items, it would not be feasible to attempt to implement a process with fixed exposure and controlled development. It would be better to attempt to control contrast by control of the exposure.

One technique for control of exposure which has been proposed in U. S. Pat. No. 3,321,307 employs an electrometer to measure the average charge on the photoconductive film during the exposure, and a control circuit responsive to the electrometer output for terminating the exposure when a predetermined average level is reached, or when a predetermined change in the average charge has been reached. Thus, this technique relies upon termination of the exposure of the photoconductive layer when the layer light decays to a predetermined average potential, which is set by the operator. This technique is independent of original charge, dark decay, light intensity, and photographic speed of the layer; however, it is not independent of the copy density of the original. As an example, if the printed area of an original is 25 percent of the total area and the charge acceptance is 500 volts, then the optimum exposure results when the exposure is terminated at the average potential of 125 volts. If the operator then changes originals to say one with 10 percent of the area printed and does not reset the exposure control, the result will be an underexposed copy. Thus, the operator will have to adjust the exposure control each time he changes originals.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the invention is to provide an improved electrostatic photocopying process to yield optimum exposure for contrast.

Another object is to provide apparatus for automatically terminating exposure in an electrostatic photocopying process for optimum contrast.

These and other objects of the invention are achieved by providing an electrometer to measure the average charge of a photoconductive film in an electrostatic copying process during exposure. The output of the electrometer is a signal having a first rate of change prior to initiation of exposure as the initial uniform charge decays due to dark current, a second fast rate during initial underexposure, and a third slow rate during final discharge due to overexposure if exposure is not terminated. In one embodiment, the electrometer is comprised of a transparent conductive sheet over the photoconductive film, a conductive ground plate under the film, and a high input impedance amplifier connected to amplify the potential between the transparent conductive film and the ground plate. By differentiating the electrometer output signal twice, a pulse is obtained during the transition from the second rate to third rate. Terminating the exposure in response to that pulse will yield optimum exposure, i.e., optimum contrast.

The novel features of the invention are set forth with particularity in the appended claims. The novelty will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic diagram of apparatus for producing a latent image in an electrostatic copying process with optimum contrast in accordance with the present invention.

FIG. 2 is a waveform diagram useful in understanding the principles of the present invention as embodied in the apparatus of FIG. 1.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIG. 1, a sheet of zinc-oxide coated paper 10 is positioned between a transparent, electrically conductive sheet 11 (such as a sheet of glass commercially available under the trade designation NESA) and a conductive ground plate 12. The apparatus for positioning the paper (not shown) is conventional. What is important to the present invention is only that the zinc-oxide coated paper functions as a photoconductive film. A latent (electrostatic) image is produced on that film, as will be presently described more fully. The paper is then removed for developing in a conventional manner.

In electrostatic copying machines of the type in which the latent image is produced on a reusable photoconductive film, the image is developed and then transferred onto a sheet of paper by pressure. In either case the developed image is fixed on the paper, usually by heat, to provide a permanent copy. The present invention which pertains to controlling the exposure of the photoconductive film to produce the latent image is applicable to both types of electrostatic copying machines. The one using zinc-oxide coated paper is illustrated in a simplified schematic diagram only for the purpose of describing an exemplary embodiment of the invention.

The item 13 to be copied, such as a sheet of paper on which a letter has been typed, is placed face down on a plate 14 of glass. Light from a source 15 illuminates

the face of the sheet 13. An optical system focuses a light image of the item onto the zinc oxide coated paper through the conductive sheet 11. Prior to that, the entire coated surface of the paper 11 has been uniformly charged to a potential V_T of several hundred volts in a conventional manner (by means not shown). After optimally exposing the charged surface of the paper to the light image, thus producing a latent electrostatic image, the latent image is developed, as just noted hereinbefore.

The light source 15 is turned on by momentarily depressing a push-button switch S, thus applying a signal $-V_R$ to both inputs of an AND gate 20. At this time, the output Q of a differential amplifier 21 (used as a voltage comparator) is also $-V_R$, thus enabling a second AND gate 22 to transmit a signal Y equal to $-V_R$. That signal latches the AND gate 20 on to continue to provide the signal Y to a controlled light switch 23 after the switch S is opened. The control element of the light switch 23 may be, for example, a silicon controlled rectifier (SCR) having its gate so biased that when the signal Y is set equal to $-V_R$, the SCR will go into its high conduction region. When Y is no longer equal to $-V_R$ (a condition indicated by $\bar{Y}$ in the Veitch diagram included in FIG. 1), because the AND gate 22 is off, current through the SCR drops below its holding current, a minimum value required to maintain conduction through the SCR. In that manner, the AND gates 20 and 22 control the light switch to cause it to be turned on and to hold it on, but only as long as the output of the differential amplifier 21 is true, i.e. equal to $-V_R$. That output signal is designated Q for use in the Veitch diagram included in FIG. 1.

What has been described thus far, excepting the transparent conductive sheet 11, is simply the environment for the present invention. That environment may be implemented in a variety of different ways without departing from the true concept of the present invention. The sheet 11, together with the ground plate 12, and a high input impedance amplifier 25, function as an electrometer to provide an output signal A proportional to the average charge on the coated paper from the time t_0 as shown by waveform A in FIG. 2.

Initially, the film of zinc oxide on the paper is charged to a surface potential of V_T . This charge may dark decay at a rate R_1 to a potential V_1 at time t_1 , when the light is turned on and exposure of the paper is started. The charge then light decays at a rate R_2 for a time $(t_2 - t_1)$. At time t_2 , the rate of change of the potential on the paper surface changes to a rate R_3 as the condition of the paper passes from under-exposure to over-exposure. The potential V_2 remaining at the time t_2 is then the average surface potential for an optimum exposure. The rate of potential decay after time t_2 is due to over exposure which this invention prevents.

The concept of the invention is to take the first and second derivatives of the signal A, as shown in waveforms B and C, to obtain a pulse at time t_2 , and to terminate the exposure in response to that pulse. FIG. 1 shows an exemplary system for accomplishing that. A first differentiating circuit 26 provides the first derivative (waveform B) and a second differentiating circuit 27 provides the second derivative (waveform C). A diode 28 passes only the negative pulse at time t_2 . Consequently, a junction between resistors 29 and 30 connected to the inverting (+) input terminal of the differential amplifier 21 is at ground potential until time t_2 .

During that time (t_0 to t_2), the output of that amplifier is at the reference voltage $-V_R$ connected to the non-inverting (-) input terminal. This is so because resistors 31 and 32 cause the amplifier to function as a simple 0 operational during that time.

At time t_2 , the negative pulse of waveform C is coupled to the inverting input terminal of the differential amplifier, thereby causing the output Q of the amplifier to be driven to some positive level. That output is then "false," i.e., is not equal to $-V_R$. In the notation of Boolean logic, the output is then $\bar{Q}$. Consequently, the output of the AND gate 22 becomes false ($\bar{Y}$) to turn off the controlled light switch 23. That terminates the exposure at time t_2 leaving the average surface potential at the optimum level V_2 .

The level V_2 is not fixed; it is a function of the density of dark areas in the object being copied. However, in each case it is determined by a change from one fast rate of discharge during the first part of exposure to a slow rate of discharge during the last (over-exposure) part. The particular rate experienced during the first and second parts will also depend upon the density of the item being copied, but in each normal case there will be a sufficiently rapid change from one rate to the other to permit a pulse to be produced and detected of sufficient amplitude to turn the light off at time t_2 . That stops the exposure from proceeding beyond the optimum at the next lower rate (R_3 in FIG. 2). The abnormal cases will be those in which the item to be copied is so dense that the "fast" rate (R_2 in FIG. 2) of under-exposure is very nearly the "slow" rate of over-exposure.

This technique may be used in other electrostatic photocopying processes and with other components. For example, it may be used to "print" from a "negative" by simply arranging the optics to transmit light through the "negative" onto the film of photoconductive material. As to other hardware components, the electrometer may be of the side-looking type shown in the aforesaid U. S. Pat. No. 3,321,307. Consequently, it is intended that the claims be interpreted to cover such other processes and components.

What is claimed is:

1. In an electrostatic photocopying process, controlling the exposure of a charged film of photoconductive material by turning on a light source to initiate exposure of said film with a light image, to thereby produce a latent electrostatic charge image on said film, detecting the average charge of said film from at least the time exposure is initiated; detecting the rate of change of said average charge and terminating exposure of said film to said light image when a rate of change of said average charge is detected from one rate to a lower rate.

2. In an electrostatic photocopying process of the type using a photoconductive film charged uniformly to a high potential to produce a latent electrostatic charge image by exposing said uniformly charged film to a light image, the improvement of controlling the time of exposure of said film to said light image for optimum contrast exposure by turning on a light source to initiate exposure of said film with said light image; detecting the average charge of said film and producing a first electrical signal proportional to the average charge detected, passing said electrical signal through two differentiating circuits in cascade to produce a signal that is the second derivative of said first electrical signal,

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thereby producing a pulse at the time the change of said average charge changes from a first rate characteristic of an under-exposed condition to a second rate characteristic of an over-exposed condition, and turning off said light source in response to said pulse, thereby terminating exposure of said film to said light image when said film has been exposed for optimum contrast.

3. In electrostatic photocopying apparatus having means for exposing a uniformly charged film of photoconductive material to a light image, thereby to discharge illuminated areas on the surface of said film and leave a latent electrostatic charge image for development, the improvement comprising

means for continually sensing the average surface charge of said film from at least the time said exposing means is turned on,

means for producing a signal proportional to the average surface charge sensed as exposure continues, means for differentiating said average surface charge signal to obtain a first derivative signal proportional to the rate of change of said surface charge signal, and therefore proportional to the rate of change of said surface charge,

means for differentiating said first derivative signal to obtain a second derivative signal proportional to the rate of change of said first derivative signal, thereby producing a pulse in said second derivative signal when the rate of change of said average surface charge signal changes from one rate during initial exposure to a second rate characteristic of an over-exposure condition of said film surface, and

means responsive to said pulse for turning off said exposing means.

4. In electrostatic photocopying apparatus of the type in which a photoconductive film is first uniformly charged to a high potential and then exposed to a light image to produce on said film a latent image that may be developed by comminuted, triboelectric material,

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the combination comprising:

a controlled light source,

means for turning on said light source in response to an electrical control signal of predetermined value,

means for initiating said electrical control signal,

means responsive to light from said source for producing said light image,

means for directing said light image onto said photoconductive means,

means for producing a first electrical signal proportional to the average charge of said photoconductive film during exposure to said light image,

means responsive to said first electrical signal proportional to the average charge of said photoconductive film for producing a second electrical signal proportional to the rate of change of said first signal,

means responsive to said second electrical signal proportional to the rate of change of said first signal for producing a third electrical signal proportional to the rate of change of said second signal, thereby producing a pulse when said first signal changes from a first rate of change during initial exposure to a second rate of change characteristic of an over-exposed condition of said film, and

means for terminating said electrical control signal in response to said pulse, thereby turning off said light source when said charged conductive film has been optimumly exposed to said light image.

5. Apparatus as defined in claim 4 wherein said means for producing said first electrical signal proportional to the average charge of said photoconductive film comprises a transparent conductive sheet over said photoconductive film, a conductive plate under said photoconductive film and a high input impedance connected to said transparent sheet and said conductive plate to amplify the potential between said sheet and said plate.

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