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(54) EXPOSURE CONTROL FOR COLOUR PRINTER

(71) We, EASTMAN KODAK COMPANY, a Company organized under the Laws of the State of New Jersey, United States of America of 343 State Street, Rochester, New York 14650, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to exposure control means for a photographic colour printer for automatically altering the colour composition of the printing beam of a colour printer in accordance with the degree of colour balance of a negative to be printed.

In subtractive colour printers, for example, it is common practice to illuminate a colour transparency, either positive or negative, with a broad band radiation source, e.g. white light, and to project an image of the illuminated transparency in a printing beam onto a sheet of colour print material. Three subtractive primary filters F_c (cyan), F_m (magenta) and F_y (yellow) may be arranged to be selectively movable into and out of the printing beam of the projected image. The colour composition of the printing beam may be monitored by three photosensitive devices which are selectively responsive to the density of the red, green and blue colour components of the projected image. Each of the photosensitive devices may be connected to a capacitor which, under the influence of the output signal from the photosensitive device, charges to a predetermined voltage. As each capacitor charges to the predetermined voltage, a corresponding one of the three subtractive primary filters F_c , F_m and F_y is inserted into the printing beam. For example, after a time delay directly dependent upon the intensity of red light striking the red photosensitive device, the cyan filter F_c is inserted into the printing beam to halt the red exposure of the sheet of colour print material. Similarly, the blue exposure of the sheet of colour print material is halted when the yellow filter F_y is inserted into the print-

ing beam; and the green exposure is halted when the magenta filter F_m is inserted into the printing beam. When all three filters are moved into the printing beam, the exposure is stopped, since theoretically, all light is cut off from the printing beam by the filters; however, as a safeguard, an opaque shutter is usually inserted thereafter into the printing beam. A colour printer similar to that herebefore described is disclosed in U.S. Patent 3,184,307.

The rate at which the associated capacitors charge to the predetermined voltage sufficient to insert the colour filters is dependent upon the red, green and blue large area transmission densities (LATD) of the negative to be printed. The colour balance of an average population of negatives that the printer must accommodate widely varies from a normal or average colour balance wherein the red, green and blue LATD's are relatively equal. A basic assumption of the large area monitoring concept is that the LATD's are representative of the densities of the principle subject area of interest in the negative. Thus, if the principal subject of interest such as a distant water skier or sailboat, is photographed against a background of predominantly blue sky or water, the large area density monitoring system does not sense the fact that the unusually high blue density of the negative is not typical of the principle subject area of interest. When the full colour correction capabilities of the exposure determination system are utilized as described hereinbefore, the blue exposure will be terminated quickly and the colour balance of the resulting print will be objectionably yellow. Such a print is referred to as a colour subject failure resulting from a predominance of one colour in the scene which has been recorded by the negative. Obviously, colour subject failures are not limited to any particular colours, but the most frequently encountered cases are associated with red backgrounds (furniture, clothing, etc.), green grass or foliage, and blue sky or water.

In order to prevent the printing of colour subject failures, it has been found desirable

to reduce the high color correction level of the exposure determining system described above by a linear combination of the red, green and blue LATD's of the negative to be printed. Thus the red exposure, for example, is made a function of all three LATD's rather than being based on red transmittance alone. In U.S. Patent 3,120,782 issued February 11, 1964, to Goddard et al, and assigned to Eastman Kodak Company, there is disclosed a system that has made it possible to manually adjust the rate of correction which the printer will introduce for variations in the LATD's of the population of negatives being printed.

However, there is another class of errors produced by sensitometric problems associated with camera exposure level, spectral quality of the exposing illuminant, film deterioration due to improper storage, processing variations and so forth, that require high levels of correction. The introduction of dual purpose colour films designed to be exposed with either daylight or artificial illumination, as distinguished from earlier single purpose colour films which were balanced for use with only one type of light, i.e., only daylight or artificial light, has resulted in a class of illuminant failure negatives, e.g., negatives erroneously exposed with tungsten lamps. In order to compensate for such sensitometric errors, it is necessary to maintain a high color correction level during printing.

Thus very low rates of correction for LATD variability are desirable when printing negatives which are normal in the sensitometric sense but abnormal in the sense that the distribution of colours in the original scene is unequal, i.e., when the negative exhibits a colour subject failure. Further, relatively high rates of colour correction for LATD variability are desirable when printing negatives which are abnormal in the sensitometric sense, i.e., illuminant failure negatives. This general problem is discussed at length in an article in the Journal of SMPTE, April 1956, entitled "Exposure Determination Methods for Colour Printing: The Concept of Optimum Correction Level" by Bartelson and Huboi. The authors conclude that there is an optimum compromise correction level for any integrated transmittance printing system which can be derived using linear regression techniques to provide the best statistical fit to the characteristics of the negative or transparency population being printed. In general, this optimum correction level falls in the range of 70% to 90% of the full correction level for LATD variability, dependent on the season of the year.

Colour subject failure remains a serious problem, however, even at correction levels as low as 70%. In more typical situations, where correction levels of 85% to 90% are required to adequately normalize the real

errors in the negative or transparency population, the anomalous errors due to scene attributes result in extremely poor quality prints.

The production of such prints is wasteful of paper and time, since inspection of the prints and reprinting are required in order to maintain high standards of colour printing.

In accordance with the present invention there is provided exposure control means for a photographic colour printer, the exposure control means being responsive to the intensities of light of at least two different wavelengths in the printing beam to establish the exposure time periods to light of the said wavelengths, and the exposure control means being adapted to adjust the exposure time periods to provide either a high or a low degree of colour correction in the printing beam, and including means for producing a control signal or signals having a periodic waveform of first and second amplitudes, the durations at the first and second amplitudes being determined by the said intensities and being indicative of the proportion of each exposure cycle in which high or low colour correction is required, and means responsive to the control signal or signals for adjusting the exposure time period to provide the degree of colour correction indicated by the control signal or signals.

The present invention can provide a gradual transition from a low colour correction level to a high colour correction level in accordance with a function of the red, green and blue LATD's of the negative to be printed.

A preferred embodiment of the present invention is disclosed in connection with the exposure control system of the colour printer which comprises means to change the mode of operation of a colour printer from a low colour correction mode required for normal negatives and colour subject failure negative to a relatively high colour correction mode required for the correction of abnormal sensitometric errors, such as illuminant failure negatives. A high level of density correction is maintained in both modes of operation.

More particularly, in accordance with one preferred embodiment of the invention exposure control apparatus is provided for controlling the degree of colour correction in response to first and second radiation signals generated by first and second radiation sensitive devices, each sensitive to radiation of a different wavelength in the printing beam of a photographic printer. Means responsive to the first and second radiation signals produce a third signal having a periodic waveform of first and second amplitude, the durations at the first and second amplitudes being dependent upon the first and second radiation signals. Further means responsive to the first amplitude of the third signal introduce a high degree of colour correction in the printing

beam of the photographic printer and, responsive to the second amplitude of the third signal, introduce a low degree of colour correction in the printing beam.

- 5 The high degree of colour correction is provided by means responsive to each individual radiation signal for determining the individual exposure time periods of print material to the first and second wavelengths.
- 10 The low degree of colour correction is provided by means responsive to a combination of the first and second radiation signals for determining a common exposure time period for the print material to the first and second wavelengths.

- 15 In the detailed description of the prior art and preferred embodiment of the invention presented below by way of example, reference is made to the accompanying drawings in which:

Fig. 1 is a circuit diagram of a prior art filter control operative in a high colour correction mode;

- 25 Fig. 2 is a circuit diagram of the prior art filter control of Fig. 1 modified to operate in a low colour correction mode; and

- 30 Fig. 3 is a circuit diagram of an illuminant failure detector and clamp signal generator in conjunction with a filter control selectively operative in a high colour correction mode and a low colour correction mode.

- Referring now to the drawings and first to Fig. 1, there is shown a high colour correction circuit known in the prior art which consists of three separate integrating circuits that are exclusively responsive to the red, green and blue LATD's of the projected image of the negative to be printed, to insert the cyan, magenta and yellow subtractive filters into the printing beam upon the charging of capacitors C_r , C_g and C_b to a predetermined voltage level. More particularly, the red, green and blue photosensors 10, 12 and 14 are located with respect to the printing beam of a color printer (not shown) to detect the red, green and blue LATD's of the negative and to generate respective photocurrent signals I_r , I_g and I_b having a magnitude dependent thereon. The three photocurrent signals I_r , I_g and I_b are applied to the input terminals of amplifiers 16, 18 and 20, respectively, which transform the current signals to voltage signals V_r , V_g and V_b , respectively. The amplification of amplifiers 16, 18 and 20 may be preset to produce an acceptable print from a colour balanced reference negative, exposed to daylight or blue flash, and the amplification need not be altered thereafter. The voltage signals V_r , V_g and V_b are applied through attenuating resistors 22, 24 and 26, respectively, to the input terminals of amplifiers 28, 30 and 32 which transform the voltage signals V_r , V_g and V_b into charging current signals I_r' , I_g' and I_b' , respectively. The charging current signals I_r' , I_g' and I_b' simultan-

ously charge capacitors C_r , C_g and C_b to a predetermined voltage level which, when attained, is sufficient to energize printer filter controls that insert the filters F_c , F_m and F_y into the printing beam.

The high colour correction circuit of Fig. 1 controls the exposure time for each of the three printing colours exclusively from the detected red, green and blue LATD's. The circuit of Fig. 1 is sufficient to satisfactorily control the printing of normal negatives having substantially equal densities of red, green or blue and also to control the printing of negatives that exhibit illuminant failure.

The low colour correction circuit of Fig. 2 is a modification of the high colour correction circuit of Fig. 1 that is provided by the interconnection of the impedance circuits including the resistors 22', 24', 26', 22'', 24'' and 26''. Assuming that the resistors are equal in value, the impedance circuits operate to equalize the voltage signals V_r' , V_g' and V_b' and to consequently equalize the printing times for the red, green and blue colours. A printer operating in a low colour correction mode as described is referred to as a "colour blind" printer, since the three filters F_c , F_m and F_y are inserted into the printing beam of the printer substantially simultaneously regardless of the colour balance of the negative. Thus a "colour blind" printer will satisfactorily control the printing of a normal, colour balanced negative.

Normally, however, the interconnecting resistors are varied in value in known mathematical relationships to establish a standard level of colour correction suited to the characteristics of the source of light for the printing beam, the type of negative to be printed, and the type of paper upon which the print is to be made. Once established for any particular printer and sensitized strip, these resistance values may be left untouched until changed by the operator of the printer to compensate for observed variations in the negatives, such as under or over exposed negatives and/or negatives having unusual or undesirable colour balance. Further explanation of the operation of a low colour correction circuit such as that depicted in Fig. 2 may be obtained from the explanation of the circuitry disclosed in the aforementioned U.S. Patent 3,120,782.

As it is desirable to increase the speed of color printers, it has been found necessary to automate many functions previously performed by an operator of the printer. In accordance with the teachings of the present invention, there is shown in the preferred embodiment of Fig. 3 a color correction circuit responsive to the integrated red, green and blue LATD's of the negative to be printed that automatically provides a continuously variable low to high colour correction that will balance colour subject failure and illu-

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minant failure negatives. The circuit of Fig. 3 eliminates the necessity of inspection of the negative to be printed by an operator, and it eliminates the situation wherein two similar negatives near the illuminant failure threshold would be printed differently—one with high colour correction and the other with low colour correction.

Referring now to Fig. 3, there is shown a colour correction circuit in accordance with the invention but which includes certain elements common to the color correction circuits of Figs. 1 and 2, namely the red, green and blue photosensors 10, 12 and 14 connected respectively to the input terminals of amplifiers 16, 18 and 20 respectively. The high colour correction impedances 22, 24 and 26, respectively, are connected between the output terminals of the amplifiers 16, 18 and 20 and the input terminals of amplifiers 28, 30 and 32, respectively. The integrating capacitors C_r , C_g and C_b are connected to the output terminals of the amplifiers 28, 30 and 32, respectively. In accordance with the teachings of the present invention, an illuminant failure detector circuit 27, connected to the output terminals of the amplifiers 16, 18 and 20, generates a pair of control signals A and

$\bar{A}$ which switch the colour correction circuit from a normal low colour correction mode, provided by the interconnecting impedance networks 102, 104 and 106, to a high colour correction mode, provided by the impedances 22, 24 and 26, over a variable proportion of the total printing time.

A negative exhibiting a typical illuminant failure will produce LATD voltage signals such that $V_b > V_g > V_r$, due to the fact that daylight and blue flash type film exposed to a warmer illuminant, such as a tungsten lamp, which is deficient in blue and green light, results in a negative which has a low density of blue and green. A print made from such a negative exhibits an extreme reddish-yellow hue due to the lack of the aforementioned colours in the illuminating light. The illuminant failure detector circuit 27 is responsive to the LATD voltage signals V_b , V_g and V_r to provide the proper colour correction to produce a colour balanced print.

The illuminant failure detector circuit 27 includes the electrical components enumerated hereinafter and including a first differential amplifier 34 having a first input terminal 36 connected to the output terminal of amplifier 18 and a second input terminal 38 connected to the output terminal of amplifier 16 and an output terminal 40. The differential amplifier 34 operates to subtract the LATD voltage signal V_r at input terminal 38 from the LATD voltage signal V_g at input terminal 36 to produce a first voltage difference signal $V_g - V_r$ at output terminal 40. A second differential amplifier 42 has a first

input terminal 44 connected to the output terminal of amplifier 20, a second input terminal 46 connected in common with the first input terminal 36 of differential amplifier 34 to the output terminal of amplifier 18. The differential amplifier 42 is operative to subtract the LATD voltage signal V_g at input terminal 46 from the LATD voltage signal V_b at input terminal 44 to produce a second voltage difference signal $V_b - V_g$ at output terminal 48. The output terminals 40 and 48 of the differential amplifiers 34 and 42, respectively, are connected to the cathodes of diodes 50 and 52, respectively. Diodes 50 and 52 are connected at their anode terminals to the conductor 54 which is connected to a positive voltage source $+V$ through a relatively large resistor 56. The conductor 54 is also connected to the input terminal 58 of variable pulse width oscillator (VPWO) 60 through conductor 62 and resistor 64.

The variable pulse width oscillator (VPWO) 60 may be of any suitable design that is operative to produce a pair of complementary

control signals A and $\bar{A}$ having a substantially constant frequency, e.g. 2,000 Hz, that is selected to have a short period with respect to the total printing time of an average negative, at its output terminals 66, and 68, respectively.

The control signals A and $\bar{A}$ are designed to have complementary square wave forms that are either at a high voltage level $+V_b$ or at ground potential for reasons set forth in the description of the operation of the apparatus of Fig. 3. The VPWO 60 is responsive to the voltage level of the input signal V_i applied at its input terminal 58 to vary the square wave pulse width of the

2,000 Hz control signals A and $\bar{A}$ in proportion thereto.

The VPWO 60 may consist of a free running sawtooth wave form signal generator 70 that is operative to continuously produce a 2,000 Hz sawtooth wave form voltage signal having a maximum and minimum positive voltage amplitude and a short rise time which is illustrated as 70a. The sawtooth wave form signal 70a is applied to the negative input terminal 71 of operational amplifier 72 through resistor 73. The negative input terminal 71 of the operational amplifier 72 is further connected to the input terminal 58 of the VPWO 60 through resistor 74. A negative bias voltage $-V$ is also applied to the negative input terminal 71 of the operational amplifier 72 through resistor 75. The absolute value of the voltage $-V$ is selected to exceed the absolute value of the sum of the maximum voltage level of the sawtooth wave form signal 70a and the minimum voltage level of the input signal V_i applied at input terminal 58 so that, in the absence of input sig-

nal V_i at input terminal 58 exceeding the minimum voltage level, the operational amplifier 72 develops a zero voltage or ground potential output signal at its output terminal. A further operational amplifier 76 is connected by its input terminal to the output terminal of the operational amplifier 72 and is operative to invert the output signal of the operational amplifier 72. The output terminals 66 and 68 of the VPWO 60 are connected to the output terminals of the operational amplifiers 76 and 72, respectively.

The VPWO 60 operates as follows. The DC voltage level of the input signal V_i applied to input terminal 58 is summed with the instantaneous voltage of the 2,000 Hz sawtooth wave form 70a and the negative bias voltage $-V$ at the negative input terminal 71 of the operational amplifier 72. As the DC voltage level of the input signal V_i increases, the net input signal to the operational amplifier 72 becomes positive for a time duration in each cycle when the instantaneous voltage of the 2,000 Hz sawtooth wave form signal 70a and the input signal V_i exceeds the sum of the negative bias signal $-V$ and the input signal V_i . Operational amplifier 72 amplifies the net input signal at input terminal 71 to produce con-

trol signal $\bar{A}$ at terminal 68 having a voltage level $+V_b$. The control signal $\bar{A}$ is inverted by amplifier 76 to provide the complementary control signal A at output terminal 66. Thus, when the control signal A is at the high voltage level $+V_b$ in each cycle, the control signal $\bar{A}$ is at ground potential, and, in the portion of each cycle that control signal

A is at ground potential, the control signal $\bar{A}$ is at the high voltage level $+V_b$. The portion of each cycle in which the complementary control signals A and $\bar{A}$ are at the high voltage level $+V_b$ is therefore dependent upon the voltage level of the input signal at the input terminal 58.

In the manner described, the VPWO 60 is operative to produce control signals A and $\bar{A}$ that have complementary pulse widths during each cycle of the 2,000 Hz sawtooth wave form signal 70a that are dependent upon the DC voltage level applied at the input terminal 58.

The output terminal 66 of the VPWO 60 is connected to the cathodes of diodes 78, 80 and 82 which are connected at their anodes to the common terminal of high colour correction resistors 22, 24 and 26, respectively, and variable resistors 84, 86 and 88, respectively. When the control signal A produced at output terminal 66 is at the high voltage

level $+V_b$, the diodes 78, 80 and 82 do not conduct current. However, when the control signal A is at ground potential, the diodes 78, 80 and 82 conduct current to ground, and the interconnecting point between the resistors 22 and 84, 24 and 86, and 26 and 88 is at ground potential. The variable resistors 84, 86 and 88 are provided to prevent the input terminals of amplifiers 28, 30 and 32, respectively, from attaining ground potential.

The output terminal 68 of the VPWO 60 is connected to the cathodes of diodes 90, 92 and 94. The anodes of diodes 90, 92 and 94 are connected to the common terminals 96, 98 and 100 of the low colour correction circuits 102, 104 and 106. The low colour correction circuits 102, 104 and 106 are substantially identical to the low colour correction circuits of Fig. 2, and each low colour correction circuit includes a plurality of impedances that are operative to connect the output terminals of amplifiers 16, 18 and 20 to all the input terminals of the amplifiers

28, 30 and 32. When the control signal $\bar{A}$ produced at the output terminal 68 is at the high voltage level $+V_b$, the diodes 90, 92 and 94 are reverse-biased and do not conduct current from the interconnecting points 96, 98 and 100. Therefore, the circuit operates in the low colour correction mode as the voltage signals V_r , V_g and V_b are summed together at the input terminals of the amplifiers 28, 30 and 32. However, when the con-

trol signal $\bar{A}$ is at ground potential, the diodes 90, 92 and 94 conduct current from the interconnecting points 96, 98 and 100. Thus, the low colour correction circuits 102, 104 and 106 are disabled, since the interconnecting points 96, 98 and 100 are at ground potential.

Thus it can be readily observed that when the control signal A is at the high voltage

$+V_b$, the control signal $\bar{A}$ is at ground potential and the low colour correction circuits 102, 104 and 106 are disabled, and the circuit operates in the high colour correction mode.

When the control signal $\bar{A}$ is at the high voltage level $+V_b$, the control signal A is at ground potential and the high colour correction circuits 22, 24 and 26 are disabled, and the circuit operates in the low colour correction mode.

Returning now to the development of the input signal V_i at the input terminal 58 of the VPWO 60, it will be recalled that a first difference signal $V_g - V_r$ and a second difference signal $V_b - V_g$ are applied to the cathode terminals of the diodes 50 and 52 in the illuminant discriminator circuit 27. The voltage source $+V$ is chosen to exceed the maximum

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voltage level attainable by the first and second difference signals. Thus, the diodes 50 and 52 are forward-biased. However, only one of the two diodes 50 and 52 will conduct current, and that diode will be the one across which is developed the greatest voltage drop. For example, if difference signal $V_g - V_r$ is larger than difference signal $V_b - V_g$, the voltage level of the signal developed on the conductor 54 will be equal to the difference signal $V_b - V_g$. In this example, the diode 50 will not conduct current because the voltage level of conductor 54 becomes lower than the difference signal $V_g - V_r$, when diode 52 conducts current. Therefore the voltage level of the input signal V_i established at the input terminal 58 of the VPWO 60 is directly related to the least positive voltage of the first and second difference signals.

The signal on the conductor 54 is conducted by resistor 64 to the input terminal 58 of VPWO 60. The voltage level of the input signal V_i at the input terminal 58 is operative to control the pulse width of the square wave complementary signals A and A in the manner described hereinbefore. If it is considered desirable to limit the voltage level range of the signal applied at the input terminal 58, there are shown further circuit elements which provide a maximum and minimum voltage level. A diode 108 is connected at its anode terminal to point 62 and at its cathode terminal to the movable contact arm 110 of a rheostat 112. In like manner, a diode 114 is connected at its cathode terminal to point 62 and at its anode terminal to the movable contact arm 116 of the rheostat 118. The rheostats 112 and 118 have a relatively low total impedance with respect to the impedance of resistor 56 and are connected in series between the positive voltage source +V and ground potential.

The setting of movable contact arm 110 of rheostat 112 determines the maximum voltage level of the signal developed at point 62, because the diode 108 is rendered conductive when the voltage level at point 62 exceeds the voltage level determined by the setting of movable contact arm 110. In a similar manner, the setting of movable contact arm 116 of rheostat 118 establishes the voltage level below which the signal developed at point 62 cannot fall. The diode 118 is rendered conductive if the voltage at point 62 becomes less than the voltage level established by the setting of movable contact arm 116.

Movable contact arm 110 is normally set to a voltage level that is sufficient, when applied at the input terminal 58 of the VPWO 60, to exceed the maximum voltage attained by the sum of the sawtooth wave form 70a and the negative bias voltage -V to therefore prevent the operational amplifier 72 from pro-

ducing a positive voltage signal + V_b at its output terminal. Therefore, as explained here-

inbefore, control signal $\bar{A}$ will be at ground potential, whereas control signal A will be at the voltage + V_b . Similarly, the movable contact arm 116 may be set at a voltage that is less than the sum of the minimum voltage of the sawtooth wave form 70a and the negative bias voltage -V. In the latter case, the operational amplifier 72 will produce a positive voltage signal + V_b at its output terminal during 100% of the printing time, thus

switching control signal $\bar{A}$ to the high voltage level + V_b and control signal A to ground potential.

It should be understood however that the VPWO 60 could be operated satisfactorily with or without the establishment of maximum and minimum voltage levels at point 62 as described hereinbefore.

The colour correction circuit of Fig. 3 is operative in accordance with the present invention to provide a variable amount of colour correction that is directly proportional to the degree of illuminant failure in the negative to be printed. When the negative to be printed exhibits an illuminant failure of the type described hereinbefore, the voltage signals V_b and V_g are relatively high, and the input signal V_i developed at input terminal 58 of VPWO 60 is the lower of the two relatively large difference signals $V_b - V_g$ or $V_g - V_r$.

In this instance, the control signals A and $\bar{A}$ are at a positive voltage and ground potential, respectively, for a period approaching 100% of each cycle of the VPWO 60. Thus, the color correction circuit of Fig. 3 operates primarily in the high color correction mode since the points 96, 98 and 100 of the low colour correction circuits 102, 104 and 106 are at ground potential.

A negative which exhibits only slight illuminant failure, such as mixed light sources, is represented by difference signals $V_b - V_g$ and $V_g - V_r$ which vary in proportion to the degree of difference between the signals V_r , V_g and V_b . The signal V_i developed at the input terminal 58 of the VPWO 60 also reflects the degree of illuminant failure of the negative, and it is operative to produce con-

trol signals A and $\bar{A}$ having complementary pulse widths that are between 0 and 100% of each cycle of the VPWO 60. Therefore, during each cycle, the diodes 78, 80 and 82 are rendered nonconductive for the initial portion of the cycle and conductive for the remainder of each cycle. Conversely, the diodes 90, 92 and 94 are rendered conductive for the initial portion of each cycle and nonconductive for the remainder of each cycle. Therefore, for the initial portion of each cycle, the



colour correction circuit of Fig. 3 is operative in a high colour correction mode, and for the remaining portion of each cycle, the colour correction circuit is operative in the low colour correction mode. Thus, the colour correction applied in any instance is directly proportional to the degree of detected illuminant failure.

When the negative to be printed does not exhibit an illuminant failure, the difference signals $V_b - V_g$ and $V_g - V_r$ are relatively low positive voltages or negative voltages, and the input signal V_i is equal to the minimum voltage established by the setting of movable contact arm 116. The minimum voltage level applied at input terminal 58 is effective to produce complementary clamping signals A

and $\bar{A}$ which are at ground potential and the voltage $+V_b$, respectively, for 100% of each cycle of the VPWO 60. Thus the colour correction circuit of Fig. 3 is operative in the low colour correction mode.

In summary, the circuit of Fig. 3 is normally operative in the low colour correction mode shown and described with respect to Fig. 2. An illuminant failure negative or a negative exhibiting a preponderance of red or yellow is detected by an illuminant failure detection circuit which produces variable

width clamping signals A and $\bar{A}$ which operate to switch the colour correction of the circuit to a high colour correction mode. Furthermore, the illuminant failure detector circuit is sensitive to the degree of illuminant failure to control the percentage of time in each cycle of the VPWO that the circuit operates in the low colour correction mode and the high colour correction mode.

From the description set forth above, it is apparent that the invention can be practiced in many alternative ways. It is apparent that the invention may be practiced in substantially the same manner as disclosed in the preferred embodiment to correct for a detected imbalance in the voltage signals V_r , V_g and V_b that does not satisfy the relationship $V_b > V_g > V_r$. Furthermore, it is apparent that the invention may be modified to automatically control the colour correction employed in additive as well as subtractive colour printing.

It will be obvious that the VPWO 60 and the colour correction circuit may take many forms consistent with the principles of colour correction set forth hereinbefore. For example, it is apparent that the control signals

A and $\bar{A}$ may not be exactly as described above and that switching elements may be substituted for the diodes 78, 80 and 82 and 90, 92 and 94 of Fig. 3.

Also, it is apparent that the invention may be practiced in connection with a colour cor-

rection circuit wherein the integrating capacitors are charged directly from the current generated by the photosensitive devices.

As may be seen a novel system has been disclosed for automatically and continuously varying the degree of colour correction from a low colour correction mode to a high colour correction mode in response to the detected degree of illuminant failure of the negative to be printed thus increasing the effective speed of automatic printers and reducing the number of unsatisfactory prints.

WHAT WE CLAIM IS:—

1. Exposure control means for a photographic colour printer, the exposure control means being responsive to the intensities of light of at least two different wavelengths in the printing beam to establish the exposure time periods to light of the said wavelengths, and the exposure control means being adapted to adjust the exposure time periods to provide either a high or a low degree of colour correction in the printing beam, and including means for producing a control signal or signals having a periodic waveform of first and second amplitudes, the durations at the first and second amplitudes being determined by the said intensities and being indicative of the proportion of each exposure cycle in which high or low colour correction is required, and means responsive to the control signal or signals for adjusting the exposure time period to provide the degree of colour correction indicated by the control signal or signals.

2. Exposure control means as claimed in Claim 1, wherein the means for producing the control signal or signals is arranged to produce first and second control signals of complementary wave form having first and second amplitudes respectively, the means responsive to the control signal or signals being arranged to provide a high or a low degree of colour corrections in response to the first and second amplitudes respectively.

3. Exposure control means as claimed in Claim 2, including first and second means for respectively halting the exposure of photographic print material to light of first and second wavelengths in the printing beam after first and second exposure time periods respectively; means responsive to the intensities of light of the first and second wavelengths in the printing beam for producing first and second signals each having a magnitude dependent upon the respective intensities of light of the first and second wavelengths; and means responsive to the first and second signals for establishing the said first and second exposure time periods, this signal responsive means comprising means for detecting an imbalance in the magnitudes of the first and second signals and, responsive to the detected imbalance, for producing a

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colour correction circuit of Fig. 3 is operative in a high colour correction mode, and for the remaining portion of each cycle, the colour correction circuit is operative in the low colour correction mode. Thus, the colour correction applied in any instance is directly proportional to the degree of detected illuminant failure.

When the negative to be printed does not exhibit an illuminant failure, the difference signals $V_b - V_g$ and $V_g - V_r$ are relatively low positive voltages or negative voltages, and the input signal V_i is equal to the minimum voltage established by the setting of movable contact arm 116. The minimum voltage level applied at input terminal 58 is effective to produce complementary clamping signals A

and $\bar{A}$ which are at ground potential and the voltage $+V_b$, respectively, for 100% of each cycle of the VPWO 60. Thus the colour correction circuit of Fig. 3 is operative in the low colour correction mode.

In summary, the circuit of Fig. 3 is normally operative in the low colour correction mode shown and described with respect to Fig. 2. An illuminant failure negative or a negative exhibiting a preponderance of red or yellow is detected by an illuminant failure detection circuit which produces variable

width clamping signals A and $\bar{A}$ which operate to switch the colour correction of the circuit to a high colour correction mode. Furthermore, the illuminant failure detector circuit is sensitive to the degree of illuminant failure to control the percentage of time in each cycle of the VPWO that the circuit operates in the low colour correction mode and the high colour correction mode.

From the description set forth above, it is apparent that the invention can be practiced in many alternative ways. It is apparent that the invention may be practiced in substantially the same manner as disclosed in the preferred embodiment to correct for a detected imbalance in the voltage signals V_r , V_g and V_b that does not satisfy the relationship $V_b > V_g > V_r$. Furthermore, it is apparent that the invention may be modified to automatically control the colour correction employed in additive as well as subtractive colour printing.

It will be obvious that the VPWO 60 and the colour correction circuit may take many forms consistent with the principles of colour correction set forth hereinbefore. For example, it is apparent that the control signals

A and $\bar{A}$ may not be exactly as described above and that switching elements may be substituted for the diodes 78, 80 and 82 and 90, 92 and 94 of Fig. 3.

Also, it is apparent that the invention may be practiced in connection with a colour cor-

rection circuit wherein the integrating capacitors are charged directly from the current generated by the photosensitive devices.

As may be seen a novel system has been disclosed for automatically and continuously varying the degree of colour correction from a low colour correction mode to a high colour correction mode in response to the detected degree of illuminant failure of the negative to be printed thus increasing the effective speed of automatic printers and reducing the number of unsatisfactory prints.

WHAT WE CLAIM IS:—

1. Exposure control means for a photographic colour printer, the exposure control means being responsive to the intensities of light of at least two different wavelengths in the printing beam to establish the exposure time periods to light of the said wavelengths, and the exposure control means being adapted to adjust the exposure time periods to provide either a high or a low degree of colour correction in the printing beam, and including means for producing a control signal or signals having a periodic waveform of first and second amplitudes, the durations at the first and second amplitudes being determined by the said intensities and being indicative of the proportion of each exposure cycle in which high or low colour correction is required, and means responsive to the control signal or signals for adjusting the exposure time period to provide the degree of colour correction indicated by the control signal or signals.

2. Exposure control means as claimed in Claim 1, wherein the means for producing the control signal or signals is arranged to produce first and second control signals of complementary wave form having first and second amplitudes respectively, the means responsive to the control signal or signals being arranged to provide a high or a low degree of colour corrections in response to the first and second amplitudes respectively.

3. Exposure control means as claimed in Claim 2, including first and second means for respectively halting the exposure of photographic print material to light of first and second wavelengths in the printing beam after first and second exposure time periods respectively; means responsive to the intensities of light of the first and second wavelengths in the printing beam for producing first and second signals each having a magnitude dependent upon the respective intensities of light of the first and second wavelengths; and means responsive to the first and second signals for establishing the said first and second exposure time periods, this signal responsive means comprising means for detecting an imbalance in the magnitudes of the first and second signals and, responsive to the detected imbalance, for producing a

third signal having a magnitude related to the degree of imbalance, means responsive to the third signal for producing the said first and second control signals having first and second complementary, periodic, wave forms of first and second amplitudes, the duration of the first amplitudes of the wave forms if the first and second control signals being dependent upon the magnitude of the third signal, means responsive to the first amplitude of the wave form of the first control signal for determining said first and second exposure time periods as a function of the combined magnitudes of the first and second signals, and means responsive to the first amplitude of the wave form of the second control signal for independently determining said first and second exposure time periods from the magnitudes of the first and second signal, respectively.

4. Exposure control means as claimed in Claim 3 wherein the said first and second means further comprise first and second timing circuits, respectively, each having an input terminal and an output terminal and adapted to produce a first and second respective exposure terminating signal at each respective output terminal after first and second exposure time periods determined as a function of the magnitudes of the signals applied to the input terminals.

5. Exposure control means as claimed in Claim 4, wherein the said means responsive to the first amplitude of the wave form of the first control signal comprises a first plurality of signal conducting circuits adapted to be connected, in response to the first amplitude of the first control signal, between the said means responsive to the intensities of the first and second wavelengths and each respective input terminal of the said timing circuits to separately apply the first signal to the timing circuit of the said first means and the second signal to the timing circuit of the said second means; and wherein the said means responsive to the first amplitude of the wave form of the second control signal comprises a further plurality of signal conducting circuits adapted to be connected, in response to the first amplitude of the second control signal, between the said means responsive to the intensities of the first and second wavelengths and every one of the input terminals of the said timing circuits to apply the first and second signals simultaneously to the timing circuits of first and second means.

6. Exposure control means as claimed in Claim 5 wherein the said timing circuits of said first and second means, for the duration at the first amplitude of said first control signal, determine said first and second exposure time periods as a function of the magnitudes of said first and second signals; and the said timing circuits of said first and

second means, for the duration at the first amplitude of the second control signal, determine said first and second exposure time periods as a function of the combined magnitudes of the first and second signals.

7. Exposure control apparatus as claimed in Claims 4, 5 or 6, including actuator means for controlling the individual insertion of subtractive filters in the printing beam corresponding to the said wavelengths, the actuator means being arranged to be energised by the said timing circuits.

8. Exposure control means as claimed in Claim 1, comprising at least three subtractive filters, photosensors corresponding to each of said filters and responsive to light of a different wavelength in the printing beam of said printer for producing three photocurrent signals, actuator means for controlling the individual movement of each of said filters into said printing beam, and timing means associated with each of the three subtractive colour filters for determining the printing time prior to insertion of said filters into the printing beam in response to said photocurrent signals comprising: at least three respective high colour correction circuit means responsive to each individual photocurrent signal for determining the printing time of each respective wavelength of light in the printing beam of the photographic printer; at least three low colour correction circuit means responsive to each of said photocurrent signals for determining a single printing time for all of the wavelengths of light in said printing beam; means responsive to an imbalance between the amplitudes of the photocurrent signals for determining the exposure time periods by either said high colour correction circuit means or said low colour correction circuit means, respectively; the said photocurrent signal responsive means being responsive to the amplitude of the photocurrent signals to produce a first and a second control signal having periodic complementary wave forms, each wave form having a first and a second amplitude, the first amplitude being dependent upon the relationship between the amplitudes of the photocurrent signals; the said high colour correction circuit means being responsive to the first amplitude of the first control signal to couple said three photocurrent signals individually to said three timing means so that the printing time of each of said wavelengths in the printing beam is dependent upon the amplitudes of each photocurrent and the duration at the first amplitude of the first control signal; and the said three low colour correction circuit means being responsive to the first amplitude of the second control signal for coupling each of said photocurrent signals to every one of said timing means so that said single printing time of said wavelengths in said printing beam is dependent upon an average



of the amplitudes of all of said photocurrent signals and the duration at the first amplitude of the second control signal.

- 5 9. Apparatus as claimed in Claim 8 wherein said three subtractive filters are operative to absorb red, green and blue light, respectively, in said printing beam and said photo-sensor means are responsive to the intensity of the red, green and blue light, respectively, in the printing beam to produce said three
10 photocurrent signals each having an amplitude dependent upon each respective intensity of light, and wherein said photocurrent signal responsive means further comprises first
15 means responsive to the difference between the amplitudes of the red and green photocurrent signals for producing a first difference signal having a first difference amplitude; second means responsive to the difference in the amplitudes of the green and blue photocurrent
20 signals for producing a second difference sig-

nal having a second difference amplitude; third means for establishing a first reference signal having a reference period; and means responsive to the lower amplitude of the first and second difference signals and the period of the first reference signal for producing said first and second control signals having complementary, periodic, wave forms, the periods of which are equal to the period of the reference signal.

10. A photographic colour printer incorporating exposure control means as claimed in any preceding claim.

11. Exposure control means for a photographic colour printer substantially as hereinbefore described with reference to Fig. 3 of the accompanying drawings.

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