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[54] **ELECTRONIC COMPOSITE PHOTOGRAPHY**
16 Claims, 2 Drawing Figs.

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[50] Field of Search .... 178/6 ST, 6 DIG. 6, 5.2, 5.4, 6.7 R, 5.4 CR, 5.2 D; 352/131; 355/4, 5, 7

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ABSTRACT: Separate foreground and background scenes are combined to form a composite color television picture or color motion picture film by electronic manipulation of respective sets of color component video signals, one set representing the foreground scene with an illuminated backing, typically blue, and the other set representing the background scene. Blue from the foreground backing is eliminated from the composite picture by electronically limiting the foreground blue signal to a selected function of the green signal. Portions of the background that are covered by foreground objects are eliminated in the composite picture by gating the background video signals under control of color discriminating circuitry which compares the foreground blue and green (or red) color component signals. Both the discriminating circuits and the gating circuits act proportionally, so that partially transparent objects of the foreground are correctly distinguished, making the background scene partially visible through such objects in the composite picture.

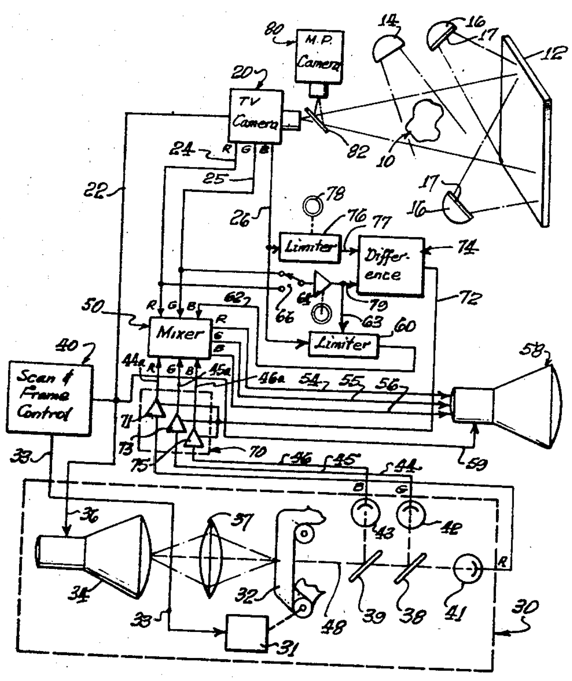


FIG. 1.

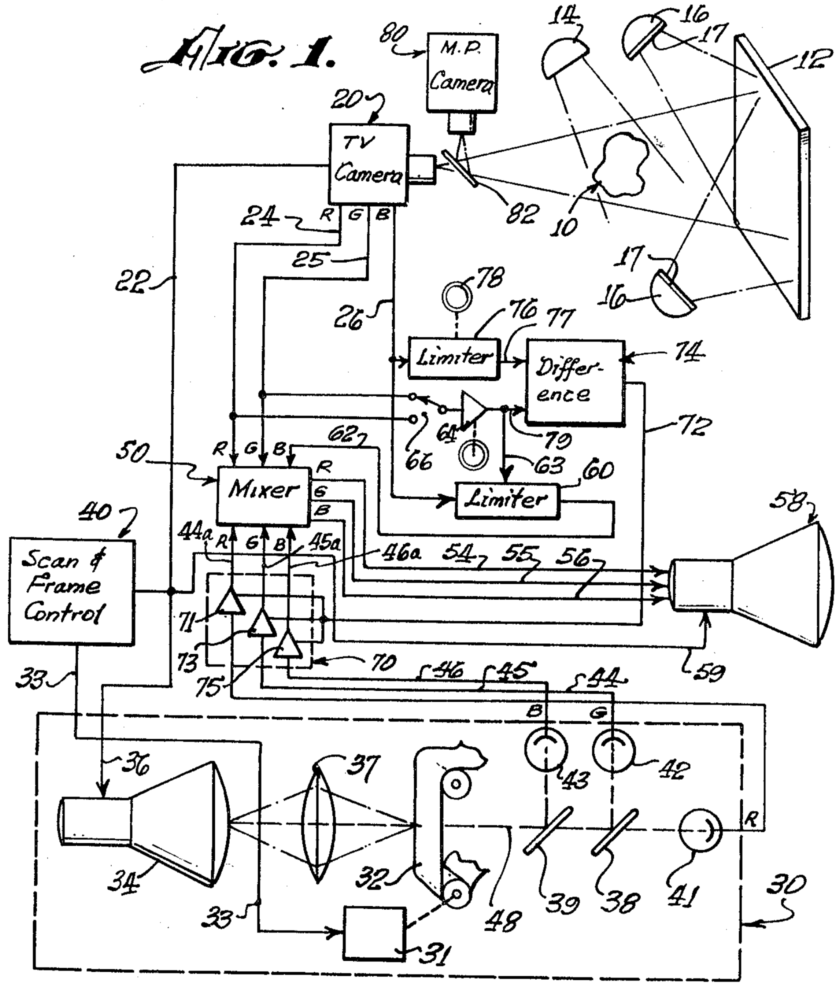
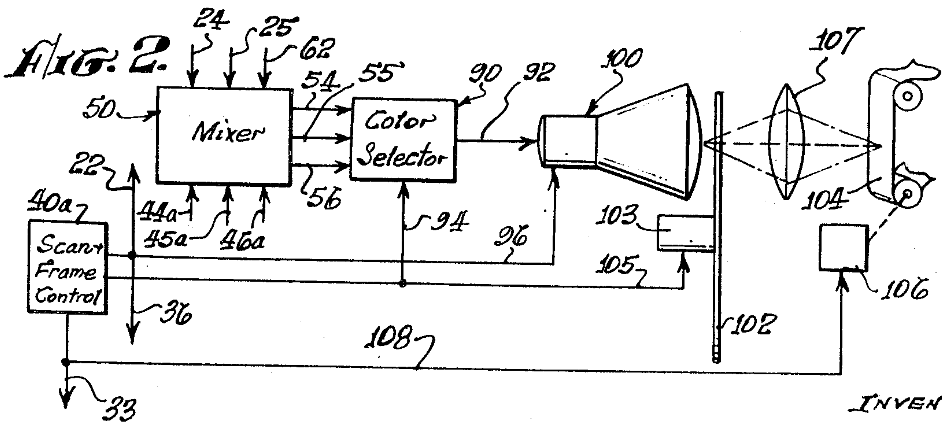


FIG. 2.



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ELECTRONIC COMPOSITE PHOTOGRAPHY

This invention has to do with electronic methods and apparatus by which a foreground scene and a background scene may be separately recorded and then combined to form a composite picture in which objects of the foreground appear superposed over objects of the background.

For convenience of description the abbreviations BG and FIG. will be used in referring to "background" and "foreground."

A particular object of the invention is to permit objects of both FG and BG scenes to be portrayed in full color, with special attention to accuracy of reproduction of such delicate colors as normally occur in flesh tones and eyes.

A further object of the invention is to permit BG objects to be seen to a realistic extent through objects of the FG that are partially or wholly transparent, and to achieve a normal degree of seethrough for such special situations as FG objects that are out of focus or blurred by rapid motion.

Whereas the invention is particularly useful in connection with television or motion picture scenes involving movement, and in connection with color reproduction, many aspects of the invention are useful for still pictures and for producing composite pictures in black and white or in partial color.

In purely photographic processes of composite photography, areas of the BG scene that are occupied by FG objects are blocked out by printing the BG through a specially prepared matte, which is referred to as a traveling matte when motion pictures are involved. In the electronic system no such physical matte is employed, but a suitable alternative capability must be provided by which the system can recognize for every spot of the picture whether the video signal should correspond to the FG or BG component.

For that purpose, the present invention utilizes the conventional procedure of arranging the objects of the FG scene before a backing of a distinctive color. FG objects are then distinguished from the colored backing by suitable comparison of the electronic color component video signals, such as are developed directly by a television color camera, for example. Those color component signals normally correspond to the colors blue, green and red, characterized typically by the respective wavelength regions of 400 to 500, 500 to 600 and 600 to 700 millimicrons, and the color component signals then represent directly the relative blue, green and red light values of the scene. Such signals for the FG and BG scenes may be developed directly from the natural scenes, as by use of television cameras or equivalent apparatus. Alternatively, the video color component signals for one or both of the picture components may be derived from a previously prepared record of the FG or BG scene. Such a record may comprise a photographic record such as a conventional motion picture film, or may comprise a video tape in which the color information has the form of a chrominance signal.

The color of the illuminated backing for the FG scene is typically restricted to one of the wavelength regions represented by the color component signals. In theory, and under special circumstances in practice, any of those component colors may be used as backing for the FG scene. However, blue is ordinarily the most practical backing color. That is because the selected backing color should not ordinarily be used in pure form in the FG scene itself; and since a saturated blue is rarely found in nature, its avoidance in the FG scene does not impose a serious limitation. Accordingly, for the sake of clarity the present description will be based on the use of blue as backing, with the understanding that other colors may be preferred under special circumstances.

The present invention provides discrimination circuitry that is typically responsive to the blue and green components of the light received from the foreground scene and that develops a control signal representing the extent to which that light was derived from the blue backing. That control signal is then employed to control the relative proportions in which the foreground and background video signals are mixed to produce the composite picture.

An important feature of the invention is that the resulting switching or gating action is preferably not a simple on-off action, but is proportional in its nature, and is thus capable of reproducing correctly partially transparent areas of the FG scene through which the BG scene is partially visible. Such proportional gating of the picture components is made possible by utilizing discriminating circuits responsive to a plurality of color component video signals, rather than attempting to distinguish between FG and BG areas of the picture on the basis of the single chrominance signal, as has been previously proposed.

The video signals representing the BG scene are proportionally gated under control of a signal that typically represents the excess of the blue light over a specified function of the green light received from the FG scene. That gating reduces the BG signals to zero when the FG blue light does not exceed that function and transmits the full BG signals when the FG blue has its maximum value, corresponding to an area of the illuminated blue backing. The gating of the FG color signals typically acts only on the blue signal, and is essentially a clipping action, limiting the blue FG signal to a value no larger than a specified function of the green FG signal.

A composite picture produced by the present invention may have the form of a video signal suitable for television broadcasting or for video tape recording, or may be recorded on photographic film such as a motion picture film suitable for conventional optical projection. Such production of composite motion picture films by electronic procedures is practicable only if the process is capable of correct reproduction of partially transparent areas of the FG scene. Such areas occur in motion pictures not only from presence of inherently transparent objects, such as glassware, smoke and wisps of hair, but also from edges of opaque objects that are blurred by movement. Since the present process can handle such areas properly, it can take the place of known photographic processes for producing composite motion pictures from separate FG and BG scenes.

When so used for motion picture composite photography, the present invention permits greater speed of operation and far greater flexibility of control than the previously known photographic processes. Whereas purely photographic traveling matte processes require more than one day to produce a composite film, the present electronic process can produce a completed film for viewing the next day.

The present invention further permits a motion picture director to observe on a television monitor a composite picture of the FG and BG scenes during photography of the FG scene. For example, the FG scene that is before the motion picture camera can be picked up also by a television camera and combined electronically with a BG scene that is introduced from an existing film. The composite picture on the monitor then permits the director to locate the FG action and lighting to match elements in the BG scene.

A full understanding of the invention, and of its further objects and advantages, will be had from the following description of certain illustrative manners in which it may be carried out. The particulars of that description, and of the accompanying drawings which form a part of it, are intended only as illustration and not as a limitation upon its scope, which is defined in the appended claims.

In the drawings:

FIG. 1 is a schematic block diagram representing an illustrative system for carrying out the invention; and

FIG. 2 is a schematic block diagram corresponding to a portion of FIG. 1 and representing a modification.

As illustratively represented in FIG. 1, the FG scene 10 is arranged before the illuminated backing 12 and is recorded by the television camera represented at 20. The FG scene is typically illuminated in conventional manner, as by the lamp 14. That lamp requires no special filtering, and may be of any type called for by the color reproduction process that is employed.

Backing **12** may be illuminated in many different ways, depending upon its nature. If the backing material is a painted canvas having a reflectivity limited to the blue region of the spectrum, it may be illuminated by the same lamps as the FG objects, though additional light is usually desirable. If the backing is a white opaque surface it may be placed out of the range of FG lamps **14** and be lighted by special lamps, such as those shown at **16**, which are provided with the blue filters **17** or otherwise constructed to emit only blue light. Alternatively, the backing may be of translucent material and be illuminated from the rear, with the color limited to blue by use of either blue material or blue lamps or both.

Television camera **20** may be of any conventional type which scans the FG scene and its backing under control of a synchronizing signal received over the line **22** from the control unit **40**, and which produces on the lines **24**, **25** and **26** respective video signals corresponding to the red, green and blue color components of the scene, designated R, G and B.

As represented in FIG. **1**, the BG scene is illustratively provided in the form of a motion picture film **32**. That film is advanced intermittently by known mechanism indicated at **31** in response to suitably timed signals received over the line **33** from control unit **40**. Each frame of film **32** is scanned in synchronism with the FG scanning action of camera **20**, as by the flying spot scanner represented in simplified and schematic form at **30**. Flying spot scanner **30** typically comprises the cathode ray tube (CRT) **34** with deflection means, not explicitly shown, for causing a spot of light to scan an area on the face of the tube under control of a synchronizing signal received over the line **36**. That signal is developed by control unit **40** in suitable time relation to the similar scanning control signal delivered to camera **20**. Those two control signals are represented in FIG. **1** as being supplied by a common line to emphasize their common time relation, but in practice distinct signals may be developed and employed for control of different scanning devices. The "flying spot" on the face of CRT **34** is focused onto a frame of film **32** by the lens **37**, so that the transmitted light **48** is modified in accordance with the color and density of the BG scene at the rapidly shifting illuminated spot. The transmitted light **48** is separated in known manner by the dichroic mirrors **38** and **39** into red, green and blue color components, which are directed to the respective light sensor **41**, **42** and **43**, represented as photocells. The respective photocell outputs on the lines **44**, **45** and **46** are video signals representing the red, green and blue color components of the BG scene and designated R, G and B. Those signals correspond directly to the FG component video signals on lines **24**, **25** and **26**, already described. That is, at any instant the FG component video signals and the BG component video signals are derived from directly corresponding points of the FG scene and of the BG scene, respectively.

The color component signals for the FG and BG scenes are mixed in the mixer **50**, to produce on the output lines **54**, **55** and **56** color component signals for the desired composite picture. The resulting composite picture can then be displayed, for example, by means of a three color cathode ray tube **58** in which the beam scanning is synchronized with that in camera **20** and CRT **34** by means of suitable synchronizing signals supplied via the line **59** from control unit **40**. In accordance with the present invention, the separate FG and BG color component signals are suitably modified in intensity, before being supplied to mixer **50**, in such a way as to make each point of the resulting composite picture correspond properly to either the FG or the BG scenc, or to a properly weighted combination of both. That signal modification thus performs fundamentally a selection function, and will be referred to for convenience as a "gating action." However, the present gating action is preferably quite different from the crude switching that is sometimes associated with that terms. The gating action of the present invention is carried out under control of color discriminating circuits which operate in response to color component signals for the FG scene only.

As illustratively shown in FIG. **1**, the red and green component signals for the FG scene are transmitted directly via the respective lines **24** and **25** to mixer **20**. The blue component signal is modified by circuitry indicated schematically at **60**, which receives the blue signal from line **26** and delivers the modified blue signal via the line **62** to mixer **50**. Circuitry **60** acts under control of an input control signal, received via the line **63**, which may be derived via the amplifier **64** from either the green or the red FG signal, according to the position of the switch **66**. For normal FG scenes switch **66** is ordinarily maintained in the position shown, supplying the green component signal from line **25** for control of circuit **60**, and that position will be assumed for clarity of description. The function of circuit **60** is then essentially to apply the green component signal as a floating peak limiter or clipper upon the blue signal. If the blue signal is equal to or less than the limiting threshold, it is transmitted without modification to output line **62** and mixer **50**.

The limiting threshold thus imposed by circuit **60** upon the FG blue signal may directly equal the green signal. However, it is ordinarily preferred to introduce biasing circuitry such that the permitted maximum value of the blue signal increases somewhat faster than the green control signal, typically corresponding approximately to the product of the green signal and a factor that exceeds unity by a selected fraction, typically of the order of 20 percent. Such a bias may be introduced in any suitable manner, as by the amplifier **64** which has a gain M that is preferably variable, as indicated by the control **65**. Variation of M from unity to about 1.5 is sufficient for most scenes. Limiter **60** then limits the blue FG signal reaching mixer **50** to a maximum value equal to the green signal multiplied by M.

A primary result of that limitation of the FG blue signal is to prevent any contribution to mixer **50** from the FG scene when the scanning action of camera **20** is confined to the blue backing **12**. When camera **20** is receiving only blue light, the green and red component signals are necessarily zero. Though the blue signal on line **26** is large, it is reduced to zero by the described limiting action of circuit **60**.

On the other hand, when camera **20** is scanning a FG object, the described limitation of the blue component ordinarily has no effect upon the reproduction of normally occurring FG colors. The exceptional effects that do occur, especially at semitransparent areas of the FG scene, are discussed more fully below.

The gating of the BG scene is carried out in FIG. **1** by circuitry indicated schematically at **70**, acting under control of a control signal E_c supplied via the line **72**. That control signal is developed by color discriminating circuitry represented at **74**, which receives the blue FG signal from line **26** via the limiter **76** and the line **77**, and receives a reference signal from the line **79**. That reference signal is typically the same as the control signal for limiter **60**, already described, being derived via amplifier **64** from either the green or the red FG signal, depending upon the position of switch **66**.

Circuit **74** is typically a different amplifier, and its output signal E_c on line **72** represents essentially the excess of the blue FG signal the output is zero. The input blue signal, however, is preferably first limited by variable limiter **76** to a value that will be denoted by B_o and that is adjustable at **78**. B_o is made no larger than the value corresponding the least brightly illuminated portion of backing **12**. It is then immaterial whether the backing is lighted with strict uniformity, so long as all areas received at least the selected threshold intensity. As a matter of fact, B_o is ordinarily set at the level corresponding to the maximum illumination of the FG objects, for reasons that will appear.

Whenever camera **20** or its equivalent is scanning the backing, the reference signal on line **79** is essentially zero. Control signal E_c then represents the full value of the input blue signal, corresponding to the threshold or minimum illumination of backing **12**. If camera **20** scans a FG object, control signal E_c is ordinarily sharply reduced for two reasons.

First, the blue content of the FG object is normally far less than the described threshold illumination of the blue backing. Secondly, most FG objects have an appreciable green content, so that the reference signal on line **79** is appreciable. Subtraction of that reference signal from the input blue signal further reduces the value of E_c. In fact, for all ordinary opaque FG objects the green content (especially after amplification at **64**) equals or exceeds the blue content, so that the output control signal is zero. Special cases, including transparent or partially transparent FG objects, are discussed more fully below.

Gating circuit **70** for the BG scene comprises essentially three variable gain amplifiers **71**, **73** and **75** for the respective color components. Each amplifier receives one of the BG color component signals on the line **44**, **45** or **46** and delivers the modified signal to mixer **50** via the corresponding line **44a**, **45a** or **46a**. Each amplifier also receives the control signal E_c from line **72** and responds by amplifying its BG color component signal with a gain substantially proportional to E_c. Thus, when E_c is zero the amplifiers of circuit **70** act as open switches, and mixer **50** receives no input corresponding to the BG scene. On the other hand, when the control signal has its maximum value, corresponding to the described threshold illumination of backing **10**, the BG signals are transmitted with full normal amplitude to mixer **50**. For intermediate values of the control signal, corresponding primarily to partially transparent objects of the FG scene, the BG color component signals are uniformly attenuated and contribute to mixer **50** only an appropriate fraction of the BG brightness sensed by BG scanner **30**.

In describing more fully the operation of the system of FIG. **1**, it will first be assumed that the colors blue and magenta do not occur in the objects of the FG scene. Magenta is defined as blue plus red, with little or no green content. With that assumption all FG colors have a blue content that is equal to or less than the green content. Thus, for all grey scale objects from black to white the blue and green contents are equal. The color cyan includes equal amounts of blue and green with little or no red. In the case of red, yellow, green, gold, copper and flesh tones the blue content is less than the green content.

For all such colors, biasing amplifier **64** can be set to a gain of unity. Limiter **60** then transmits to mixer **50** only so much of the input blue signal from line **26** as equals the green signal from line **25**. That does not affect the color of opaque FG objects, since their blue content has been assumed not to exceed the green content.

Also, control signal E_c then directly equals B_o—G, where B_o represents the output from limiter **76**, and G represents the green component signal on line **25**. That control signal distinguishes effectively between points of the blue backing and points of the FG scene itself. At any point of the backing the control signal has the full value B_o, while for any opaque object of the FG scene the control signal is zero, since the blue content has been assumed not to exceed the green content. Hence for such objects, the BG gating action of circuit **70** essentially switches the BG color signals between full transmission to mixer **50** when backing **10** is being scanned, and full suppression when a FG object is being scanned. Thus there is zero superposition of the BG scene on any opaque object of the FG scene, zero veiling of the BG scene by blue derived from backing **10**, and fully correct color reproduction of both the FG and BG objects.

With the same assumptions as to FG colors, the present system reproduces correctly most objects of the FG that are partially transparent, or are blurred by motion, which causes essentially the same effect as partial transparency of a stationary object. For example, a fully illuminated white FG object that is 50 percent transparent will reflect equal amounts of blue, green and red, but only at half the intensity that would result from an opaque white object. The green and red component signals from such an object are therefore half the normal maximum. The blue component signal has the full maximum value, half resulting from blue light reflected by the object, and half resulting from blue light from the backing, transmitted to the extent of 50 percent by the object. That blue signal is reduced by limiter **60** to the same level as the green signal, so that the total contribution from the FG scene to mixer **50** represents white light at the intensity actually reflected by the object. The BG color signals are also reduced by 50 percent, since control signal E_c=B_o—G has half its maximum value. That result follows from setting of limiter **76** to make B_o equal to the full normal blue reflection from an opaque white FG object, which makes the green reflection G from the present partially transparent object equal to half of B_o. The output of mixer **50** therefore correctly represents equal contributions from the FG and BG scenes.

A corresponding analysis shows that the system gives correct reproduction also for other degrees of transparency than 50 percent, and for all FG colors having an equal blue and green content. Such colors include not only the grey scale but also red, flesh tones, pinks and cyan. However, if the FG includes a color having a blue content much less than the green content, such as a highly saturated green or yellow, such colors will be somewhat distorted if they occur on transparent objects or at edges that are blurred by motion. For example, a green FG object with 50 percent transparency due to movement will reproduce as a rather dark cyan. At the blurred area the blue signal will correspond to half the brightness of the backing, seen through the moving object, and the green signal will also have half its normal value, producing cyan. The BG scene will not appear through that blurred edge, since the equal blue and green FG signals produce a BG control signal E_c=0. Fortunately, highly saturated colors, such as bright green and yellow, rarely occur in foreground objects and are ordinarily avoided as much as possible because of a tendency to appear fluorescent and unrealistic. Moreover, the described color distortion applies only to partially transparent objects or to edges that are blurred by motion. Since motion is usually transient the effect is not easily noticed. No corresponding distortion results, of course, if bright green or yellow occurs in the BG scene behind a blurred edge of a FG object of normal color.

The assumption made above that the FG objects contain no blue colors is not always feasible. Of particular significance are pastel blues, as in blue eyes. Such shades of blue are highly unsaturated, including a large content of white, and hence including green and red in appreciable and approximately equal amounts. The blue content of such pastel blues typically exceeds the green content by a factor of the order of 5 percent to 25 percent. All colors having that property are accommodated, in accordance with the present invention, by suitable biasing of the control circuits.

That biasing is typically represented in FIG. **1** by the biasing amplifier **64**, which boosts the green signal relatively to the blue signal at the input both to limiter **60** of the FG control circuit and to difference circuit **74** of the BG control circuit. Considering first the FG control, the biasing action increases the level at which the blue signal is clipped by limiter **60** by the factor M, from the level of the green signal to M times that level, where M represents the gain of amplifier **64**. If M=1.25, for example, a FG color containing 25 percent more blue than green will still be correctly reproduced, since limiter **60** will transmit the blue signal without reduction to mixer **50**. Yet during scanning of blue backing **12** the resulting large blue signal is still reduced to zero by limiter **60**, since the absence of any green light from the backing makes the clipping level zero. Since the described biasing action is independent of the red content, it provides correct reproduction of such colors as low saturated magenta which combine red with the described mutual proportions of blue and green.

Turning now to the gating of the BG scene, when biasing amplifier **64** is set for a gain of 1.25, as just described, difference circuit **74** produces a BG control signal E_c equal to the excess of the blue signal over 1.25 times the green signal. Hence E_c is zero for a light blue FG object, as well as for all other colors having a blue content no greater than 1.25 times the green content. Therefore such FG colors are reproduced without any superposition of light from the BG scene.

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