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Oelmayer et al.

[11] **3,783,275**

[45] **Jan. 1, 1974**

[54] **APPARATUS FOR THE OPTICAL-ELECTRICAL SCANNING OF A DRAWING HAVING A LARGE NUMBER OF POINTS OF DIFFERENT COLORS**

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[52] **U.S. Cl.** **250/226,** 250/208, 307/235

[51] **Int. Cl.** **G01j 3/34**

[58] **Field of Search** 250/226, 235, 222, 250/209, 208; 88/14; 307/290, 235; 356/173

[56] **References Cited**

UNITED STATES PATENTS

3,578,976	5/1971	Schunack	250/226
3,527,540	9/1970	Bowker	250/226
3,389,265	6/1968	Schreckendgust	250/226
3,003,388	10/1961	Hunter et al.	250/226

OTHER PUBLICATIONS

"Low Cost Schmitt-Trigger made with Digital IC" by Francis et al. Electronics Mar. 4, 1968 p. 88.

"Level Detector . . . . Point" Electronic Design, Oct. 11, 1967 p. 98.

Primary Examiner—Harold A. Dixon
Attorney—John Lezdey et al.

[57] **ABSTRACT**

Apparatus for scanning a drawing consisting of a large number of points each of which is of a colour selected from a number of colours, and for converting the information obtained by scanning the points into colour signals characteristic of the individual colours, comprising a scanning head movable relative to the drawing having a number of optical electrical scanning elements each responding to a definite spectral range and colour discriminators connected to the scanning head for producing a respective colour signal only when the analogous output signals of all the scanning elements associated with it, or signals derived from the said output signals, lie within an upwardly and downwardly limited tolerance range.

20 Claims, 7 Drawing Figures

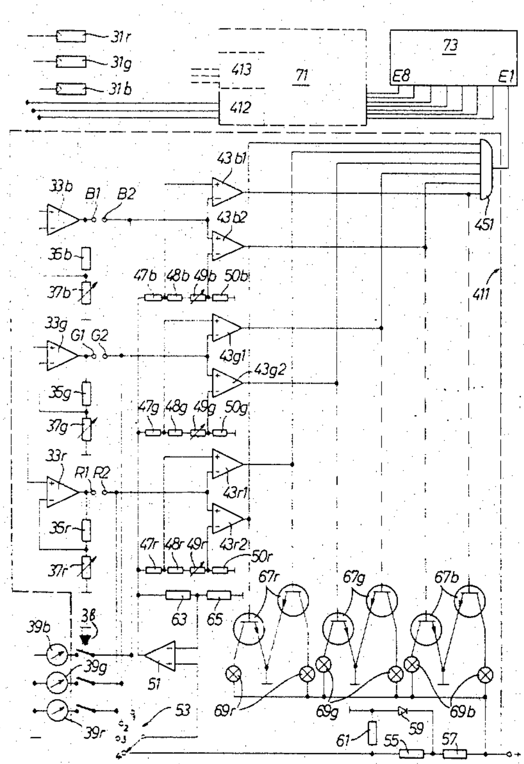

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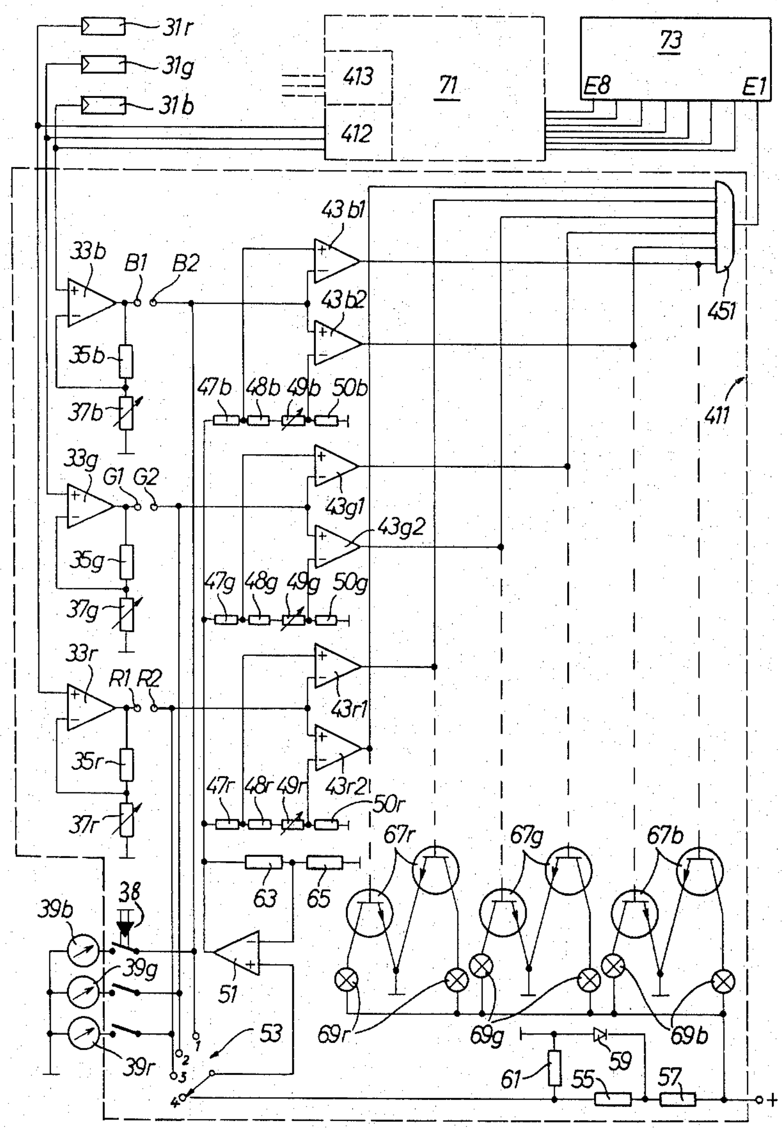
FIG. 1



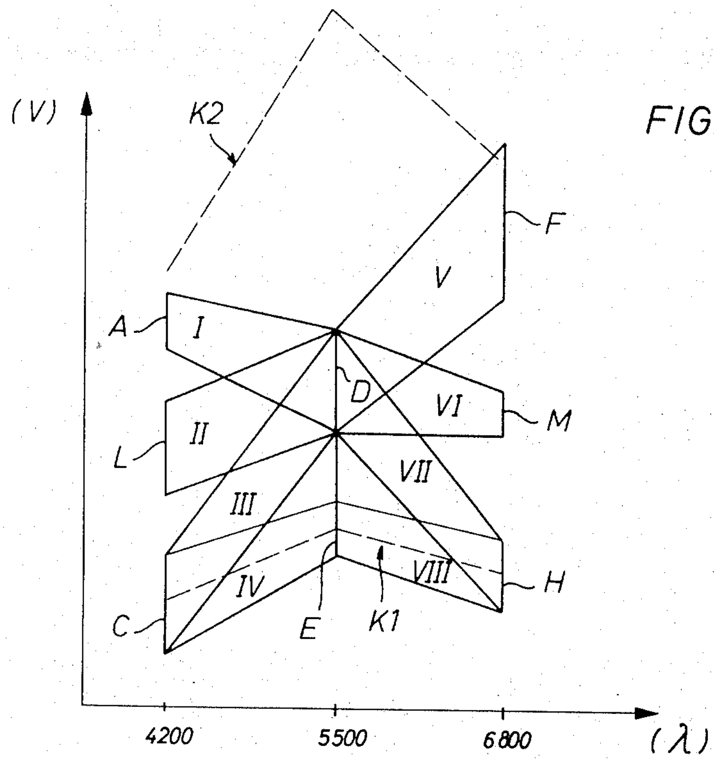

(V)
K2
A
I
L
II
III
C
IV
E
D
V
F
VI
M
VII
VIII
H
K1
4200
5500
6800
(λ)

FIG. 2

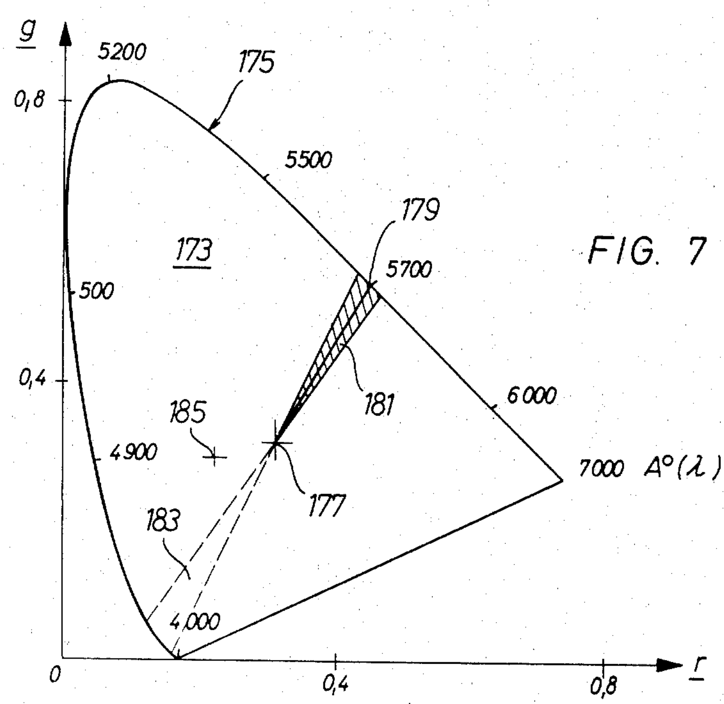
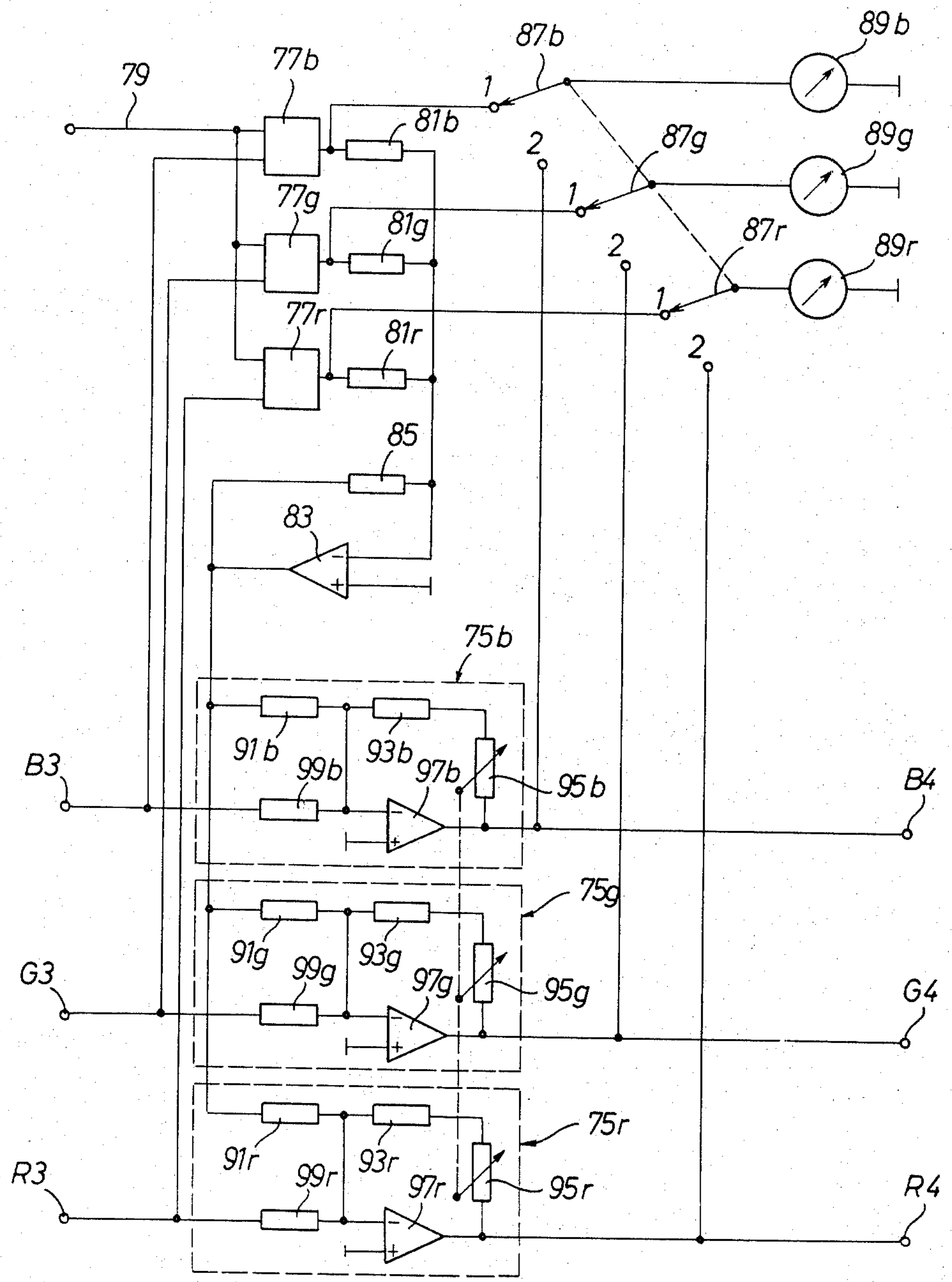

g
5200
0,8
175
5500
179
5700
173
500
0,4
6000
181
185
4900
177
7000 A°(λ)
183
4000
0
0,4
0,8
r

FIG. 7

FIG. 3


79
77b
87b
89b
81b
2
1
87g
89g
77g
81g
1
2
87r
89r
77r
81r
1
2
85
83
75b
91b
93b
B3
99b
97b
95b
B4
75g
91g
93g
G3
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95g
G4
75r
91r
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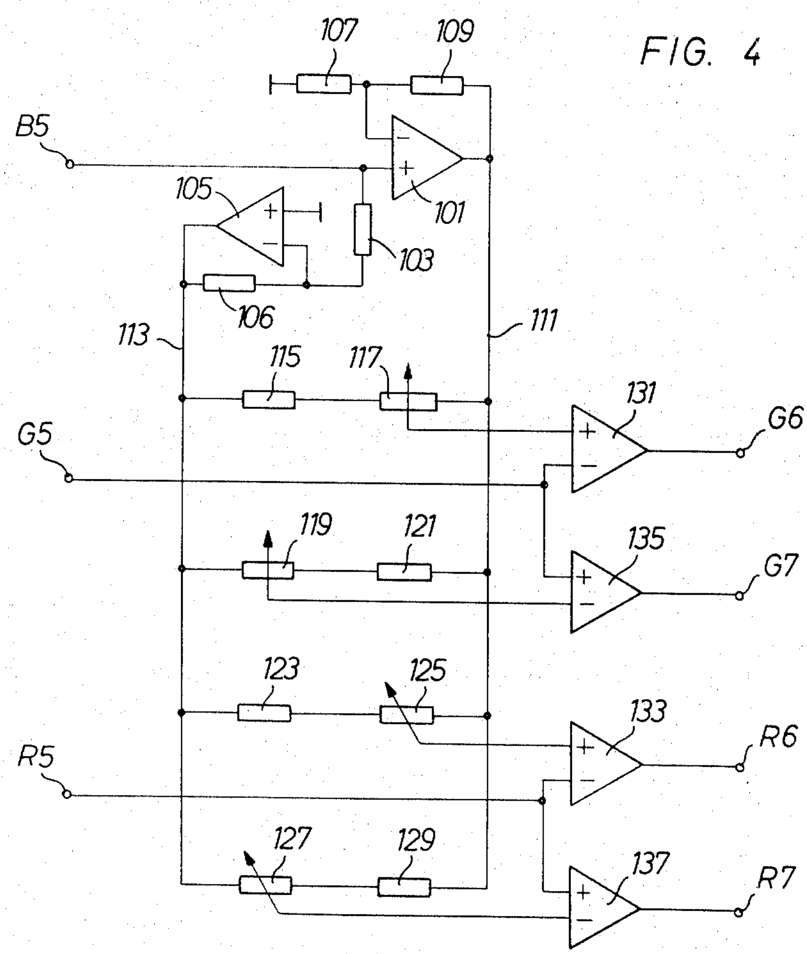
R3
99r
97r
95r
R4

FIG. 4


107
109
B5
105
101
103
106
113
111
115
117
131
G6
G5
119
121
135
G7
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133
R6
R5
127
129
137
R7

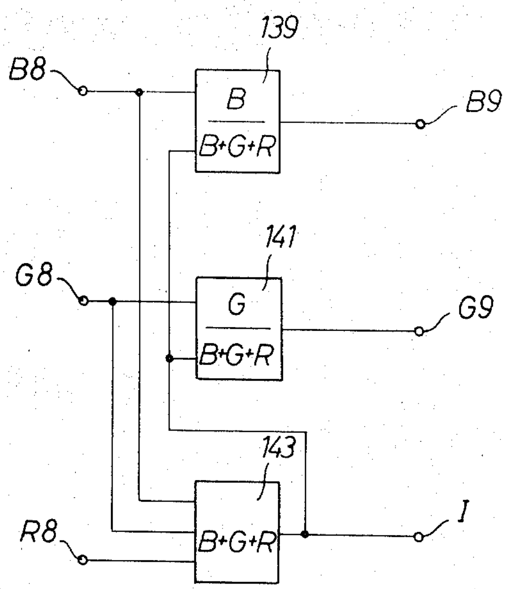
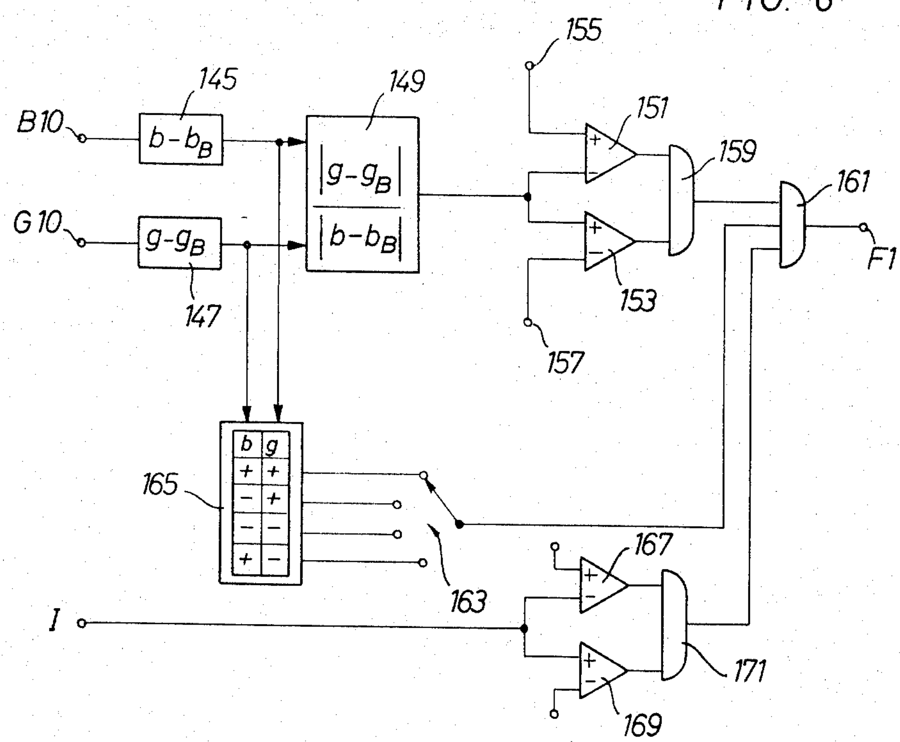

139
B8
B
B+G+R
B9
141
G8
G
B+G+R
G9
143
R8
B+G+R
I

FIG. 5

FIG. 6


155
145
149
151
B10
b-b_B
159
161
G10
g-g_B
153
F1
147
157
165
b g
+ +
− +
− −
+ −
167
163
I
171
169

APPARATUS FOR THE OPTICAL-ELECTRICAL SCANNING OF A DRAWING HAVING A LARGE NUMBER OF POINTS OF DIFFERENT COLORS

The invention concerns apparatus for the optical-electrical scanning of a drawing consisting of a large number of points each of which is of a colour selected from a number of colours, and for the conversion of the information obtained by scanning the points into electrical colour signals characteristic of the individual colours.

Apparatus of this kind is known for example from British Pat. specifications Nos. 1,170,947 and 1,190,600, and comprises a scanning head movable relative to the drawing and having a number of optical-electrical scanning elements, each responsive to a definite spectral range, and which are followed by colour discriminators for the production of a respective colour signal.

A serious disadvantage of such apparatus is that for producing the drawing only very definite colours may be used in order to permit clear and reproducible recognition of these colours. Also when the quality of the colour applied to the drawing paper fluctuates considerably or when, owing to poor covering power of the colour, the generally white colour of the drawing paper shows through with varying intensity the apparatus is liable to operate incorrectly. It is in fact also already known from British Pat. specification No. 1,190,600 to eliminate partly by dynamic regulation the errors caused by fluctuations in the illumination intensity and/or the distance of the scanning head or the source of light from the drawing being scanned, but the number of usable colours is not thereby increased.

In the known apparatus, the scanning head comprises for example three phototransistors, in front of each of which is placed a respective colour filter (for example blue, green and red) and each of which is followed by an amplifier. By adjusting the threshold value of these amplifiers, it is possible, if definite colours are used (for example blue, green and red), to ensure that in scanning these colours only one of the amplifiers delivers an output signal and thus produces a definite colour signal. In the use of a number of similar colours (for example two different red colours), however, difficulties occur because the reflection or transmission maxima of the two similar colours may overlap, depending on the colour application and colour covering power, in such a manner that satisfactory recognition of the two colours is no longer possible. The same difficulties arise if, for example, the colours blue, green, red, turquoise, violet and yellow are used, because in this case, it is necessary to ensure that the so-called mixed colours turquoise, violet and yellow have high reflection or transmission factors just where two of the individual colours blue, green or red have a maximum.

Limitation to only a few colours is undesirable because, on the one hand, the known apparatus is required for example in the knitting and weaving arts, to prepare control strips for the electronic control of knitting or weaving machines by means of which goods are made, having a pattern identical with the scanned drawing and as multicoloured as possible, and because, on the other hand, the patterns drawn by the designer in the special colours frequently give quite a different impression from the finished knitted or woven goods, whose colours only in seldom cases agree with the colours required for the drawing.

According to this invention there is provided apparatus for scanning a drawing consisting of a large number of points each of which is of a colour selected from a number of colours, and for converting the information obtained by scanning the points into colour signals characteristic of the individual colours, comprising a scanning head movable relative to the drawing having a number of optical-electrical scanning elements each responding to a definite spectral range and colour discriminators connected to the scanning head for producing a respective colour signal only when the analogous output signals of all the scanning elements associated with it, or signals derived from the said output signals, lie within an upwardly and downwardly limited tolerance range. The tolerance ranges are preferably upwardly and downwardly adjustable.

The invention provides the important advantage that any two colours can be differentiated from each other by means of a single scanning element if their tolerance ranges do not overlap. For increasing the accuracy, reproducibility and number of the colours used, however, for scanning each one colour there are used for example three scanning elements each having three associated tolerance ranges, so that each colour is recognised when the output signals of the three scanning elements lie in the three fixed tolerance ranges. It is sufficient, therefore, if the output signals of at least one scanning element are associated with different tolerance ranges.

In an advantageous embodiment of the invention, the scanning elements are followed by subtracting circuits for forming differential signals, the differential signals resulting from the subtraction of the analogous output signals of the scanning elements from a normalised "white" signal.

The formation of differential signals is considered expedient for the following considerations. It will be assumed that three scanning elements are provided by means of which the blue, green and red proportions of a colour drawn on a white background are measured, and that the scanning elements are followed by preamplifiers which in the scanning of the white background lead to normalised output signals of + 1 volt. If with the three scanning elements a colour is scanned, which with full covering power, i.e., when the white backing does not show through, produces output signals of 0.2 volt for the blue portion, 0.6 volt for the green portion and 0.9 volt for the red portion, then in the case of half the covering power, i.e., when the white ground colour half shows through, these signals amount to about 0.6, 0.8 and 0.9 volt respectively. In the case of no covering power at all, i.e., when practically only the white background colour shows through, these signals on the contrary amount to + 1 volt each. The differences between the said output signals with full covering power and the normalised "white" voltage is therefore 0.8, 0.4 and 0.1 volt respectively and in the case of half the covering power, on the contrary, 0.4, 0.2 and 0.05 volt, respectively. In the case of both full covering power and half the covering power, the differential signals are in the proportions 100:50:12.5, whereas the analogous output signals in the case of full covering power are in the proportions 22:66:100 and in the case of half the covering power they are in the proportions 63:84:100. The ratios of the differential signals, therefore, remain practically constant, despite the different covering powers, so that different degrees of covering power have no substantial influence, whereas the ratios of the analogous output signals vary relatively considerably, so that the tolerance ranges would have to be made so wide that only a few colours could be used side by side.

In a further preferred embodiment of the invention, the scanning elements are followed by dividing circuits for forming quotient signals, the quotient signals from the division of the analogous output signals of at least one scanning element being given by the sum of the analogous signals of the scanning elements. This circuit offers the advantage that fixed factors, resulting for example from fluctuations of temperature, mains voltage, air humidity or for example by ageing, become negligibly small after division and cause only small errors. The quotient method, in addition, has the advantage that with the use of three scanning elements sensitive to blue, green and red, in general only the quotient signals of two scanning elements need be evaluated, because the sum of all three quotient signals is always unity.

Finally, a particularly preferred embodiment of the invention is provided by the dividing circuits being followed by further subtracting and dividing circuits for forming quotient signals, the quotient signals being proportional to the slope of a line through two points in the colour triangle, and one of these points being fixed by the colour of the background and the other by the colour to be recognised. This circuit has the advantage that relatively narrow tolerance ranges can be assigned to the slopes of the colours, which in the colour triangle are theoretically equal for all possible degrees of covering power, so that the number of usable colours is very large.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 shows apparatus embodying the invention for ensuring recognition of a number of colours;

FIG. 2 shows diagrammatically the tolerance ranges of a number of colours scannable by means of three scanning elements;

FIG. 3 shows part of an embodiment of the invention for the production of differential signals;

FIG. 4 shows a circuit arrangement, modified in comparison with FIG. 1, for varying the tolerance ranges;

FIGS. 5 and 6 show part of embodiments of the invention for the production of quotient signals; and

FIG. 7 shows diagrammatically the incorporation of all colours in a colour triangle.

In the embodiment of the invention shown in FIG. 1, of which only the parts essential for understanding are shown, altogether three scanning elements **31***b* (blue channel), **31***g* (green channel) and **31***r* (red channel) are provided, which for example may consist of photocells, photodiodes or phototransistors, and are accommodated in a scanning head, not shown, which can be moved relative to the drawing to be scanned, also not shown.

The drawing consists for example of white squared paper, the squares being filled in with different colours, so that a pattern of the type of a screen pattern is produced. Between the drawing and the scanning elements **31**, there are provided, also within the scanning head, colour filters or dichroic mirrors, so that there impinges on each scanning element only the light of a relatively narrow spectral range (for example, blue, green, and red).

Connected to the outputs are the three inputs of a number of colour discriminators **411**, **412** and **413** of which only the colour discriminator **411** is shown in detail in FIG. **1.** Connected to each input is an operational amplifier **33**, connected as non-inverting preamplifier, to the negative input of which there is connected a voltage divider **35,37** having a fixed and an adjustable resistance, by means of which the amplification factor of the preamplifier **33** can be adjusted. The outputs of the preamplifiers **33** can be connected by means of a push switch **38**, individually or jointly, to voltmeters **39**, it being assumed that the points B1 and B2, G1 and G2 and R1 and R2, respectively, are in each case connected together. For ease of description, the suffixes *b* (blue), *g* (green) and *r* (red) will be omitted from reference numerals where the description applies to all three channels.

The colour discriminators comprise as essential parts three comparators **43***b***1**, **43***b***2** and **43***g***1**, **43***g***2** and **43***r***1**, **43***r***2**, respectively, and an AND element **451**, whose six inputs are connected to the outputs of the six comparators **43.** The comparators consist of antiparallel-connected differential amplifiers having two inputs. The output of the preamplifier **33***b* is connected to the inverting input of the comparator **43***b***1** and to the non-inverting input of the comparator **43***b***2**, the output of the preamplifier **33***g* is connected to the inverting input of the comparator **43***g***1** and to the non-inverting input of the comparator **43***g***2**, and finally the output of the preamplifier **33***r* is connected to the inverting input of the comparator **43***r***1** and to the non-inverting input of the comparator **43***r***2.**

Furthermore, there is associated wth each group of comparators **43***b,g,r*, a respective voltage divider **47,48,49,50,** each voltage divider having an adjustable resistance **49.** The positive ends of these voltage dividers are connected to the output of an operational amplifier **51**, connected as non-inverting amplifier, while their negative ends are earthed. The positive inputs of the comparators **43***b***1**, **43***g***1** and **43***r***1** are in each case connected to the junction of the resistances **47** and **48,** while the negative inputs of the comparators **43***b***2**, **43***g***2** and **43***r***2** are connected in each case to the junction of the resistances **49** and **50.**

The operational amplifier **51** is connectable by its non-inverting input, by way of the contact **4** of a switch **53** and two resistances **55** and **57**, to the positive terminal of a battery. The junction of the resistances **55** and **57** is earthed via a Zener diode **59**, whose anode is connected by a resistance **61** also to the contact **4** of the switch **53.** The inverting input of the operational amplifier **51** is connected to the tap of a voltage divider **63,65**, by means of which the operational amplifier **51** is adjusted to a fixed amplification factor of 2 for example. The resistances **55,57** and **61** thus reduce the positive working voltage to a voltage, stabilised by the Zener diode, of for example 4 volts which, in the position of the switch **53** shown in FIG. **1**, results in a potential of **8** volts at the output of the operational amplifier **51.** The non-inverting input of the operational amplifier **51** may, however, be connected by means of the switch **53** (positions **1**, **2** or **3**) also directly to an output of the preamplifiers **33.**

The outputs of the comparators **43** are connected by suitable decoupling elements to the base of respective switching transistors **67**, in whose collector-emitter circuits are connected respective lamps **69**, indicated merely diagrammatically in FIG. **1.**

The mode of operation of the arrangement described is as follows. First of all, a point of the drawing is brought below the scanning head such that it is fully covered by the three scanning elements **31.** According to the colour of the point under the scanning head, there is obtained equal or different portions of the spectral ranges associated with the scanning elements **31**, this being shown by the potentials of different magnitudes at the outputs of the preamplifiers **33.** The switch **53** is in position **4,** so that a potential of 8 volts is applied to the positive ends of the voltage dividers **47** to **50.**

On the assumption that the resistances **47,49** and **50** all have for example a value of 10 kΩ, while the resistances **48** have a value of 0.82 kΩ, the non-inverting inputs of comparators **43*b*1, 43*g*1** and **43*r*1,** by adjustment of the resistances **49,** can be connected to potentials of between about 4.16 and 5.40 volts, while the inverting inputs of the comparators **43*b*2, 43*g*2** and **43*r*2** are connected correspondingly to potentials of between about **3.84** and 2.60 volts. Consequently, the comparators **43*b*1, 43*g*1** and **43*r*1** deliver output signals only when the output potentials of the preamplifiers **33** lie below a maximum potential of from 4.16 to 5.40 volts, while the comparators **43*b*2, 43*g*2** and **43*r*2** deliver output signals only when the output potentials of the preamplifiers **33** lie above a minimum potential of 3.84 to 2.60 volts.

In the adjustment of the colour discriminator **411,** the resistance **49*b*** is first adjusted to "zero" value, so that the output potential of the amplifier **33*b*** must lie between 3.84 and 4.16 volts if both lamps **69*b*** are to light up. If the colour portion associated with the scanning element **31*b*** is relatively small, the output potential of the preamplifier **33** is increased by means of the resistance **37*b*** until it lies in the said tolerance range of 4 volts ± 2 percent and the lamps **69*b*** light up. The same adjustment is then made with the preamplifiers **33*g*** and **33*r*** until finally the lamps **69*g*** and **69*r*** also light up. Lighting up of all the lamps means that there occurs at the output of the AND element **451** a colour signal which is characteristic of the colour under the scanning head.

Normally, in scanning each point of the drawing with the same colour, a colour signal ought now to occur at the output of the AND element **451.** Owing to the different colour covering power and the different colour application, however, in practice this is only rarely the case within the said tolerance limits of ± 2 percent. Consequently, for adjusting the colour discriminator **411** with the three scanning elements **31.** preferably a number of points of the same colour with particularly good and particularly poor properties are picked up and the tolerance ranges are adjusted by means of the resistances **49** such that scanning of all points of the same colour leads to a colour signal at the AND element **451,** which can be checked by the lighting up of the lamps **69.** According to requirement or experience, the output potential of the preamplifiers can be applied by means of the resistances **37** to the middle of the tolerance range or can be adjusted unsymmetrically.

The outputs of the scanning elements **31** may be connected to a number of colour discriminators **412, 413,** etc., which are of the same construction as the colour discriminators **411.** These further colour discriminators in FIG. **1** are shown diagrammatically in block **71,** which for example has seven outputs, which together with the output of the AND element **451** are connected to the eight inputs E1 to E8 of a logical circuit **73** in which a definite code signal can be formed for each colour. The seven colour discriminators accommodated in block **71,** as was described above with reference to the colour discriminator **411,** are adjusted to points having other colours, whereby correspondingly other tolerance ranges are obtained. If a number of colour discriminators **411, 412, 413,** etc., are used, it is sufficient if these differ from each other in at least one tolerance range. The tolerance ranges may be of different sizes, especially also within the same colour discriminator, and for the weak colour portions may be larger than for the strong colour portions.

FIG. **2** indicates diagrammatically the possibilities for colour scanning presented by the use of the apparatus described with reference to FIG. **1.** There are indicated along the ordinate at the wavelengths 4,200, 5500 and 6,800 A tolerance ranges to which the three scanning elements **31** in different colour discriminators are adjusted, as expressed by the potentials at the inputs of the preamplifiers **33** with the tolerances ranges referred back to the said potentials. The ranges I to IV combine with the ranges V to VIII to form a plurality of scannable colours, the lengths A to M always indicating the tolerance ranges.

For example, let the ranges I and V be associated with the colour **1** and the range I and VII be associated with the colour **2.** This would mean that the colour discriminators **411** and **412** associated with these colours have two common tolerance ranges, i.e., A and D, which however clearly differ from each other in the third tolerance range F or H. In the circuit diagram shown in FIG. **1,** this means that the comparators **43*b*** and **43*g*** respond in the scanning of colour **1** and also in the scanning of colour **2,** while the comparators **43*r*** in the case of one colour discriminator respond only in scanning of the colour **1** and in the case of the other colour discriminator, respond only on scanning of the colour **2,** so that only one colour is associated with each colour discriminator.

It follows further from FIG. **2** that colours, which for example are composed from the ranges III, V; III, VII and IV, VIII can also be used very well side by side, since they differ relatively strongly from one another in at least one tolerance range. On the other hand, the colours composed for example from the ranges I, VI or II, V or II, VII cannot be scanned so well side by side, although they also differ from one another in at least one tolerance range. In the case of these colours, however, slight fluctuations in illumination or fluctuations in the scanning head/drawing distance or illumination lamp/drawing distance can lead to overlapping of the tolerance ranges and hence to errors.

To remove this disadvantage also, an adjustment is provided which ensures that such fluctuations act in the same proportion on all existing comparators **43,** so that the relative distance of the tolerance ranges is maintained. As shown in FIG. **1,** switch **53** after calibration of the colour discriminator **411** can be switched to one of the contacts **1, 2** or **3,** whereby instead of the stabilised potential of 4 volts, a potential is now applied to the positive ends of the resistances **47** which is dependent on the output potential of one of the preamplifiers

33. By operating the push switch **38**, it is possible to ascertain how the output potentials of the preamplifiers **33** behave in the said fluctuations. According to this behaviour, after calibration is concluded, switch **53** can be switched over to the output of the desired preamplifier **33**, so that in the case of subsequent fluctuations during scanning, the tolerance ranges are also correspondingly shifted, and the output potentials at the preamplifiers **33** remain in the adjusted tolerance range despite possible considerable fluctuations. It will often be preferable to switch the switch **53** to the output of that preamplifier **33** which delivers the strongest output signal for the same adjustment of the resistances. The effect of the adjustment is shown by line K2 in FIG. **2**, which indicates the shift of the line K1, drawn through the centres of the tolerances ranges C, E and H, when the amplification is increased.

FIG. **3** shows a device whereby it is not the analogous output signals delivered by the preamplifiers **33**, but signals derived from the said output signals which are associated with the tolerance range described with reference to FIG. **1**, the derived signals being defined as differential signals between normalised "white" signals and the output signals of the preamplifiers **33**.

For forming the differential signals, subtracting circuits **75** are provided as shown in FIG. **3**, the points B3, G3 and R3 of the circuit of FIG. **3** being connected to the points B1, G1 and R1, and the points B4, G4 and R4 of the circuit of FIG. **3** being connected to the points B2, G2 and R2 of the circuit of FIG. **1**. The outputs of the preamplifiers **33** are in this way connected to inputs of a respective store unit **77**, to whose other inputs timing signals are supplied by a lead **79**. The outputs of the store units **77** are connected to resistances **81**, whose other ends are connected in common to the inverting input of an operational amplifier **83**, and in addition are connected to the output of the latter by a resistance **85**. The non-inverting input of the operational amplifier **83** is earthed. The junctions between the store units **77** and the resistances **81** are connected to the contacts **1** of three switches **87**, which are switchable in common. The movable contacts of these switches **87** are each connected to a respective voltmeter **89**, the other sides of which voltmeters are earthed.

The output of the operational amplifier **83** is connected to a voltage divider of each of the subtracting circuits **75**. Each voltage divider comprises three series-connected resistances **91, 93** and **95**, the resistances **95** being adjustable in common and being connected by their free ends to the outputs of respective amplifiers **97**. The outputs of the preamplifiers **33** and the junctions of the resistances **91** and **93** are connected to the inverting inputs of the operational amplifiers **97** by resistances **99*b*, 99*g*** and **99*r***, while their non-inverting inputs are earthed. The outputs of the operational amplifiers **97** lead on the one hand through the points B4, G4 and R4 to the comparators **43** (FIG. **1**) and, on the other hand, can be connected either to a further set of voltmeters or by matching circuits, not shown, to the contents **2** of the switches **87**, so that the output signals of the operational amplifiers **97** can also be measured by means of the voltmeters **89**.

The device described operates as follows. Before commencing automatic scanning of the drawing, the scanning elements **31** (FIG. **1**) are adjusted to a white point of the drawing. This corresponds to a condition which always arises when a colour, for example blue, has been applied so thinly to the background that its covering power may be equated to a minimum value of "zero." The inputs of the store units **77** are thus supplied with analogue signals which in scanning, give a white point. For storing these signals, a key may be provided, on the operation of which, timing signals are supplied to the store units by the lead **79**. The output signals of the store units **77** are then increased or decreased by adjustment of the resistances **37** until all three voltmeters **89** give a full deflection or, if they are calibrated in percentages, stand at 100 percent. A voltage of exactly + 1 volt may correspond for example to this value of 100 percent.

The potentials adjusted at the outputs of the three storage units **77** are averaged by means of the three resistances **81**. The averaged potential is inverted by the operational amplifier **83** so that a voltage of, for example, exactly − 1 volt appears at its output if the ratio of the resistance **85** to the parallel circuit of the resistances **81** is equal to 1:1.

The second extreme condition is then adjusted by the scanning elements **31** being directed to one of the colour points having optimum covering power associated with the said colour discriminator, at which point, therefore, the white colour of the background shows through as little as possible. For this case, there appears at the outputs of the preamplfiers **33** analogue signals which, in the embodiment of FIG. **1**, would lie within the tolerance ranges adjusted for the corresponding colour discriminator. In the embodiment of FIG. **2**, however, it is not these positive signals but their differential signals which are used for the "white" signals stored in the store units **77**. The formation of the differential signals is obtained by supplying to the inverting input of the operational amplifiers **97**, on the one hand, directly those analogue signals corresponding to the colour portions of the colour just scanned, and on the other hand, by way of the resistances **91**, the inverted "white" signals formed at the output of the operational amplifier **83**, while at the same time the output signals of the operational amplifiers **97** are returned by way of the adjustable resistances **95** and the resistances **93** also to the inverting inputs of the operational amplifiers **97**. Potentials are formed, therefore, at the outputs of the operational amplifiers **97** which compensate by countercurrents the currents flowing through the resistances **91** to the amplifier inputs, the said countercurrents flowing through the resistances **93** as long as no signals are applied to the preamplifiers **33**. If resistances **91** and **93** with values of **10 kΩ** each are used, there is formed at the resistances **93** a voltage of + 1 volt corresponding to the positive "white" voltage. If, on the contrary, for example a potential of + 0.2 volt is applied to the point B3 and if the resistance **99*b*** is also 10 kΩ, the countercurrent to be supplied by the output of amplifier **97*b*** is reduced by the current flowing through the resistance **99*b***, so that at the resistance **93*b*** there is now only a voltage drop equal to the difference between the "white" voltage and the voltage at the point B3, and in the said example amounts to + 0.8 volt.

The potentials appearing at the output of the three operational amplifiers **97** are measured and compared with one another by means of the voltmeters **89**. The maximum potential at the three amplifier outputs, by adjustment of the resistance **95**, which fixes the amplification factor of the operational ampliifer **97**, is brought to an arbitrarily normalised value of 100 percent, which in the example selected amounts to + 1 volt at the output of the operation amplifier 97*b*. In the example selected, therefore, after the normalising process, all operational amplifiers **97** have an amplification factor of 1.25, since the three resistances **95** are coupled mechanically together. Advantageously, the voltmeters **89** are calibrated in percentages, so that the value of 100 percent can be read off directly on the voltmeter **89***b*.

The outputs B4, G4 and R4 of the circuit of FIG. 3 are connected to the inputs of the comparators **43.** In using the circuit of FIG. 3, therefore, a signal will always appear at the output of the AND element **451** when the conditions of the three differential signals are in a certain ratio to one another.

In a further embodiment of the invention, the points B4, G4 and R4 are not connected to the points B2, G2 and R2 of the circuit of FIG. **1,** but to the points B5, G5 and R5 of the circuit of FIG. 4. According to FIG. 4, the point B5 is connected to the non-inverting input of an operational amplifier **101** and in addition by a resistance **103** to the inverting input of an operational amplifier **105,** whose non-inverting input is earthed and whose output is connected to its inverting input by a resistance **106.** The inverting input of the operational amplifier **101** is earthed by a resistance **107** and is connected to its output by a resistance **109.** The outputs of both operational amplifiers **101** and **105** are connected together by two leads **111** and **113,** which, as shown in FIG. 4, are connected together by four pairs of resistances **115,117; 119,121; 123,125; 127,129.** The resistances **117, 119, 125** and **127** have an adjustable tap. The taps of resistances **117** and **125** are connected respectively to the non-inverting inputs of comparators **131** and **133** and the tappings of the resistances **119** and **127** are connected to the inverting inputs of comparators **135** and **137,** respectively. The inverting inputs of the comparators **131** and **133** and the non-inverting inputs of the comparators **135** and **137** are connected to the points G5 and R5, respectively.

The outputs G6, G7, R6 and R7 of the comparators lead by means of suitable switching circuits to the AND element **451** (FIG. 1), which gives an output signal when the differential signal supplied to the inputs G5 and R5 lie within the tolerance ranges adjusted at the resistances **117, 119, 125** and **127.**

As distinct from FIG. **1,** in thee circuit of FIG. 4, the tolerance ranges can be adjusted independently of one another and independently of the centre of the tolerance ranges. In addition, only two groups of comparators are provided, while the strongest output signal at the output of the amplifiers **97,** in the example selected the output signal of the operational amplifier **97***b*, is supplied to the two amplifiers **101** and **105.** The end voltages of the tolerance ranges are fixed by the output signals of the two operational amplifiers **101** and **105,** in a manner similar to that whereby this is achieved by the operational amplifier **51** in the circuit of FIG. **1.** The operational amplifiers **101** and **105,** therefore, undertake regulation, i.e., for the case where the potential at the point B5 has not reached or has exceeded the normalised value of 100 percent, the end voltages of the tolerance ranges are varied accordingly. If, for example, in the case of illumination which is too weak, the differential signal at the point B5 is only 50 percent of the normalised value, the end potentials of the tolerance ranges will be correspondingly 50 percent lower.

The adjustable resistances **117, 119, 125** and **127** are advantageously calibrated in percentages and have such values that the tolerance ranges of the two differential signals appearing at the inputs **G5** and **R5** can be adjusted relative to the strongest signal at the input **B5** between about 0 and 150 percent at the resistances **117** and **125** or between about −50 and +100 percent at the resistances **119** and **127.**

Finally, in the embodiment of FIG. **4,** as in the embodiment of FIG. **1,** three groups of comparators may likewise be provided. In that case, however, the signal appearing at the point B5 would have to be regulated, by an additional regulating circuit, to a constant value of 100 percent, as is described for example in British Pat. specification No. 1,190,600. Finally, suitable switches may be provided for always connecting to the point B5 the strongest output signal of the three operational amplifiers **97.**

A further embodiment of the invention is obtained if the points B1, G1 and R1 are connected to the points B8, G8 and R8 of the circuit of FIG. **5,** and its points B9 and G9 are connected to two of the three points G2, B2 or R2 of the circuit of FIG. **1.** The circuit of FIG. **5** has as essential components two dividing circuits **139** and **141,** as well as an adding circuit **143.** The analogue signals delivered by the preamplifiers are added in the adding circuit **143,** while the quotients of the signal delivered by a preamplifier and the sum of signals delivered by all three preamplifiers is formed in the dividing circuits **139, 141.** The quotient signals appearing at the points B9 and G9 are evaluated in FIG. 1 by groups, each consisting of two comparators with an adjustable tolerance range.

With FIG. **5,** altogether only two groups of comparators are required since the sum of the three quotient signals B/(B + G + R), G/(B + G + R) and R/(B + G + R) is always equal to 1, and this formula is merely confirmed by the third group of comparators, but no additional property of the scanned colour would be found.

The quotient formation precludes for example errors which, due to external factors, such as temperature, illumination or voltage fluctuations, are formed by variations in the absolute value of the signals delivered by the preamplifiers. If it is assumed, for example, that due to a variation in illumination, the output signals of the preamplifiers **33** instead of the values B, G and R have the values kB, kG or kR, where k is any constant which acts on all three colour portions in substantially the same manner, then this constant k is eliminated in the formation of the quotients.

A further embodiment of the invention is obtained by connecting the points B1, G1 and R1 of the circuit of FIG. 1 to the points B8, G8 and R8 of the circuit of FIG. 5, and the points B9, G9 and I of the circuit of FIG. 5 to the points B10, G10 and I of the circuit of FIG. 6. The point B10 is connected to a subtracting circuit **145** and the point G10 to a subtracting circuit **147.** In these subtracting circuits **145** and **147,** the differences between the quantities formed according to FIG. **5,** $b = B/(B + G + R)$ and $g = G/(B + G + R)$ respectively and fixed base values are formed; the significance of these quantities will be described later with reference to FIG. **7.** The output signals of the subtracting circuits **145** and **147** are supplied to a dividing circuit **149,** in which the absolute value of the quotient $(g - g_B)/(b - b_B)$ is formed.

The output signal of the dividing circuit **149** is evaluated by means of two comparators **151** and **153** as in the embodiments described so far, it being possible to fix at the point **155** the upper limit and at the point **157** the lower limit of a tolerance range. By means of an AND element **159** following the comparators, signals thus arrive at one input of a further AND element **161** only when both comparators **151** and **153** deliver an output signal, i.e., when he output signal of the dividing circuit lies in the fixed tolerance range.

There is supplied to a further input of the AND element **161** by way of a switch **163** a positive output signal of a coding unit **165**, whose inputs are connected to the outputs of the subtracting circuits **145, 147.** There is ascertained by means of the coding unit whether the differential signals formed in the subtracting circuits **145, 147** have a positive or negative sign.

In this way, it is possible to adjust manually whether the signal appearing at the output F1 of the AND element **161**, of which signal only the absolute value is formed in the dividing circuit, should have a positive value or a negative value. Thus, by means of the circuit of FIG. **6** it is possible to recognize according to the position of the switch **163** two colours with which are associated signals having the same absolute value but different signs.

Finally, it is possible to supply to a third input of the AND element **161** also the sum signal $B + G + R$, formed in the adding circuit **143** (FIG. **5**), by way of comparators **167** and **169** with adjustable tolerance range, and by way of an AND element **171.** It is thereby possible to distinguish from one another colours whose quotient signals have the same sign and the same absolute value, but a different total intensity.

The mode of operation of the circuit described with reference to FIGS. **5** and **6** follows from FIG. **7**, showing diagrammatically the usual colour triangle **173.** Along the abscissa axis are plotted the values $r = R/(B + G + R)$ and on the ordinate axis the values $g = G/(B + G + R)$. The values of r and g give the red or green portion of a colour point referred to the total intensity. Because $b + g + r = 1$, the blue component $b = R/(B + G + R)$ need not be considered separately. The colour triangle **173** forms an area comprising all possible colours and colour combinations. The colour triangle **173** in addition is enclosed by a line **175**, along which the wavelength of the colours is plotted between 4,000 and 7,000 A. The point denoted by **177** with the coordinates $r = 0.33$ and $g = 0.33$ (and correspondingly $b = 0.33$) corresponds to the colour white, or, depending on the total intensity, different shades of grey up to the colour black; white, black and grey points, therefore, can be differentiated not by their position in the colour triangle, but only by their total intensity (output I in FIG. **5**). The point **177** is termed the base point.

If there is drawn on a white, grey or black background a colour which leads to a point **179** on the line **175**, this means that this colour has been applied with optimum covering power, i.e., it transmits or possesses an infinitesimally small "white" portion. Substantially, the coordinates $r = 0.44$ and $g = 0.56$ are associated with the point **179.** If one advances from the point **179** towards the base point **177**, this means that the "white" portion of the colour is constantly increased or the covering power of the colour becomes even smaller, until finally at the point **177**, the "white" portion is practically 100 percent, or the covering power is practically "zero." For the operation of the present apparatus, it is important that over all possible degrees of covering power, i.e., from the point **179** with the strongest covering power to the point **177** with the weakest covering power, a straight line drawn for example through the two points **177** and **179** with constant slope is characteristic of each colour. The slope of these straight lines is formed with the circuit of FIGS. **5** and **6**, and is used for recognising a definite colour.

To ensure that no errors can be produced by slight external influences, a colour is recognised in FIGS. **5** and **6** when the straight line associated with it in the colour triangle **173** lies within a tolerance region **181.** The quadrant in which the straight line should lie is fixed by the coding unit **165**, with reference to the base point **177**, since for example in the first quadrant a yellow colour is obtained (tolerance range **181**), in the third quadrant, on the contrary, for the same value of the output signal of the dividing circuit **149**, a blue colour is obtained (tolerance range **183**).

Many modifications can be made to the apparatus described. More particularly, the form of the different amplifier stages or comparators, of the switches and verification or check elements (e.g., lamps **69**) is in itself optional, provided only that, for the purpose of recognising a colour with certainty, at least one variable tolerance range can be adjusted. Also the number of scanning elements selected for each colour discriminator or the number of colour discriminators themselves is freely selectable. In individual cases, a single scanning element per colour discriminator is in itself sufficient for distinguishing a number of colours with certainty. According to FIG. **2**, it is possible, for example, to connect to a scanning element sensitive to "blue" three colour discriminators with the tolerance ranges A, L and C. If tolerance ranges narrower than ± 2 percent are desired, the resistances **48** may be omitted. The lower tolerance limit can also be fixed at 0 volt by switches which bridge the resistances **50.**

The special advantage of all embodiments described is to be seen in the fact that, on the one hand for making a drawing, a number of colours with similar properties may be used, and on the other hand, these colours may be selected from an almost unlimited number of colours, without specific reflection or transmission factors being required.

In the embodiments of FIGS. **4** to **6**, which of the two colour portions is used for evaluation is optional and in the individual case depends on which colour portions lead to strong, readily evaluatable signals. Thus, for example, in FIG. **4** it is indicated that only green and red colour portions are evaluated, whereas according to FIGS. **5** and **6** blue and green colour portions are evaluated. In addition, it follows from the description of FIG. **7** that instead of using the values r and g, colour triangles are also obtained with the values r and b or g and b. Furthermore, in the embodiment of FIG. **3**, the manner in which the timing signals supplied over the lead **79** are produced depends on the device for scanning the drawing. If, for example, this is a device according to British Pat. specifications No. 1,170,947 or 1,190,600, it is advantageous, after scanning a line of the drawing, to carry the scanning head over the white margin of the background and at that moment to produce a timing pulse by means of a contact, not shown. If, on the contrary, the drawing to be scanned is clamped for example to the periphery of a rotating drum, then also by means of a suitable contact a timing pulse can be released when the scanning head is situated over a part of the drum periphery covered by the background but not by the pattern. In both cases, before renewed scanning of a line, the "white" or "base" signal, characteristic of the background used will thereby be stored in the store units **77** for the duration of the scanning of a line.

Finally, the apparatus is also not limited to the colour of the background of the drawing. As follows from FIG. **7**, in the circuits of FIGS. **5** and **6**, it is immaterial whether a white, grey or black background is used. It is also possible to use a background with a light blue, red or green undertone. In such cases, the base point for example is shifted to the place marked **185** in FIG. **7**, so that only the zero point of the coordinate system selected is altered, and the circuit of FIG. **6** has merely to be adjusted to a new base point (b_B, g_B, r_B). For this purpose, the subtracting circuits **145, 147** have suitable potentiometers. A correct adjustment always occurs when the output signals of the subtracting circuits **145, 147** disappear when the background is being scanned. In the circuit of FIG. **5**, the colour of the background plays no part because it is the intensities of the individual colour portions, divided by the total intensity, which are evaluated. In connection with the signals appearing at the output *I*, there is finally the possibility of distinguishing colours which certainly lie on the same straight lines in the colour triangle according to FIG. **7**, but are characterised by different degrees of covering power or different mixtures with white colour.

We claim:

1. Apparatus for scanning a drawing consisting of a large number of points each of which is of a color selected from a number of colors, and for converting the information obtained by scanning the points into color signals characteristic of the individual colors, comprising a scanning head movable relative to the drawing having a number of optical-electrical scanning elements each responding to a definite spectral range by producing analog output signals; at least one electrical circuit coupled to said scanning elements for producing derived signals by combining said output signals with other signals; at least one color discriminator connected to said electrical circuit, said discriminator producing a respective color signal only when the derived signals of the electrical circuit associated with it lie within an upwardly and downwardly limited tolerance range; and means for upwardly and downwardly adjusting the tolerance range.

2. Apparatus according to claim **1**, including means for forming a normalized "white" signal wherein the electrical circuits are subtracting circuits for forming differential signals, the differential signals being formed by subtraction of the analogous output signals of the scanning elements from the normalized "white" signal, and the derived signals being said differential signals.

3. Apparatus according to claim **2**, wherein one derived signal is used for the dynamic regulation of the tolerance ranges of the other derived signals and wherein only the other derived signals are provided for forming the color signal.

4. Apparatus according to claim **1**, wherein the electrical circuits are first dividing circuits for forming first quotient signals, the first quotient signals being formed by division of the analogous output signals of at least one scanning element by the sum of the analogous output signals of all the scanning elements, and the derived signals being said first quotient signals.

5. Apparatus according to claim **1**, wherein the electrical circuits include first dividing circuits for forming first quotient signals, said first quotient signals being formed by division of the analogous output signals of at least two scanning elements by the sum of the analogous output signals of all the scanning elements, and further including subtracting circuits and second dividing circuits for producing second quotient signals, the second quotient signals being proportional to the slope of a line formed by two definite points in the color triangle, one of these points being fixed by the color of the background and the other point by the color to be recognized, and the derived signals being said second quotient signals.

6. Apparatus according to claim **5**, wherein there is associated with the second dividing circuit a means for detecting selected output signals of the second dividing circuit.

7. Apparatus according to claim **5**, wherein there is associated with the second dividing circuit a further device by means of which such output signals of the second dividing circuit can be distinguished which are associated with colors of the same slope but different intensity.

8. Apparatus according to claim **1**, the means for adjusting the tolerance ranges being voltage dividers.

9. Apparatus according to claim **8**, including means for selectively applying a fixed stabilized voltage to at least one of all the voltage dividers.

10. Apparatus according to claim **9**, including a switch by means of which to one end of all the voltage dividers of a color discriminator can be supplied a derived signal.

11. Apparatus according to claim **1**, each derived signal being supplied to two connected inputs of a pair of comparators, to the other inputs of which are connected the taps of a voltage divider for upwardly and downwardly adjusting the tolerance range.

12. Apparatus according to claim **11**, wherein each comparator is followed by a verification element which indicates the presence or non-presence of an output signal at the comparator.

13. Apparatus according to claim **11**, wherein each color discriminator has an AND element coupled to said comparators for producing the color signal.

14. Apparatus, according to claim **1**, including means for measuring the analog output signals at the scanning elements.

15. Apparatus according to claim **1**, including preamplifiers with variable amplification factors connected between each scanning element and the color discriminator.

16. The apparatus according to claim **1**, wherein there are provided three scanning elements for the colors blue, green and red.

17. Apparatus for scanning a drawing consisting of a large number of points each of which is of a color selected from a number of colors, and for converting the information obtained by scanning the points into color signals characteristic of the individual colors, comprising a scanning head movable relative to the drawing having a number of optical-electrical scanning elements each responding to a definite spectral range; preamplifiers with variable amplification factors coupled to said scanning elements; color discriminators connected to the preamplifiers for producing a respective color signal only when the analogous output signals of all the preamplifiers associated with it lie within an upwardly and downwardly limited tolerance range; and means for upwardly and downwardly adjusting the tolerance range.

18. The apparatus according to claim **17**, wherein said discriminators include pairs of comparators, two inputs of the comparators of each pair being connected and also connected to a preamplifier and the other inputs of the comparators of each pair being connected to the taps of a voltage divider for upwardly and downwardly adjusting the tolerance ranges; and wherein the outputs of said comparators are connected to the inputs of an AND gate which produces a color signal only when all comparators produce an output signal.

19. The apparatus according to claim **18**, including means for selectively applying a fixed stabilized voltage to at least one end of all the voltage dividers.

20. The apparatus according to claim **18**, including a switch for selectively applying to at least one end of all the voltage dividers a fixed stabilized voltage or the output of one of the preamplifiers, respectively.

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