US 20210180934A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2021/0180934 A1

ISHIBASHI (43) Pub. Date: Jun. 17, 2021

(54) MEASURING INSTRUMENT AND MEASURE

(71) Applicant: **FUJITSU COMPONENT LIMITED**, Tokyo (JP)

(72) Inventor: **Kazunori ISHIBASHI**, Tokyo (JP)

(73) Assignee: **FUJITSU COMPONENT LIMITED**, Tokyo (JP)

(21) Appl. No.: **17/113,556**

(22) Filed: **Dec. 7, 2020**

(30) **Foreign Application Priority Data**

Dec. 12, 2019 (JP) 2019-224854
Nov. 13, 2020 (JP) 2020-189632

Publication Classification

(51) **Int. Cl.**
G01B 5/02 (2006.01)
G01B 5/008 (2006.01)
G01D 5/26 (2006.01)

(52) **U.S. Cl.**
CPC ***G01B 5/02*** (2013.01); ***G01D 5/26*** (2013.01); ***G01B 5/008*** (2013.01)

(57) **ABSTRACT**

A measuring instrument includes a plurality of first readers that optically read a plurality of patterns from a measure having a color pattern including the plurality of patterns arranged at a regular interval in a length direction, the plurality of first readers being arranged at the regular interval in the length direction, a converter that converts the plurality of patterns read by the plurality of first readers into a value of an N-ary number (N is 3 or more), and a calculator that calculates a scale value of the measure based on data that defines a relationship between the value of the Nary number and the scale value of the measure.

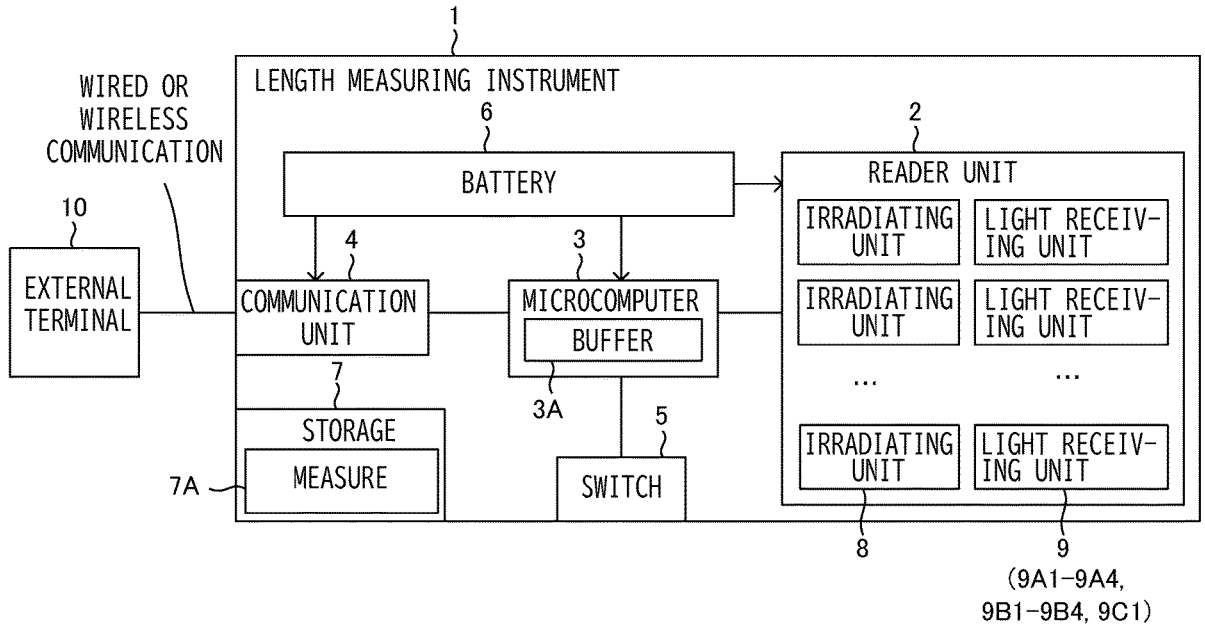


FIG. 1

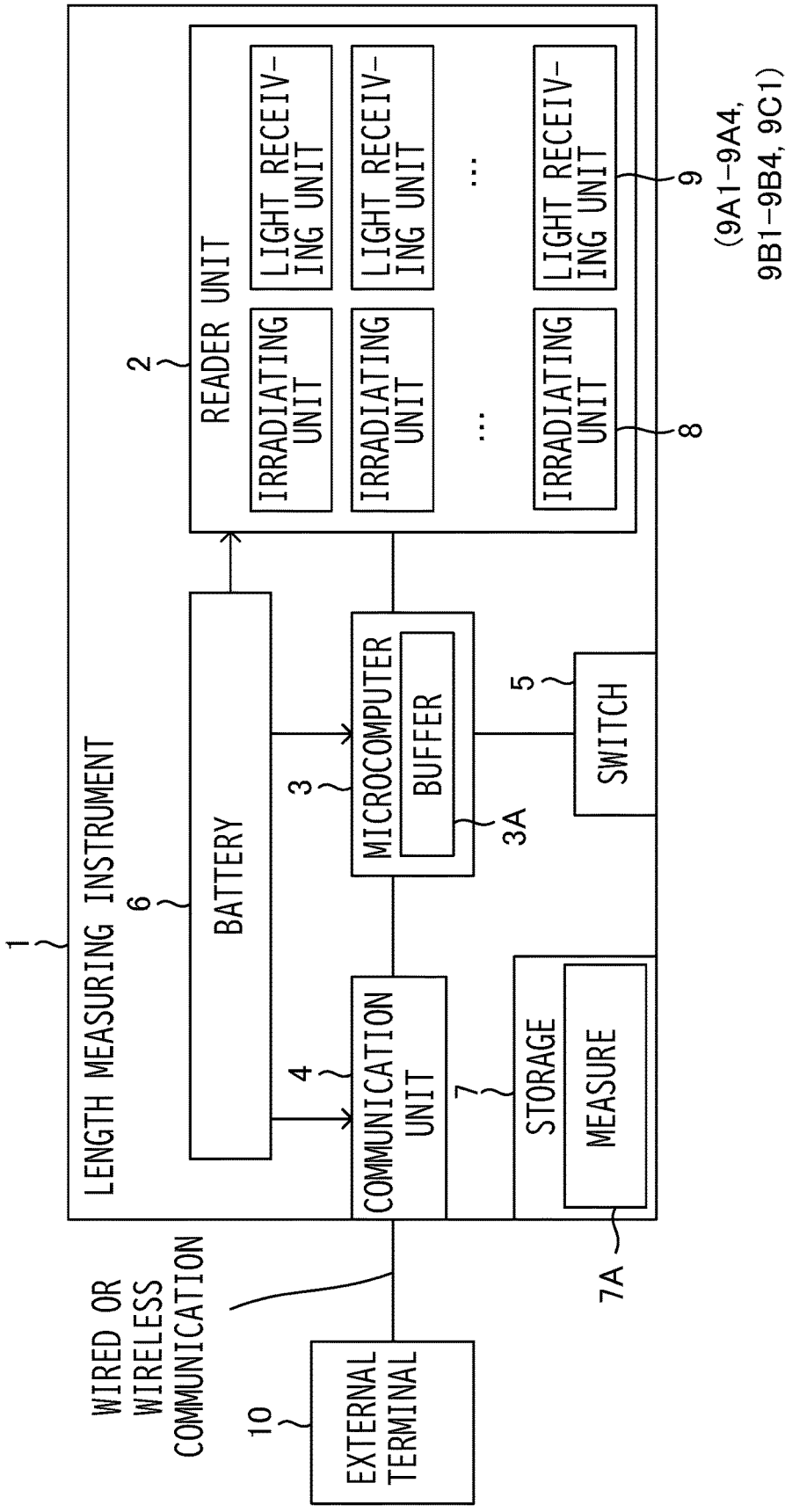

LENGTH MEASURING INSTRUMENT
1
READER UNIT
2
IRRADIATING UNIT
LIGHT RECEIV-ING UNIT
8
9
(9A1–9A4, 9B1–9B4, 9C1)
BATTERY
6
MICROCOMPUTER
3
BUFFER
3A
SWITCH
5
COMMUNICATION UNIT
4
STORAGE
7
MEASURE
7A
WIRED OR WIRELESS COMMUNICATION
EXTERNAL TERMINAL
10

FIG. 2

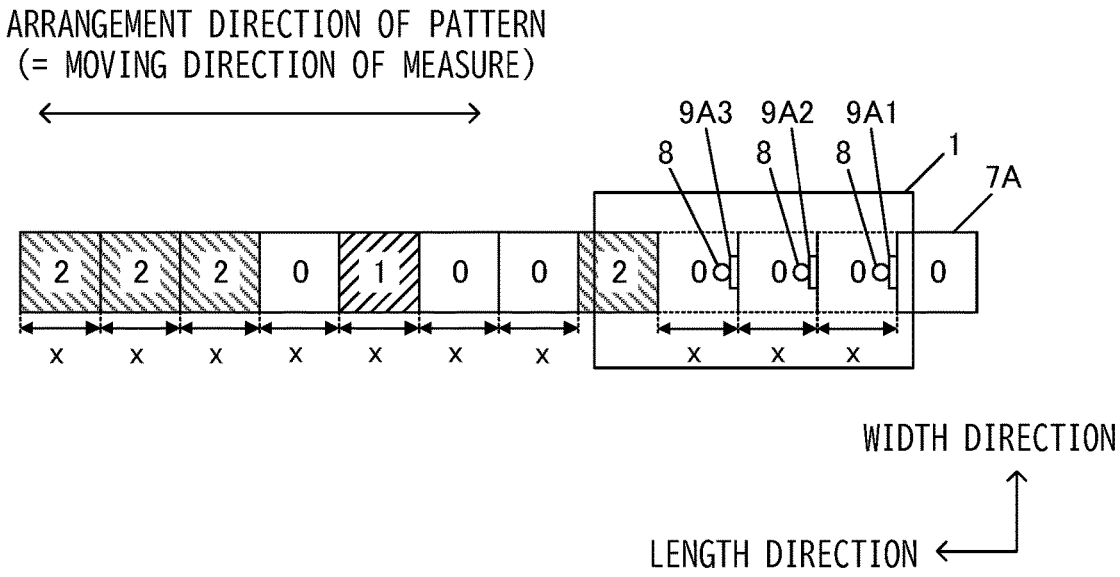

ARRANGEMENT DIRECTION OF PATTERN
(= MOVING DIRECTION OF MEASURE)
9A3
9A2
9A1
8
8
8
1
7A
2
2
2
0
1
0
0
2
0
0
0
0
x
x
x
x
x
x
x
x
x
x
WIDTH DIRECTION
LENGTH DIRECTION

FIG. 3

LIGHT RECEIVING UNIT			CONVERSION VALUE		SCALE VALUE OF MEASURE
9A3	9A2	9A1	TERNARY NUMBER	DECIMAL NUMBER	
0	0	0	000	0	0
0	0	1	001	1	1
0	1	0	010	3	2
1	0	1	101	10	3
0	1	1	011	4	4
1	1	1	111	13	5
1	1	0	110	12	6
1	0	0	100	9	7
0	0	2	002	2	8
0	2	0	020	6	9
2	0	1	201	19	10
0	1	2	012	5	11
1	2	0	120	15	12
2	0	2	202	20	13
0	2	1	021	7	14
2	1	0	210	21	15
1	0	2	102	11	16
0	2	2	022	8	17
2	2	1	221	25	18
2	1	2	212	23	19
1	2	1	121	16	20
2	1	1	211	22	21
1	1	2	112	14	22
1	2	2	122	17	23
2	2	2	222	26	24
2	2	0	220	24	25
2	0	0	200	18	26

FIG. 4

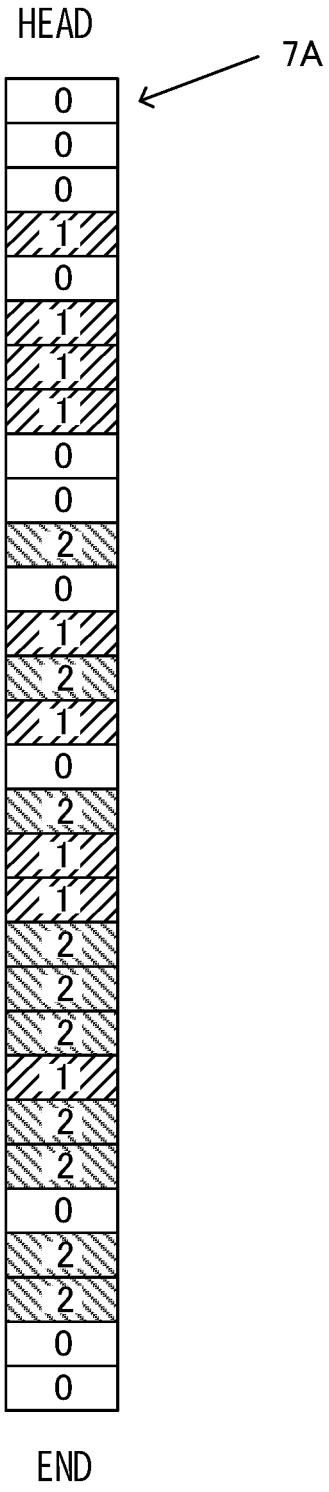


FIG. 5

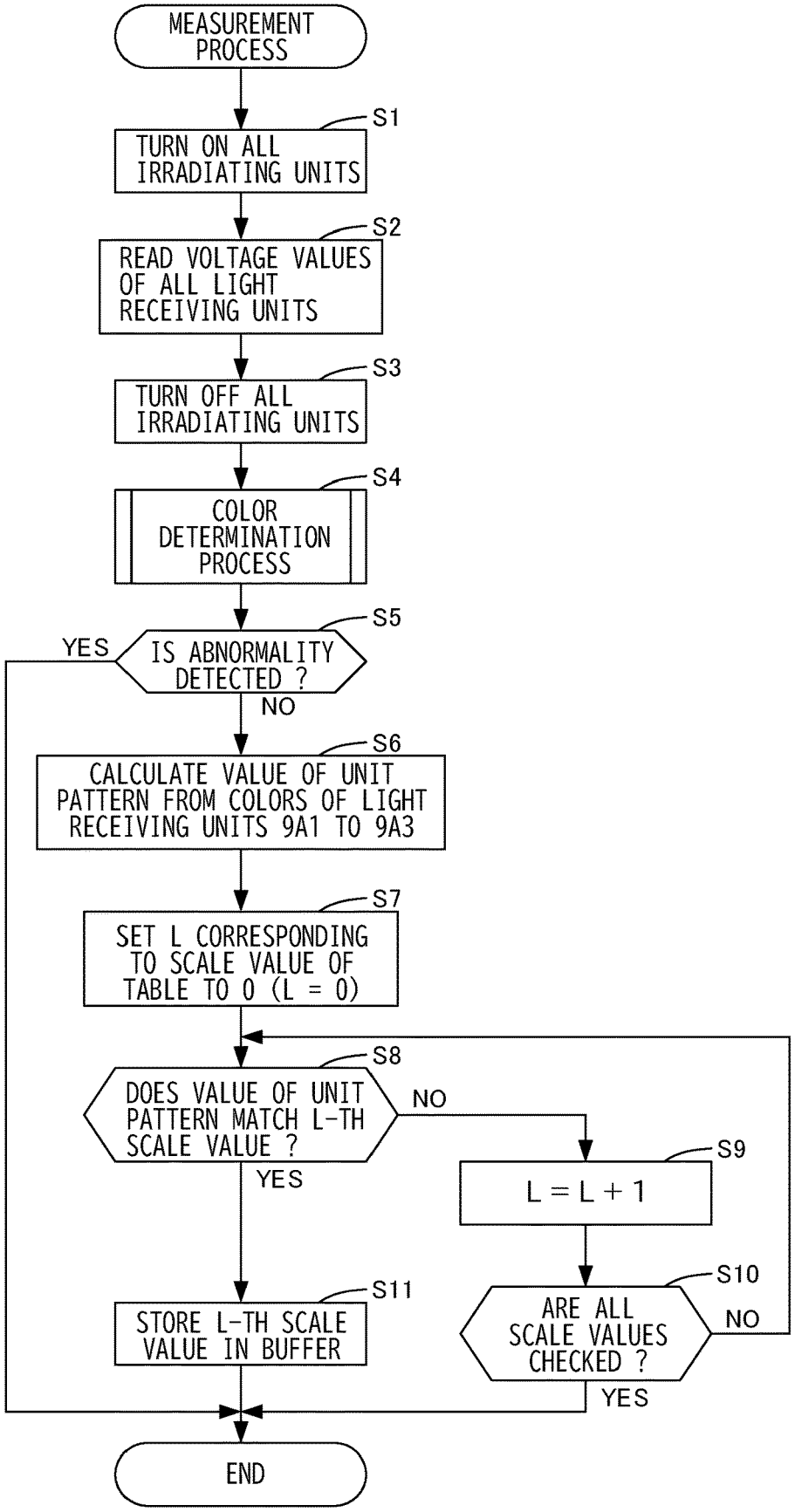

MEASUREMENT PROCESS
S1
TURN ON ALL IRRADIATING UNITS
S2
READ VOLTAGE VALUES OF ALL LIGHT RECEIVING UNITS
S3
TURN OFF ALL IRRADIATING UNITS
S4
COLOR DETERMINATION PROCESS
S5
IS ABNORMALITY DETECTED ?
YES
NO
S6
CALCULATE VALUE OF UNIT PATTERN FROM COLORS OF LIGHT RECEIVING UNITS 9A1 TO 9A3
S7
SET L CORRESPONDING TO SCALE VALUE OF TABLE TO 0 (L = 0)
S8
DOES VALUE OF UNIT PATTERN MATCH L-TH SCALE VALUE ?
NO
YES
S9
L = L + 1
S10
ARE ALL SCALE VALUES CHECKED ?
NO
YES
S11
STORE L-TH SCALE VALUE IN BUFFER
END

FIG. 6

COLOR NUMBER	DETECTED VALUE (VOLTAGE)
1	2.0V±5%
2	1.5V±5%
3	1.0V±5%

FIG. 7

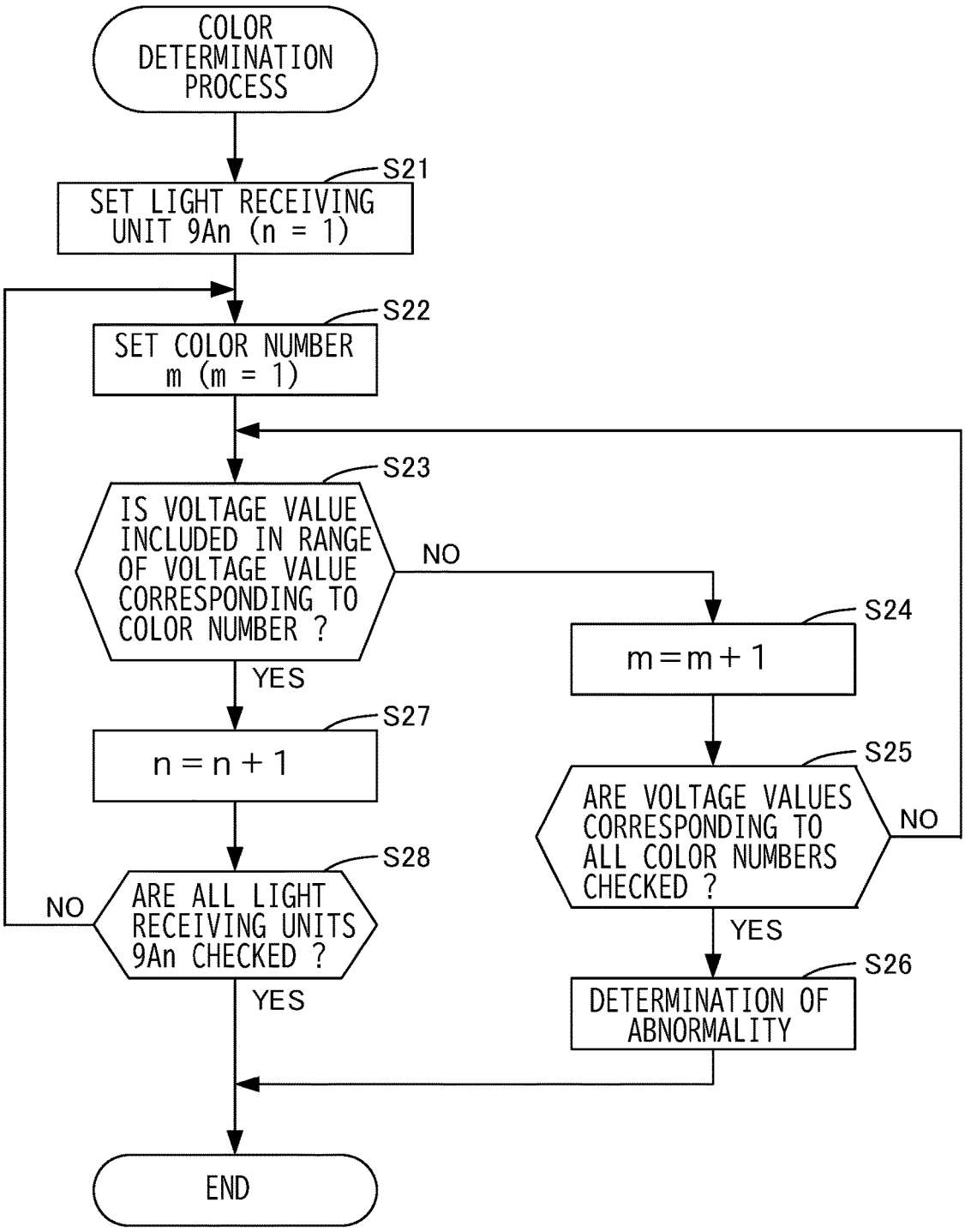

COLOR DETERMINATION PROCESS
S21
SET LIGHT RECEIVING UNIT 9An (n = 1)
S22
SET COLOR NUMBER m (m = 1)
S23
IS VOLTAGE VALUE INCLUDED IN RANGE OF VOLTAGE VALUE CORRESPONDING TO COLOR NUMBER ?
NO
YES
S24
m = m + 1
S25
ARE VOLTAGE VALUES CORRESPONDING TO ALL COLOR NUMBERS CHECKED ?
NO
YES
S26
DETERMINATION OF ABNORMALITY
S27
n = n + 1
S28
ARE ALL LIGHT RECEIVING UNITS 9An CHECKED ?
NO
YES
END

FIG. 8

COLOR NUMBER (FIRST COLOR)	COLOR NUMBER (SECOND COLOR)	BOUNDARY DETECTED VALUE (VOLTAGE VLUE)	CORRESPONDING COLOR NUMBER
1	2	1.75	NONE
	3	1.50	2
2	1	1.75	NONE
	3	1.25	NONE
3	1	1.50	2
	2	1.25	NONE

FIG. 9

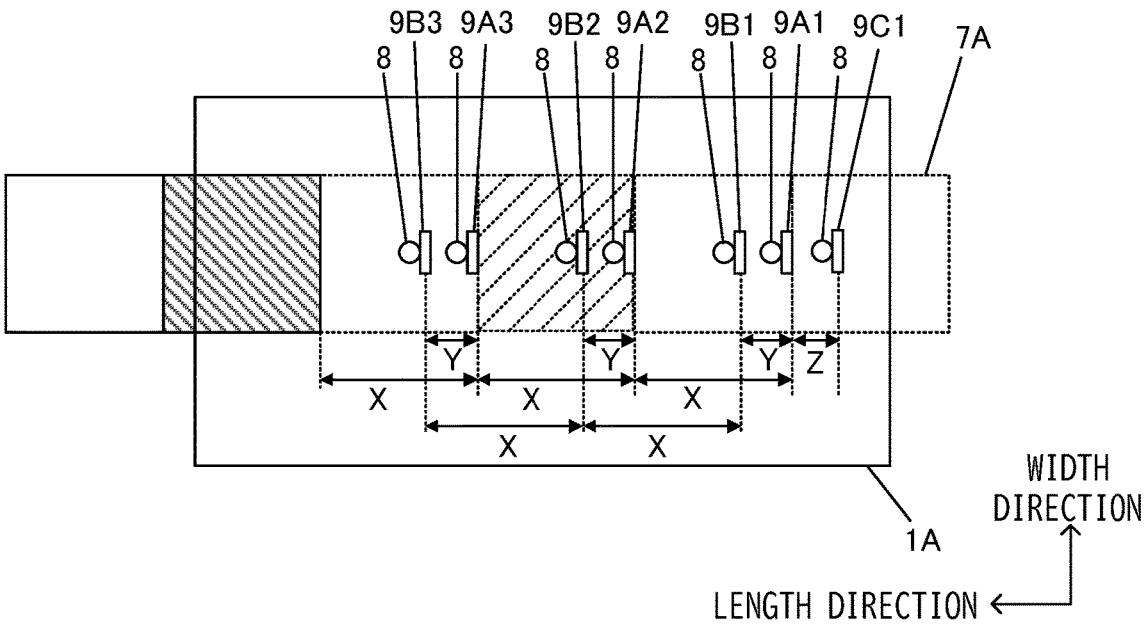

9B3
9A3
9B2
9A2
9B1
9A1
9C1
8
7A
Y
Z
X
1A
WIDTH DIRECTION
LENGTH DIRECTION

FIG. 10

LIGHT RECEIVING UNIT 9B1	LIGHT RECEIVING UNIT 9A1	LIGHT RECEIVING UNIT 9C1	LIGHT RECEIVING UNIT TO BE USED FOR SCALE CONVERSION
COLOR NUMBER 2	COLOR NUMBER 2	COLOR NUMBER 1	9A1-9A3
COLOR NUMBER 1	COLOR NUMBER 2	COLOR NUMBER 2	
COLOR NUMBER 2	COLOR NUMBER 2	COLOR NUMBER 3	
COLOR NUMBER 3	COLOR NUMBER 2	COLOR NUMBER 2	
COLOR NUMBER 2	COLOR NUMBER 2	COLOR NUMBER 2	
COLOR NUMBER 1	COLOR NUMBER 2 (BOUNDARY)	COLOR NUMBER 3	9B1-9B3
COLOR NUMBER 3	COLOR NUMBER 2 (BOUNDARY)	COLOR NUMBER 1	

FIG. 11

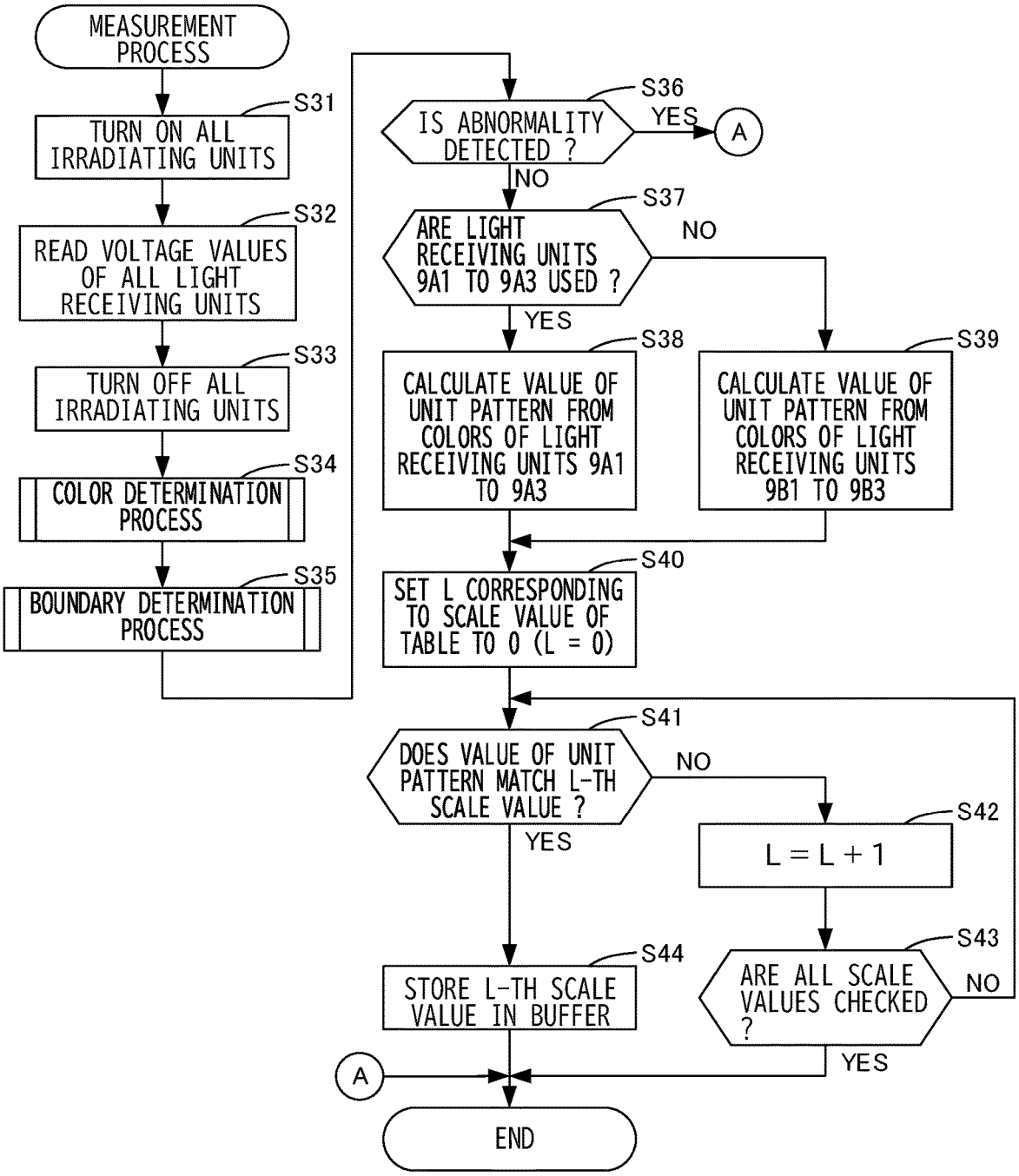

MEASUREMENT PROCESS
S31
TURN ON ALL IRRADIATING UNITS
S32
READ VOLTAGE VALUES OF ALL LIGHT RECEIVING UNITS
S33
TURN OFF ALL IRRADIATING UNITS
S34
COLOR DETERMINATION PROCESS
S35
BOUNDARY DETERMINATION PROCESS
S36
IS ABNORMALITY DETECTED ?
YES
A
NO
S37
ARE LIGHT RECEIVING UNITS 9A1 TO 9A3 USED ?
NO
YES
S38
CALCULATE VALUE OF UNIT PATTERN FROM COLORS OF LIGHT RECEIVING UNITS 9A1 TO 9A3
S39
CALCULATE VALUE OF UNIT PATTERN FROM COLORS OF LIGHT RECEIVING UNITS 9B1 TO 9B3
S40
SET L CORRESPONDING TO SCALE VALUE OF TABLE TO 0 (L = 0)
S41
DOES VALUE OF UNIT PATTERN MATCH L-TH SCALE VALUE ?
NO
YES
S42
L = L + 1
S43
ARE ALL SCALE VALUES CHECKED ?
NO
YES
S44
STORE L-TH SCALE VALUE IN BUFFER
A
END

FIG. 12

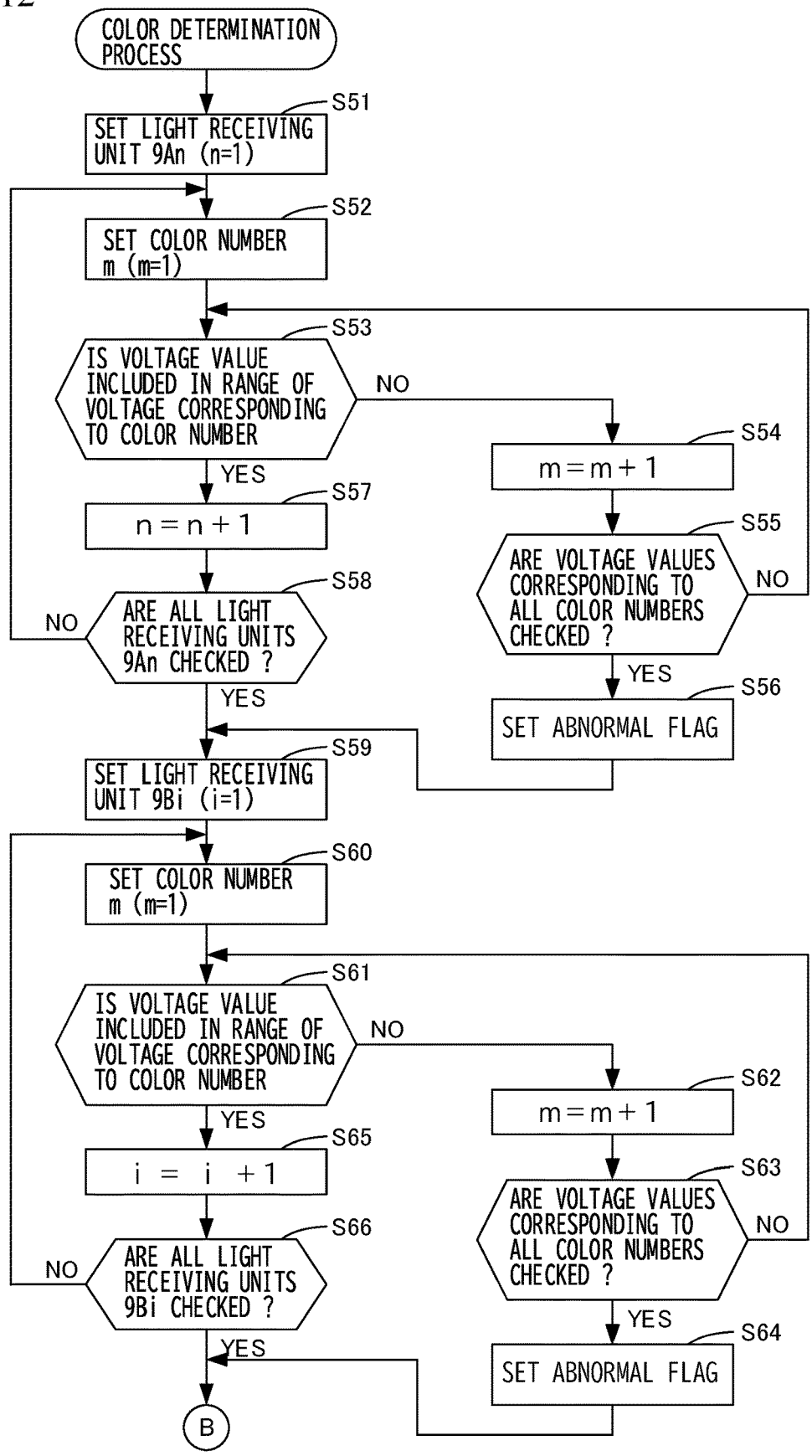
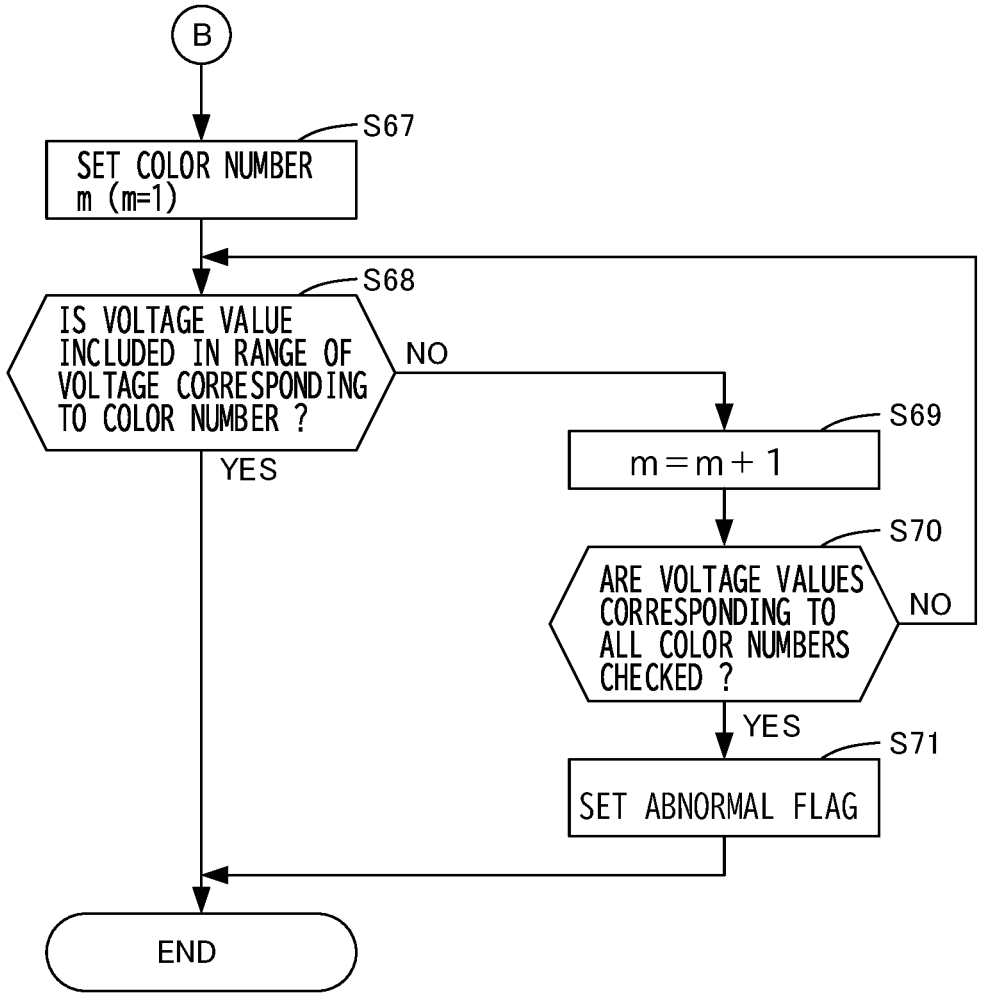

COLOR DETERMINATION PROCESS
S51
SET LIGHT RECEIVING UNIT 9An (n=1)
S52
SET COLOR NUMBER m (m=1)
S53
IS VOLTAGE VALUE INCLUDED IN RANGE OF VOLTAGE CORRESPONDING TO COLOR NUMBER
NO
YES
S54
m = m + 1
S55
ARE VOLTAGE VALUES CORRESPONDING TO ALL COLOR NUMBERS CHECKED ?
NO
YES
S56
SET ABNORMAL FLAG
S57
n = n + 1
S58
ARE ALL LIGHT RECEIVING UNITS 9An CHECKED ?
NO
YES
S59
SET LIGHT RECEIVING UNIT 9Bi (i=1)
S60
SET COLOR NUMBER m (m=1)
S61
IS VOLTAGE VALUE INCLUDED IN RANGE OF VOLTAGE CORRESPONDING TO COLOR NUMBER
NO
YES
S62
m = m + 1
S63
ARE VOLTAGE VALUES CORRESPONDING TO ALL COLOR NUMBERS CHECKED ?
NO
YES
S64
SET ABNORMAL FLAG
S65
i = i + 1
S66
ARE ALL LIGHT RECEIVING UNITS 9Bi CHECKED ?
NO
YES
B

FIG. 13


B
S67
SET COLOR NUMBER
m (m=1)
S68
IS VOLTAGE VALUE
INCLUDED IN RANGE OF
VOLTAGE CORRESPONDING
TO COLOR NUMBER ?
NO
YES
S69
m = m + 1
S70
ARE VOLTAGE VALUES
CORRESPONDING TO
ALL COLOR NUMBERS
CHECKED ?
NO
YES
S71
SET ABNORMAL FLAG
END

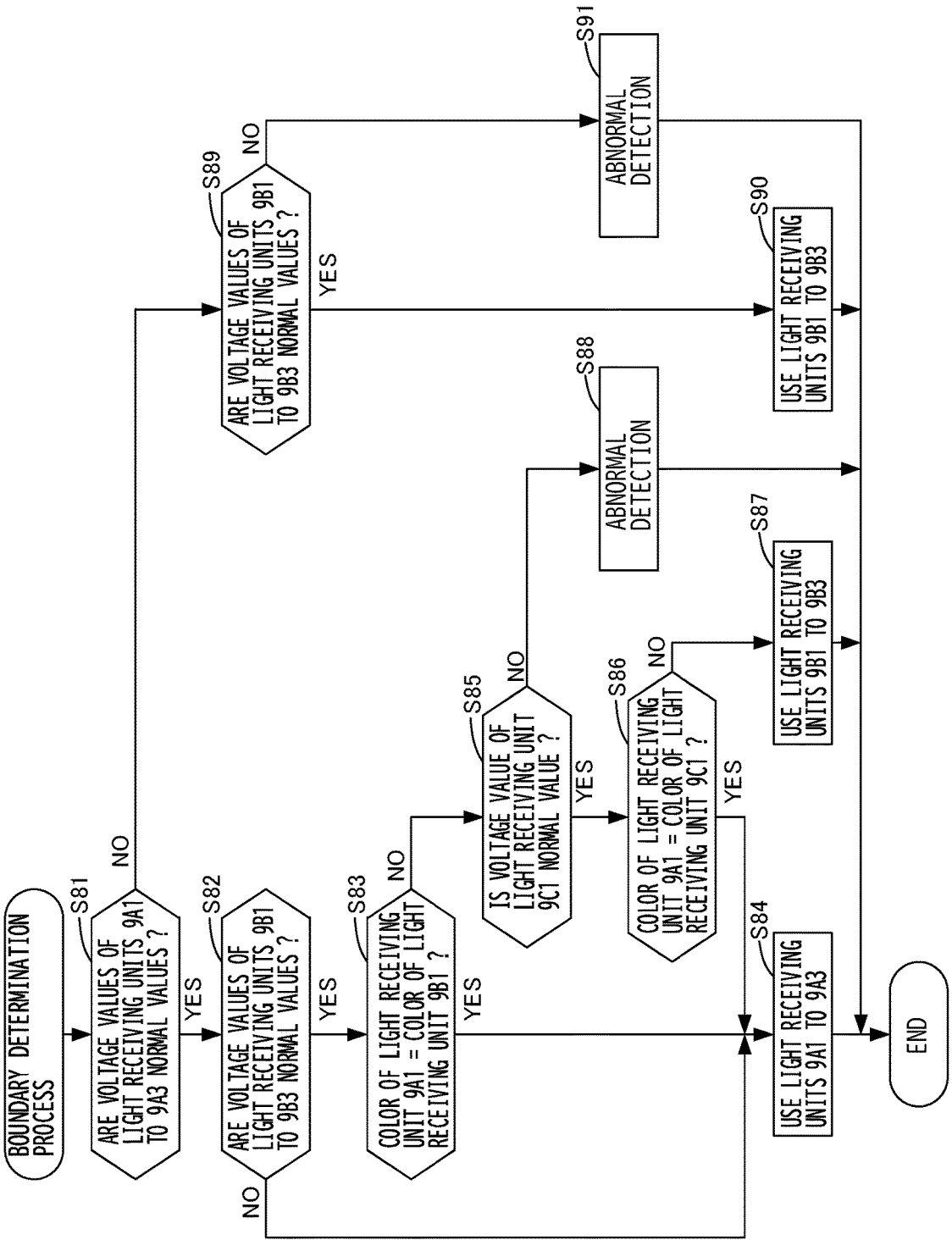

BOUNDARY DETERMINATION PROCESS
S81
ARE VOLTAGE VALUES OF LIGHT RECEIVING UNITS 9A1 TO 9A3 NORMAL VALUES ?
NO
YES
S82
ARE VOLTAGE VALUES OF LIGHT RECEIVING UNITS 9B1 TO 9B3 NORMAL VALUES ?
YES
NO
S83
COLOR OF LIGHT RECEIVING UNIT 9A1 = COLOR OF LIGHT RECEIVING UNIT 9B1 ?
NO
YES
S85
IS VOLTAGE VALUE OF LIGHT RECEIVING UNIT 9C1 NORMAL VALUE ?
NO
YES
S86
COLOR OF LIGHT RECEIVING UNIT 9A1 = COLOR OF LIGHT RECEIVING UNIT 9C1 ?
NO
YES
S89
ARE VOLTAGE VALUES OF LIGHT RECEIVING UNITS 9B1 TO 9B3 NORMAL VALUES ?
NO
YES
S91
ABNORMAL DETECTION
S88
ABNORMAL DETECTION
S90
USE LIGHT RECEIVING UNITS 9B1 TO 9B3
S87
USE LIGHT RECEIVING UNITS 9B1 TO 9B3
S84
USE LIGHT RECEIVING UNITS 9A1 TO 9A3
END

FIG. 14

FIG. 15A

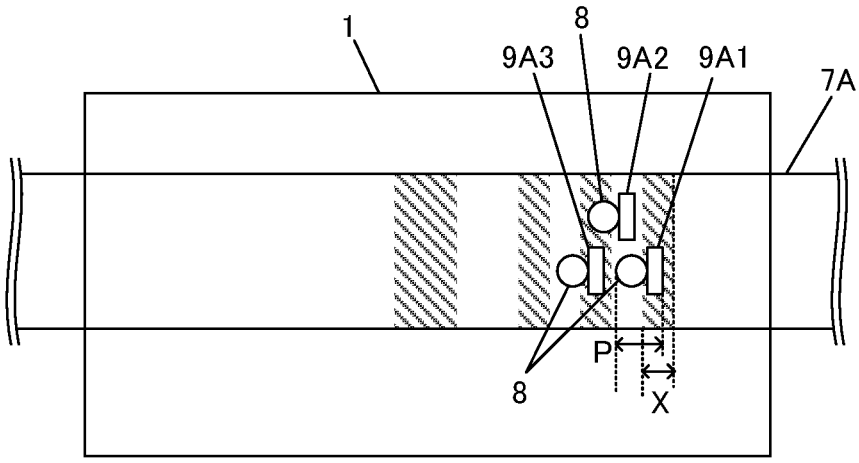


FIG. 15B

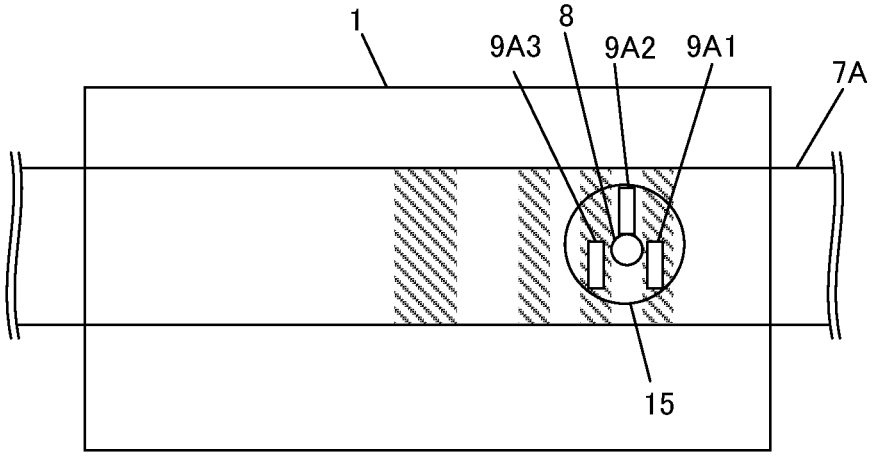


FIG. 16A

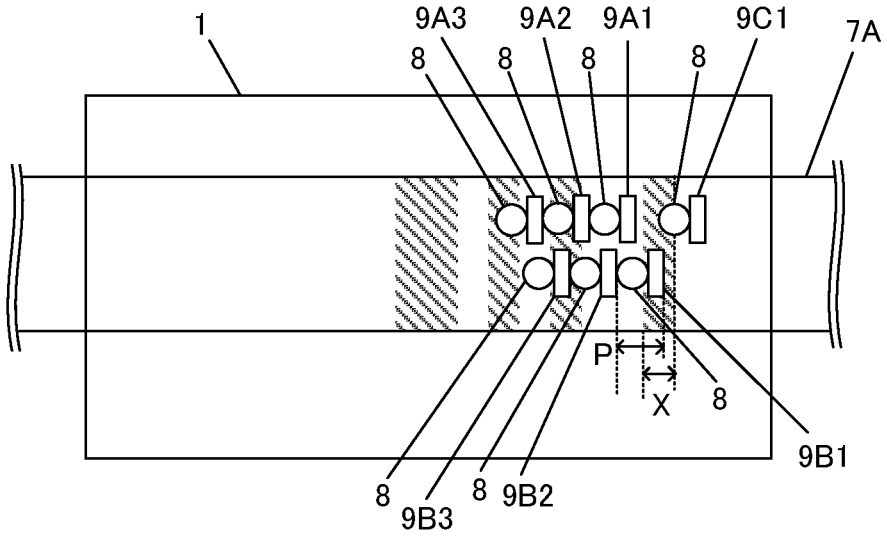


FIG. 16B

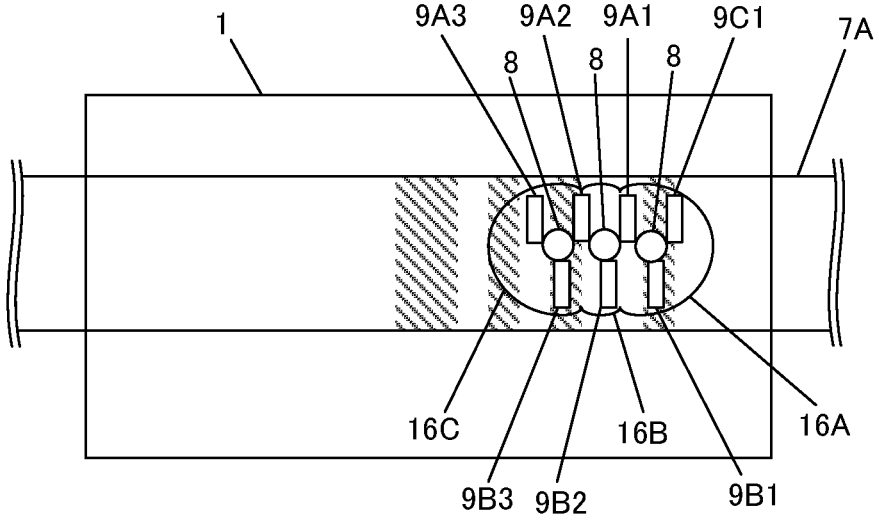


FIG. 17A

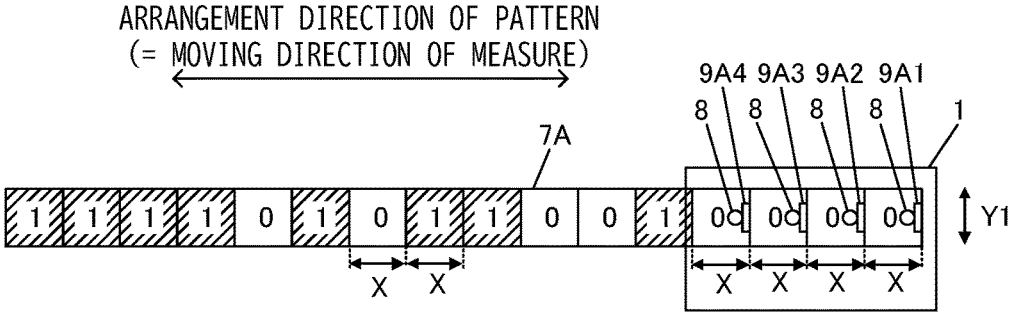


FIG. 17B

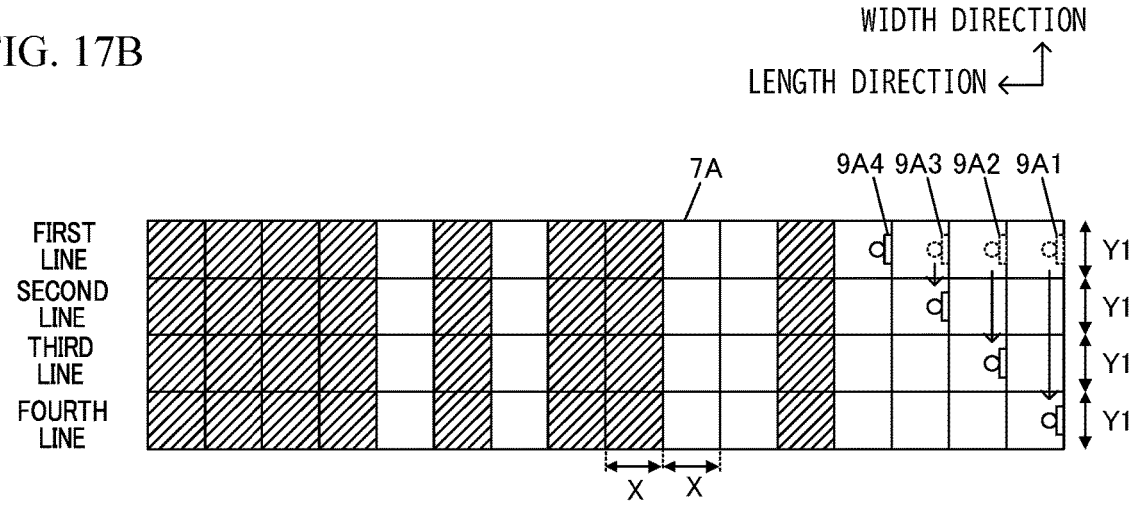


FIG. 17C

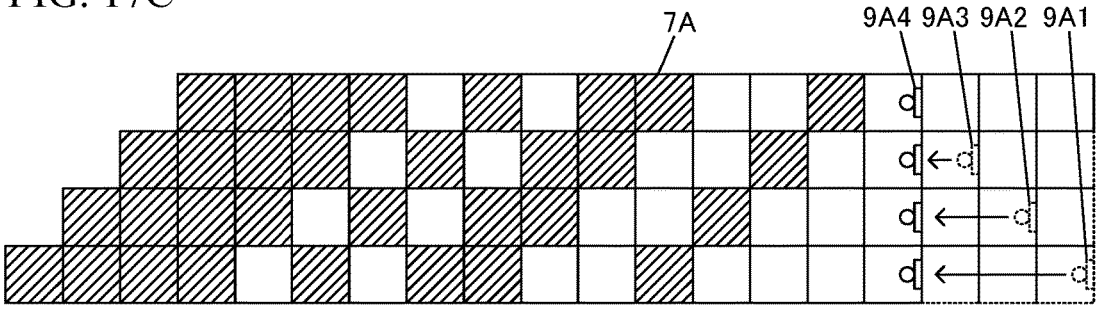


FIG. 17D

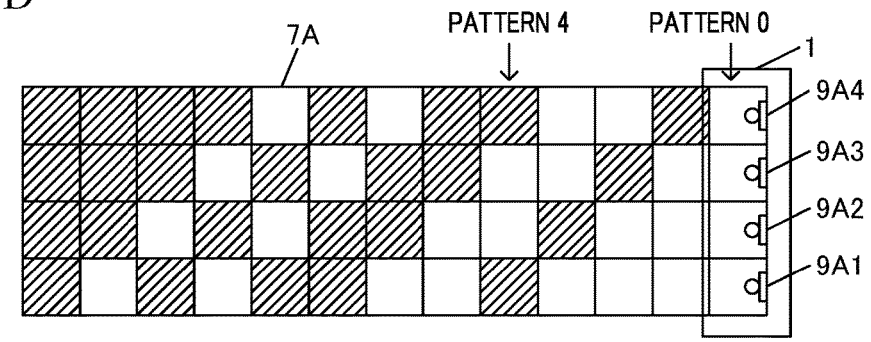


FIG. 18

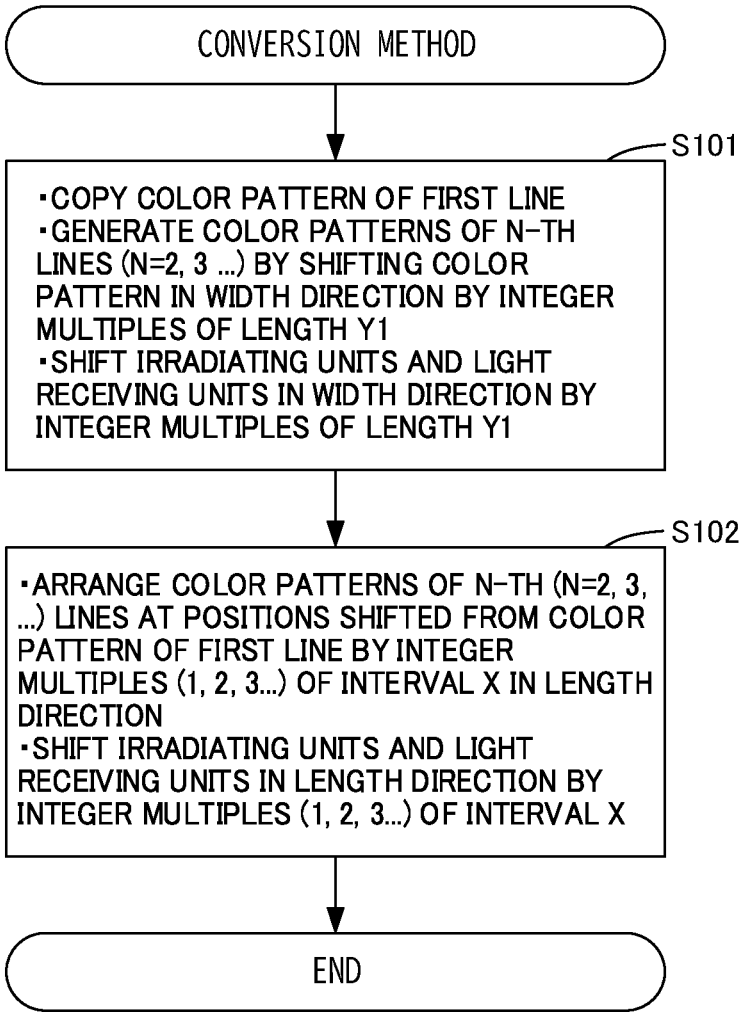
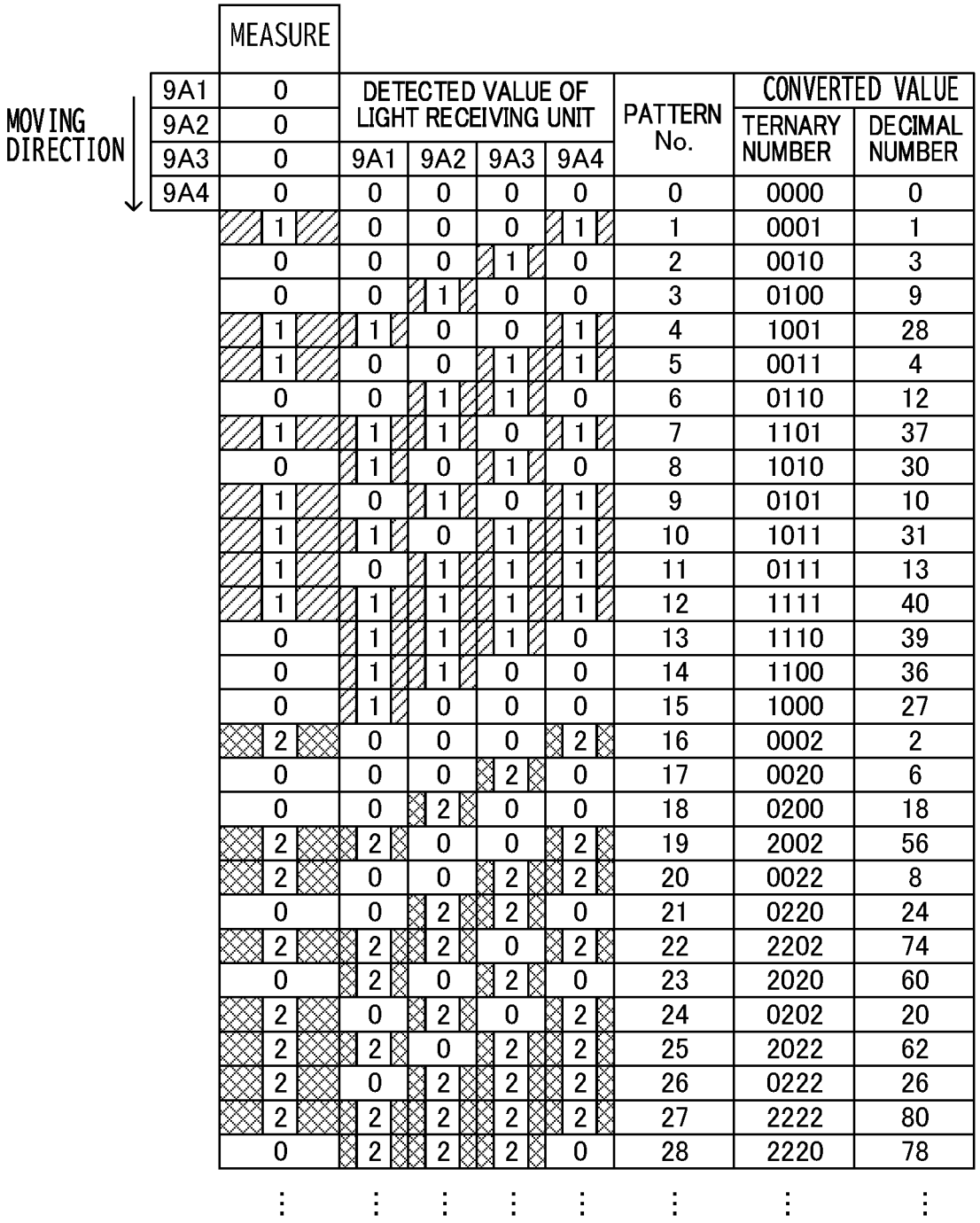

CONVERSION METHOD
S101
・COPY COLOR PATTERN OF FIRST LINE
・GENERATE COLOR PATTERNS OF N-TH LINES (N=2, 3 ...) BY SHIFTING COLOR PATTERN IN WIDTH DIRECTION BY INTEGER MULTIPLES OF LENGTH Y1
・SHIFT IRRADIATING UNITS AND LIGHT RECEIVING UNITS IN WIDTH DIRECTION BY INTEGER MULTIPLES OF LENGTH Y1
S102
・ARRANGE COLOR PATTERNS OF N-TH (N=2, 3, ...) LINES AT POSITIONS SHIFTED FROM COLOR PATTERN OF FIRST LINE BY INTEGER MULTIPLES (1, 2, 3...) OF INTERVAL X IN LENGTH DIRECTION
・SHIFT IRRADIATING UNITS AND LIGHT RECEIVING UNITS IN LENGTH DIRECTION BY INTEGER MULTIPLES (1, 2, 3...) OF INTERVAL X
END

FIG. 19



MEASURE							
9A1	0	DETECTED VALUE OF LIGHT RECEIVING UNIT				PATTERN No.	CONVERTED VALUE	
9A2	0						TERNARY NUMBER	DECIMAL NUMBER
9A3	0	9A1	9A2	9A3	9A4			
9A4	0	0	0	0	0	0	0000	0
	1	0	0	0	1	1	0001	1
	0	0	0	1	0	2	0010	3
	0	0	1	0	0	3	0100	9
	1	1	0	0	1	4	1001	28
	1	0	0	1	1	5	0011	4
	0	0	1	1	0	6	0110	12
	1	1	1	0	1	7	1101	37
	0	1	0	1	0	8	1010	30
	1	0	1	0	1	9	0101	10
	1	1	0	1	1	10	1011	31
	1	0	1	1	1	11	0111	13
	1	1	1	1	1	12	1111	40
	0	1	1	1	0	13	1110	39
	0	1	1	0	0	14	1100	36
	0	1	0	0	0	15	1000	27
	2	0	0	0	2	16	0002	2
	0	0	0	2	0	17	0020	6
	0	0	2	0	0	18	0200	18
	2	2	0	0	2	19	2002	56
	2	0	0	2	2	20	0022	8
	0	0	2	2	0	21	0220	24
	2	2	2	0	2	22	2202	74
	0	2	0	2	0	23	2020	60
	2	0	2	0	2	24	0202	20
	2	2	0	2	2	25	2022	62
	2	0	2	2	2	26	0222	26
	2	2	2	2	2	27	2222	80
	0	2	2	2	0	28	2220	78
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

MOVING DIRECTION

FIG. 20A

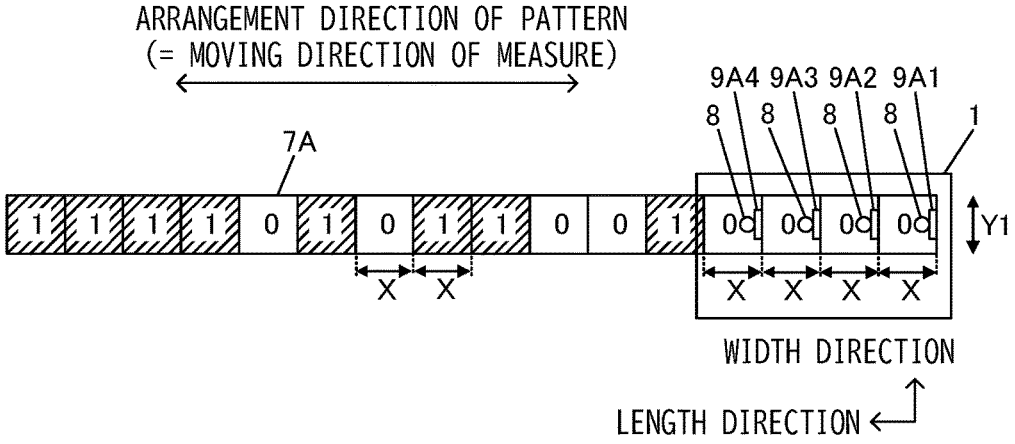


FIG. 20B

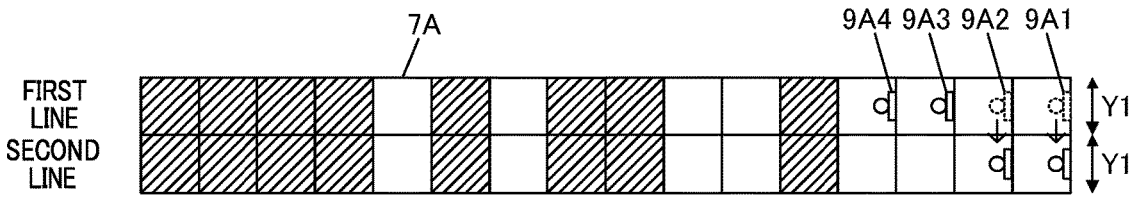


FIG. 20C

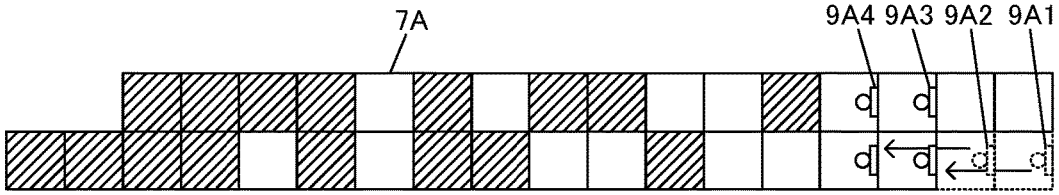


FIG. 20D

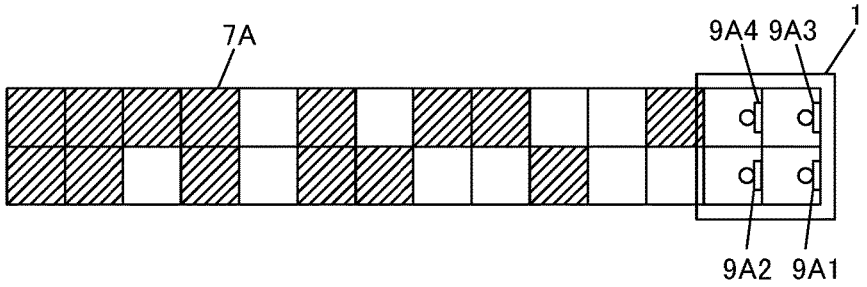


FIG. 21A

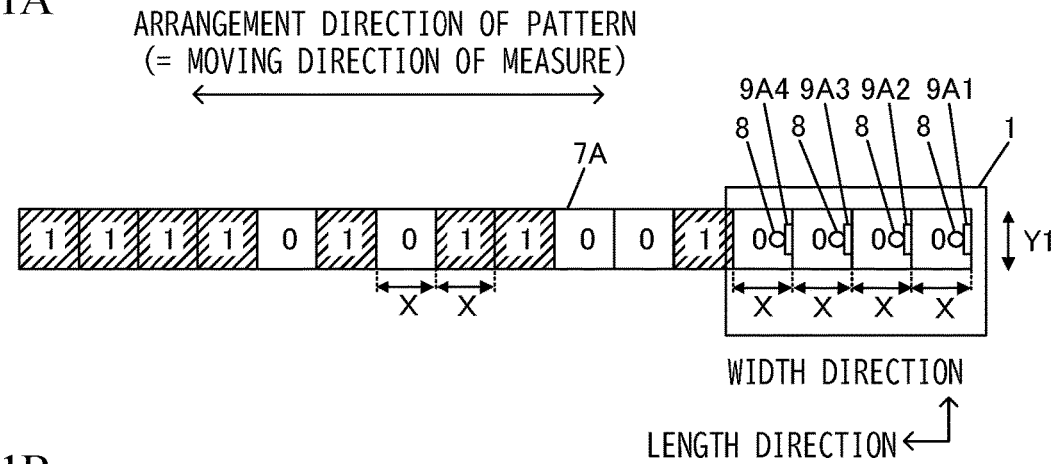


FIG. 21B

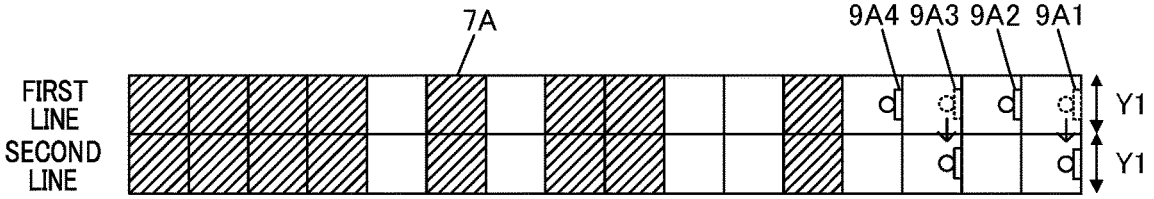


FIG. 21C

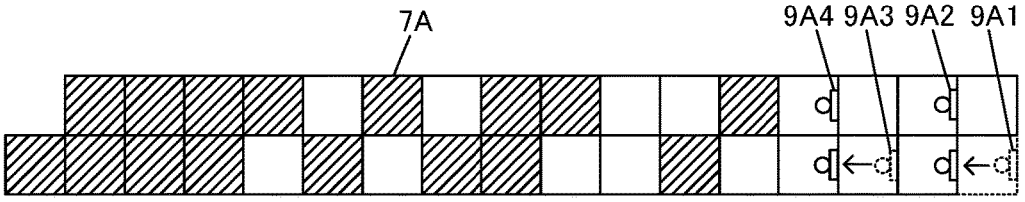
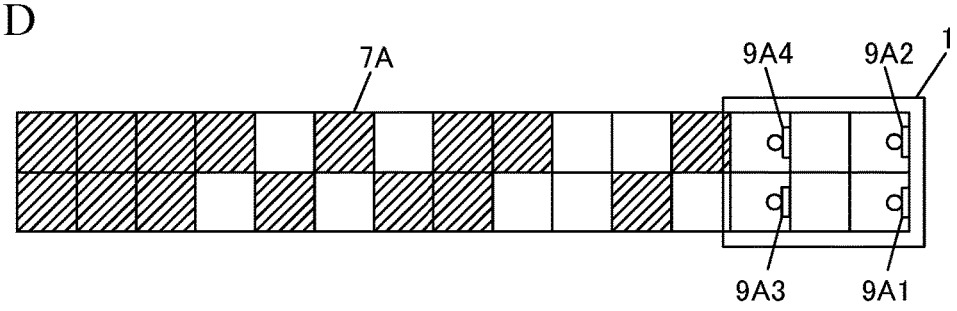


FIG. 21D



MEASURING INSTRUMENT AND MEASURE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority of the prior Japanese Patent Applications No. 2019-224854 filed on Dec. 12, 2019 and No. 2020-189632 filed on Nov. 13, 2020, the entire contents of which are incorporated herein by reference.

FIELD

[0002] A certain aspect of the embodiments is related to a measuring instrument and a measure.

BACKGROUND

[0003] There is known a measurement system that can directly input length data obtained by measuring a length of an object to an external terminal (e.g. Japanese Laid-open Patent Publication No. 7-35535). In the measurement system, a two-color dot pattern printed on a measure is read, and the read pattern is converted into the length data and transmitted.

[0004] There is known a handy terminal with a dimensional measurement function (e.g. Japanese Laid-open Patent Publication No. 10-105639). Furthermore, there are known techniques for optically reading a pattern printed on a measure (e.g. Japanese Laid-open Patent Publications No. 2009-75013, No. 5-272916 and No. 7-294238).

SUMMARY

[0005] According to an aspect of the present invention, there is provided a measuring instrument including: a plurality of first readers that optically read a plurality of patterns from a measure having a color pattern including the plurality of patterns arranged at a regular interval in a length direction, the plurality of first readers being arranged at the regular interval in the length direction; a converter that converts the plurality of patterns read by the plurality of first readers into a value of an N-ary number (N is 3 or more); and a calculator that calculates a scale value of the measure based on data that defines a relationship between the value of the N-ary number and the scale value of the measure,

[0006] The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

[0007] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** is a configuration diagram of a length measuring instrument according to a first embodiment;

[0009] FIG. **2** is a diagram illustrating an example in which the measuring instrument having three sets of light receiving units reads a measure;

[0010] FIG. **3** is a diagram illustrating an example of a table in which a single scale value of the measure is assigned to three patterns.

[0011] FIG. **4** is a diagram illustrating an example of color patterns on the measure;

[0012] FIG. **5** is a flowchart illustrating a measurement process to be executed by the measuring instrument;

[0013] FIG. **6** is a diagram illustrating a correspondence relationship between a color number detected by each light receiving unit and a detected voltage value;

[0014] FIG. **7** is a flowchart illustrating a color determination process in S**4**;

[0015] FIG. **8** is a diagram illustrating a relationship between color numbers, a voltage value, and a corresponding color number of the two patterns when the light receiving units read a boundary between the two patterns;

[0016] FIG. **9** is a diagram illustrating an example in which a measuring instrument according to a second embodiment reads the measure;

[0017] FIG. **10** is a diagram illustrating a relationship between color numbers detected by three light receiving units and light receiving units to be used for scale conversion;

[0018] FIG. **11** is a flowchart illustrating a measurement process to be executed by the measuring instrument according to the second embodiment.

[0019] FIG. **12** is a flowchart illustrating a color determination process in S**34**;

[0020] FIG. **13** is a flowchart illustrating the color determination process in S**34**;

[0021] FIG. **14** is a flowchart illustrating a boundary determination process in S**35**;

[0022] FIG, **15**A is a diagram illustrating a first variation of the measuring instrument according to the first embodiment;

[0023] FIG. **15**B is a diagram illustrating a second variation of the measuring instrument according to the first embodiment;

[0024] FIG. **16**A is a diagram illustrating a first variation of the measuring instrument according to the second embodiment;

[0025] FIG. **16**B is a diagram illustrating a second variation of the measuring instrument according to the second embodiment;

[0026] FIGS. **17**A to **17**D are diagrams illustrating a method for converting a plurality of patterns arranged in a row in the length direction into the plurality of patterns arranged in four rows in the width direction in order to read the color pattern using four light receiving units arranged in a row in the width direction;

[0027] FIG. **18** is a flowchart illustrating a method for arranging color patterns arranged in four rows in the width direction of FIG. **17**D using the color pattern arranged in a row in the length direction of FIG: **17**A;

[0028] FIG. **19** is a diagram illustrating a correspondence relationship between the measure of FIG. **17**A, values read by the four light receiving units, a pattern No., and converted values of a ternary number and a decimal number;

[0029] FIGS. **20**A to **20**D are diagrams illustrating a method for converting the plurality of patterns and the four light receiving units arranged in a row in the length direction into the plurality of patterns arranged in two rows in the width direction and the four light receiving units arranged in two rows in the width direction; and

[0030] FIGS. **21**A to **21**D are diagrams illustrating a variation of the method for converting the plurality of patterns and the four light receiving units arranged in a row in the length direction into the plurality of patterns arranged

in two rows in the width direction and the four light receiving units arranged in two rows in the width direction.

DESCRIPTION OF EMBODIMENTS

[0031] In a measure in which a plurality of line patterns each having a plurality of patterns in a width direction are printed, a single line pattern corresponds to a single measured value. Therefore, when a length that can be measured by the measure is increased, the number of patterns constituting the single line pattern must be increased, and the width of the measure needs to be increased.

[0032] In the case of a curved measure such as a convex type steel measure, if the plurality of patterns are printed in the width direction of the measure, a distance between a sensor and each pattern changes depending on a position in the width direction, so that an error may occur in a reading result of each sensor. For example, in the case of a measure that is curved toward the sensor at a central portion, a sensor arranged opposite to a pattern located at the center of the measure is close to the measure, but sensors located at the ends of the measure in the width direction are away from the measure. For this reason, even if the pattern of the same color is read, the color of the pattern may not be accurately detected due to the influence of fluctuations in the amount of light received by the center sensor and the end sensors. This problem can occur not only in the steel measure but also in a resin measure when a detector is tilted or the measure is twisted.

[0033] Hereinafter, a description will be given of the present embodiment of the present invention with reference to the drawings.

First Embodiment

[0034] FIG. **1** is a configuration diagram of a length measuring instrument according to a first embodiment. In one example, the length measuring instrument may be used in a clothing store, but may be used for any other purposes.

[0035] A length measuring instrument (hereinafter referred to as "a measuring instrument") **1** includes: a reader unit **2** that reads a color pattern from a measure **7**A; a microcomputer **3** that calculates a length of a measurement object from data read by the reader unit **2**; a communication unit **4** that transmits data on the calculated length of the measurement object to an external terminal **10** by wired or wireless communication; a switch **5** that instructs the start of the measurement to the microcomputer **3**; a battery **6** that supplies an electric power to the reader unit **2**, the microcomputer **3** and the communication unit **4**; and a storage **7** that stores the measure **7**A. The microcomputer **3** includes a buffer **3**A storing data, flags, and the like.

[0036] The measuring instrument **1** and the external terminal **10**, or the measuring instrument **1** alone, may configure a measuring system for measuring and determining a length of a measurement object. When the measuring instrument **1** and the external terminal **10** are combined, a process of calculating the length of the measurement object may be performed by the external terminal **10** as a substitute for the microcomputer **3** of FIG. **1**. At this time, the measuring instrument **1** transmits a reading value read by the reader unit **2** to the external terminal **10**. When the external terminal **10** is not used, the measuring instrument **1** may execute the functions of the external terminal **10** described in first to third embodiments. The measuring system may further include other devices such as a server, a storage device, or any type of communication devices.

[0037] The measuring system may have functions for storing measured lengths, or processing the measured lengths for purposes such as measurement for making clothes for example. These functions are realized by executing software in the external terminal **10** or other devices.

[0038] The reader unit **2** includes: irradiating units **8** each of which irradiates the color pattern with a light; and light receiving units **9** each of which receives reflected light from the color pattern, and outputs a current or voltage with a value corresponding to a receiving light amount. The irradiating unit **8** is a light emitting diode (LED) **8**, and the light receiving unit **9** is a phototransistor, for example. The irradiating unit **8** is irradiated with light such as infrared light, visible light and ultraviolet light. The light receiving unit **9** receives the light reflected by the color pattern. Unless otherwise explained, the single irradiating unit **8** and the single light receiving unit **9** are used in a single set, but the single irradiating unit **8** and a plurality of light receiving units **9** may be used in the single set, as described below. When it is necessary to distinguish the plurality of light receiving units from each other, the light receiving units are designated by reference numbers such as **9**A**1** to **9**A**4**, **9**B**1** to **9**B**4** or **9**C**1**. Hereinafter, the set of the irradiating unit **8** and the light receiving unit **9** may be collectively referred to as the "light receiving unit **9**". The reader unit **2** should have at least a function corresponding to the light receiving unit **9**.

[0039] The microcomputer **3** includes a processor such as a central processing unit (CPU), and a nonvolatile memory, and functions as a converter, a calculator, and a determiner. The microcomputer **3** controls on/off of the irradiating unit **8**, and reads the current value or voltage value of the output from the light receiving unit **9**. Since the reflectivities of the light are different by colors, and the light receiving amount of the light receiving unit **9** varies depending on the reflectivities, the microcomputer **3** is capable of determining the color of each pattern by the current value or voltage value output from the light receiving unit **9**. Then, the microcomputer **3** converts a color detected by each light receiving unit **9** into a value of a ternary number or decimal number, and calculate a scale value of the measure **7**A corresponding to the converted value of the ternary number or decimal number using a table described later. Thereby, the length of the measurement object is calculated.

[0040] Scales are printed on a front surface of the measure **7**A along a longitudinal direction, and color patterns using N (N>=3) colors are printed on a back surface of the measure **7**A. The details of the color pattern are described later. The storage **7** is removably attached to a housing of the measuring instrument **1**. In FIG. **1**, the measure **7**A is housed in the storage **7**. However, the measure **7**A does not need to be stored in the storage **7** or in the measuring instrument **1** as long as the measuring instrument **1** can read color patterns on the measure **7**A. For instance, the measuring instrument **1** may have a slit for slidably passing the measure **7**A without accommodating the measure **7**A.

[0041] The external terminal **10** is a communication terminal such as a computer or smart phone having a wired or wireless communication function, receives the data of the length of the measurement object from the communication unit **4**, and registers and manages the data in the database. The database for registering the data of the length may be

incorporated in the external terminal **10**, or may be provided outside of the external terminal **10** in an accessible state, Further, software for processing the measured length may be stored in the external terminal **10** or in any other device in which the external terminal **10** is accessible.

[0042] FIG. **2** is a diagram illustrating an example of a color pattern printed on the back surface of the measure **7**A according to the present embodiment. The present embodiment represents an example of reading the color pattern of the measure **7**A by using the measuring instrument **1** having three sets of the irradiating unit **8** and the light receiving unit **9**. A vertical direction of FIG. **2** is a width direction of the measure **7**A. A horizontal direction of FIG. **2** is a length direction of the measure **7**A, and a moving direction of the measure **7**A with respect to the measuring instrument **1**.

[0043] A color pattern including a plurality of patterns arranged in a row in the length direction at regular intervals X is printed on the measure **7**A of FIG. **2**. Each pattern has any one of three different colors, and any value of 0, 1 or 2 is assigned to each color. In the example of FIG. **2**, each pattern has any one of white, blue, and black, and values of "0", "1", and "2" are assigned to white, blue, and black, respectively. In the pattern of FIG. **2**, the values of "0" to "2" corresponding to the colors are illustrated, but this is for easy understanding, and it is not necessary to print these values on the measure **7**A. Similarly, the boundaries between the patterns are also illustrated for ease of understanding, but it is not necessary to draw such boundaries on the measure **7**A.

[0044] In the example of FIG. **2**, three patterns adjacent to each other in the length direction constitute a single unit pattern, and a single ternary value is assigned to the single unit pattern.

[0045] Since it is sufficient that the three values corresponding to "0" to "2" can be output by reading by the reader unit **2**, it is not necessary to print each pattern in different colors or different hues, If respective patterns can be optically distinguished, the color patterns with different shade and reflectivity of the individual pattern may be used. For example, patterns with different brightness and saturation in the same hue may be printed, such as "light red", "slightly darker red", "even darker red" and so on, Further, as long as the reader unit **2** can distinguish the colors, the difference in color need not to be visually distinguishable. In the present embodiment, such differences in brightness and saturation, and other modes for realizing different reflectivity are also treated as "different colors", The reflectivities of the patterns may be different by changing the shapes of the respective patterns. If the "reflectivities" of the patterns are focused on, these can also be regarded as the "different colors" for convenience.

[0046] An interval X, which is also a length of the pattern, corresponds to a unit length measurable by the measure **7**A. In the measuring instrument **1**, three light receiving units **9A1** to **9A3** and three irradiating units **8** for detecting the reflected light from the color patterns of the measure **7**A are arranged at the intervals X in the same manner as the patterns. Each light receiving unit **9**A reads any one of the patterns constituting the single unit pattern. The number of sets of the irradiating unit **8** and the light receiving unit **9** may be two or four or more depending on the number of patterns constituting the single unit pattern and the like. As will be described later, the number of irradiating units **8** does not have to be the same as the number of patterns constituting the single unit pattern.

[0047] The light receiving unit **9** outputs a voltage having a value corresponding to the reflected light from the pattern. The microcomputer **3** determines the color of each pattern based on the voltage value output from the light receiving unit **9**. In the present embodiment, when the output voltage of the light receiving unit **9** is 2.0V, 1.5V or 1.0V, the microcomputer **3** determines that the pattern color is white, blue or black, respectively. The microcomputer **3** replaces the read color with one of the corresponding ternary values "0" to "2", if necessary.

[0048] Since the moving direction of the measure **7**A is the same as an arrangement direction of the patterns, each time the measure **7**A moves by the length of one pattern, the patterns read by the light receiving units **9A1** to **9A3** also shift one by one in the length direction. The three light receiving units **9A1** to **9A3** function as a plurality of first readers.

[0049] The buffer **3**A includes a table in which the scale values of the measure **7**A are assigned to the unit pattern read by the light receiving units **9A1** to **9A3**. An example of the table is illustrated in FIG. **3**, and the color pattern corresponding to the table is illustrated in FIG. **4**.

[0050] The measuring instrument **1** reads the single unit pattern including the three patterns adjacent to each other in the length direction. In FIG. **3**, the colors of the three patterns read by the measuring instrument **1**, the ternary number corresponding to each unit pattern, the decimal number converted from the ternary number, and the scale value corresponding to the unit pattern are associated with each other.

[0051] An L-th unit pattern (L>=1) in FIG. **3** corresponds to a combination of the L-th to L+2-th three patterns from the beginning among the color patterns in FIG. **4**. For example, a third unit pattern in FIG. **3** corresponds to a combination of third to fifth three patterns in FIG. **4**.

[0052] In the measure **7**A, the colors of the patterns are arranged so that the configuration of the unit patterns from the beginning to the end do not overlap with each other.

[0053] Each color pattern of the present embodiment is represented by the ternary number, but in the table illustrated in FIG. **3**, the ternary numbers corresponding to the unit patterns are not arranged in an ascending or descending order, Further, decimal values converted from ternary values are also not arranged in the ascending or descending order of the decimal number. On the other hand, the scale values arranged in the table in the ascending order do not mathematically correspond to the ternary values or the decimal values in the table. For example, a ternary value "101" in a fourth row of FIG. **3** mathematically means a decimal number "10", but is assigned to a scale value "3". For this reason, in this embodiment, the table is used to determine the correspondence between the scale value in the ascending order, and the ternary value and the decimal value that are not arranged in the ascending or descending order.

[0054] The microcomputer **3** determines the scale value corresponding to the three patterns read by the light receiving units **9A1** to **9A3** based on the table in FIG **3**, and the communication unit **4** transmits the scale value to the external terminal **10**.

[0055] FIG. **5** is a flowchart illustrating a measurement process to be executed by the measuring instrument **1**.

[0056] The irradiating unit **8** is turned off before the start of the length measurement process of the length. When a user operates the switch **5** in measuring the length of the

measurement object using the measure **7**A, the measuring instrument **1** executes the measurement process illustrated in FIG. **5**.

[0057] When the switch **5** is operated to measure the length, the microcomputer **3** turns on all the irradiating units **8** (S**1**). As a result, since the light receiving units **9**A**1** to **9**A**3** receive the reflected light from each pattern, the microcomputer **3** reads out output voltage values of the light receiving units **9**A**1** to **9**A**3** (S**2**), and then turns off the irradiating units **8** (S**3**), Next, the microcomputer **3** performs a color determination process for each pattern from the output voltage of the light receiving unit **9** (S**4**). The details of the color determination process are described later.

[0058] Next, the microcomputer **3** determines whether an abnormality is detected in the color determination process (S**5**). For example, when the output voltage value of any of the light receiving units **9** does not correspond to a predetermined voltage range to be detected, the microcomputer **3** determines that the abnormality is detected. When the abnormality is detected in the color determination process (YES in S**5**), this process ends. When the abnormality is not detected in the color determination process (NO in S**5**), the microcomputer **3** calculates the ternary value and/or the decimal value corresponding to the unit pattern from the colors of the patterns read by the light receiving units **9**A**1** to **9**A**3** (S**6**).

[0059] The microcomputer **3** initializes the value of L corresponding to the scale value in the table of FIG. **3** by setting it to 0 (L=0), in order to compare the L-value with the value calculated in S**6** (S**7**). Next, the microcomputer **3** determines whether the value calculated in S**6** matches the L-th scale value in the table of FIG. **3** (S**8**), When the value calculated in S**6** matches the L-th scale value (YES in S**8**), the microcomputer **3** stores the scale value in the buffer **3**A (S**11**), and this process ends. The scale value stored in the buffer **3**A is transmitted to the external terminal **10** using the communication unit **4**. On the other hand, when the value calculated in S**6** does not match the L-th scale value (NO in S**8**), the microcomputer **3** increments the L value by 1 (L=L+1) (S**9**). Then, the microcomputer **3** determines whether all the scale values (L=0 to 26) are checked (S**10**). When all the scale values are not checked (NO in S**10**), the process returns to SS. When all the scale value are checked (YES in S**10**), this process ends. When the answer to the determination in S**10** is YES, the unit pattern corresponding to the read unit pattern is not set in the table of FIG. **3**, and hence the process is treated as an error.

[0060] FIG. **6** is a diagram illustrating a correspondence relationship between the color number of the pattern and the output voltage value which is a detected value of each light receiving unit. When the output voltage value of the light receiving unit **9** is 2.0V±5%, the color number becomes 1. When the detected value of the light receiving unit **9** is 1.5±5%, the color number becomes 2. When the detected value of the light receiving unit **9** is 1.0V+5%, the color number becomes 3. The microcomputer **3** performs the process of S**4** by utilizing such a correspondence relationship.

[0061] FIG. **7** is a flowchart illustrating the color determination process in S**4**.

[0062] The microcomputer **3** sets a light receiving unit **9**An, which is an object of the color determination process, to **9**A**1** as an initial value (n=1) (S**21**). Next, the microcomputer **3** sets 1 as an initial value of a color number m which is a determination object (m=1) (S**22**). Then, the microcomputer **3** determines whether the voltage value detected by the light receiving unit **9**An is included in a range of the voltage value of FIG. **6** corresponding to the color number m (S**23**).

[0063] When the voltage value of the light receiving unit **9**An is not included in the range of the voltage value corresponding to the color number m (NO in S**23**), the microcomputer **3** increments a value of the color number m by 1 (m=m+1) (S**24**). The microcomputer **3** determines whether the voltage values corresponding to all the color numbers are checked (S**25**).

[0064] When the voltage values corresponding to all the color numbers are not checked (NO in S**25**), the process returns to S**23**. When the voltage values corresponding to all the color numbers are checked (YES in S**25**), the microcomputer **3** determines that the detection result is abnormal (S**26**), and this process ends.

[0065] When the voltage value of the light receiving unit **9**An is included in the range of the voltage value corresponding to the color number m (YES in S**23**), the microcomputer **3** increments a value of the light receiving unit **9**An by 1 (n=n+1) (S**27**).

[0066] The microcomputer **3** determines whether all the light receiving units **9**An are checked (S**28**). When all the light receiving units **9**An are not checked (NO in S**28**), the process returns to S**22**, and a process related to the light receiving unit **9**An 1 is performed. When all the light receiving units **9**An are checked (YES in S**28**), this process ends.

[0067] As described above, according to the first embodiment, the light receiving units **9** are arranged in a row in the length direction of the measure **7**A at regular intervals, and optically read the patterns arranged at regular intervals in the length direction of the measure **7**A. Since it is sufficient that a single row of color pattern is printed on the measure **7**A, the width of the measure can be made smaller, and the first embodiment can be also applied to a curved measure such as the convex type measure.

Second Embodiment

[0068] FIG. **8** is a diagram illustrating a relationship between the color numbers of the two adjacent patterns, the voltage value output by the light receiving unit **9** and the color number corresponding to the voltage value, when the light receiving unit **9** reads a boundary between the two patterns. A "color number (first color)" refers to a pattern located on one side of the measure **7**A in the length direction with respect to the light receiving unit **9**, and the "color number (second color)" refers to a pattern located on the other side in the length direction. Here, the detected values when the light receiving unit **9** reads the patterns of color numbers 1, 2, and 3, are about 2.0V, about 1.5V, and about 1.0V, respectively, as illustrated in FIG. **6**.

[0069] When the light receiving unit **9** reads the boundary between the pattern of color number 1 and the pattern of color number 2, the voltage value becomes about 1.75V which corresponds to an intermediate value of 2.0V and 1.5V, as illustrated in a first or third stage of FIG. **8**. However, since there is no color corresponding to the voltage of 1.75V, the microcomputer **3** can determine that the detection result is abnormal. Similarly, when the light receiving unit **9** reads the boundary between the pattern of color number 2 and the pattern of color number 3, the voltage value becomes about 1.25V which corresponds to an

intermediate value of 1.5V and 1,0V, as illustrated in a fourth or sixth stage of FIG. **8**. However, since there is no color corresponding to the voltage of 1.25V, the microcomputer **3** can determine that the detection result is abnormal.

[0070] When the light receiving unit **9** reads the boundary between the pattern of the color number 1 and the pattern of the color number 3, the output voltage value of the light receiving unit **9** becomes about 1.5V, as illustrated in a second or fifth stage of FIG. **8**. Since the voltage value of 1.5V corresponds to the color of the color number **2**, even though the boundary between the pattern of the color number **1** and the pattern of the color number **3** is read, the microcomputer **3** determines that the detection result is normal as if the light receiving unit **9** reads the pattern of color number **2**. That is, the microcomputer **3** cannot determine whether the light receiving unit **9** reads the pattern of the color number **2** or the boundary between the patterns of the color number **1** and the color number **3**, based on only the voltage value from the light receiving unit **9**A.

[0071] In order to determine whether the boundary between the two patterns is read, the measuring instrument **1**A according to the second embodiment includes four sets of light receiving units **9** (**9B1** to **9B3**, **9C1**) in addition to three sets of light receiving units **9** (**9A1** to **9A3**).

[0072] FIG. **9** illustrates an example in which a measuring instrument **1**A according to the second embodiment reads the measure **7**A. The light receiving units **9B1** to **9B3** function as a second reader, and the light receiving units **9C1** function as third reader.

[0073] Although omitted in FIG. **9**, the measuring instrument **1**A includes the microcomputer **3**, the buffer **3**A, the communication unit **4**, the switch **5**, the battery **6**, the storage **7**, and the measure **7**A, as with the measuring instrument **1** according to the first embodiment. The measuring instrument **1**A is different from the measuring instrument **1** in the number of the irradiating units **8** and the light receiving units **9**, but the other configurations are the same.

[0074] The light receiving units **9A1** to **9A3** of FIG. **9** are arranged at the intervals X in the same manner as the light receiving units **9A1** to **9A3** of FIG. **3**. The light receiving units **9B1** to **9B3** of FIG. **9** are arranged at the intervals X, and arranged away by intervals Y toward a left side of FIG. **9** in the length direction from the light receiving units **9A1** to **9A3**. The light receiving unit **9C1** is arranged away by an interval Z toward a right side of FIG. **9** in the length direction from the light receiving unit **9A1**. The intervals Y and Z are shorter than the interval X, One of the intervals Y and Z may be large, or the intervals Y and Z may be the same. Although the light receiving unit **9C1** in FIG. **9** is arranged corresponding to the light receiving unit **9A1**, the light receiving unit **9C1** may be arranged on an opposite side of the light receiving unit **9B2** with respect to the light receiving unit **9A2**, or an opposite side of the light receiving unit **9B3** with respect to the light receiving unit **9A3**,

[0075] The light receiving units **9A1** to **9A3** are the light receiving units used for normal length measurement. When each of the light receiving units **941** to **9A3** reads the boundary between the two patterns, the light receiving units **9B1** to **9B3** are used for length measurement instead of the light receiving units **9A1** to **9A3**. Since the light receiving units **9A1** to **9A3** are arranged at the intervals X equal to the length of the single pattern, when the light receiving unit **9A1** reads the boundary between the two patterns, the light receiving units **9A2** and **9A3** also read the boundaries between two other patterns. For this reason, in order to determine whether the light receiving units **9B1** to **9B3** should be used for length measurement, it is sufficient to determine whether any one of the light receiving units **9A1** to **9A3**, e.g., the light receiving unit **9A1** reads the boundary. The microcomputer **3** can determine whether the light receiving unit **9A1** reads the boundary based on the colors of the patterns read by the light receiving units **9A1**, **9B1** and **9C1**.

[0076] Since a set of the light receiving units **9**A and a set of the light receiving units **9**B are shifted by the distance Y from each other, when the light receiving units **9B1** to **9B3** are used for length measurement, the microcomputer **3** may measure the length by subtracting the interval Y from the scale value of the measure **7**A calculated from the reading results of the light receiving units **9B1** to **9B3**.

[0077] FIG. **10** is a diagram illustrating a relationship between the color numbers detected by the light receiving units **9A1**, **9B1** and **9C1** and the light receiving units to be used for scale conversion (i.e., length measurement).

[0078] The light receiving units **9B1** and **9C1** are arranged at respective positions away from the light receiving unit **9A1** by the intervals Y and Z shorter than the interval X so that at least one of the light receiving units **9B1** and **9C1** reads the same pattern as the light receiving unit **9A1** when the light receiving unit **9A1** reads only the single pattern. In this case, when the color of the pattern read by the light receiving unit **9A1** is the same as the color of the pattern read by at least one of the light receiving units **9B1** and **9C1** as illustrated in first to fifth lines of FIG. **10**, the microcomputer **3** determines that the light receiving unit **9A1** does not read the boundary between the two patterns. When it is determined that the light receiving unit **9A1** reads the single pattern, the light receiving units to be used for length measurement are the light receiving units **9A1** to **9A3**.

[0079] When the light receiving unit **9A1** reads the boundary between the pattern of the color number **1** and the pattern of the color number **3**, the light receiving units **9B1** and **9C1** output detected values corresponding to the color number **1** and the color number **3**. respectively, and the light receiving unit **9A1** outputs a detected value corresponding to color number **2** which corresponds to the intermediate between the color number **1** and the color number **3**, as illustrated in sixth to seventh lines of FIG. **10**. Therefore, the colors of the patterns detected by the light receiving units **9A1**, **9B1** and **9C1** are different from each other. Thus, when the color detected by the light receiving unit **9A1** is different from the colors detected by the light receiving units **9B1** and **9C1**, the microcomputer **3** determines that the light receiving unit **9B1** reads the boundary between the two patterns. In this case, the light receiving units to be used for length measurement are light receiving units **9B1** to **9B3**.

[0080] In the above, the light receiving units **9**B are used for two purposes, i.e., to determine whether the light receiving unit **9**A reads the boundary between the two patterns, and to measure the length in place of the light receiving unit **9**A when the light receiving unit **9**A reads the boundary. In case of the latter purpose, the same number of light receiving units **9B1-9B3** as the light receiving units **9A1-9A3** are required. In case of the former purpose, it is sufficient that any one of the light receiving units **9B1** to **9B3** is provided.

[0081] FIG. **11** is a flowchart illustrating a measurement process to be executed by the measuring instrument IA according to the second embodiment.

[0082] When the switch **5** is operated, the microcomputer **3** turns on all the irradiating units **8** (S**31**). Then, the microcomputer **3** reads the voltage values of all the light receiving units **9**A**1** to **9**A**3**, **9**B**1** to **9**B**3** and **9**C**1** (S**32**), and turns off the irradiating units **8** (S**33**). Next, the microcomputer **3** performs a color determination process and a boundary determination process based on the output of the light receiving units **9** (S**34**, S**35**). The details of the color determination process and the boundary determination process are described later.

[0083] Next, the microcomputer **3** determines whether an abnormality is detected in the color determination process, as in S**5** (S**36**), When the abnormality is detected in the color determination process (YES in S**36**), this process ends. When the abnormality is not detected in the color determination process (NO in S**36**), the microcomputer **3** determines whether the light receiving units to be used for length measurement are the light receiving units **9**A**1** to **9**A**3**, from a result of the boundary determination process (S**37**).

[0084] When the light receiving units **9**A**1** to **9**A**3** are used for length measurement (YES in S**37**), the microcomputer **3** calculates the ternary value or the decimal value from the color of each pattern detected by the light receiving units **9**A**1** to **9**A**3** (S**38**), When the light receiving units **9**B**1** to **9**B**3** are used for length measurement (NO in S**37**), the microcomputer **3** calculates the ternary value or the decimal value from the color of each pattern detected by the light receiving units **9**B**1** to **9**B**3** (S**39**). After S**38** and S**39**, the microcomputer **3** sets the L corresponding to the scale value in the table of FIGS. **3** to 0 for comparison with the value calculated in S**38** or S**39** (L=0) (S**40**), Next, the microcomputer **3** determines whether the value calculated in S**38** or S**39** matches the L-th scale value with reference to the table of FIG. **3** (S**41**). When the value calculated in S**38** or S**39** matches the L-th scale value (YES in S**41**), the microcomputer **3** stores the scale value in the buffer **3**A (S**44**), and this process ends. The scale value stored in the buffer **3**A is transmitted to the external terminal **10** using the communication unit **4**.

[0085] When the value calculated in S**38** or S**39** does not match the L-th scale value (NO in S**41**), the microcomputer **3** increments the L value by 1 (L=L+1) (S**42**). Then, the microcomputer **3** determines whether all the scale values (L=0 to 26) are checked (S**43**). When all the scale values are not checked (NO in S**43**), the process returns to S**41**. When all the scale value are checked (YES in S**43**), this process ends.

[0086] FIGS. **12** and **13** are flowcharts illustrating the color determination process in S**34**.

[0087] The microcomputer **3** sets the light receiving unit **9**An, which is the object of the color determination process, to **9**A**1** (n=1) (S**51**), and sets the color number m to 1 (m=1) (S**52**). Next, the microcomputer **3** determines whether the voltage value of the light receiving unit **9**An is included in the range of the voltage value corresponding to the color number m (S**53**). When the voltage value of the light receiving unit **9**An is not included in the range of the voltage value corresponding to the color number m (NO in S**53**), the microcomputer **3** increments the color number m by 1 (m=m+1) (S**54**). The microcomputer **3** determines whether the voltage values corresponding to all the color numbers are checked (S**55**).

[0088] When the voltage values corresponding to all the color numbers are not checked (NO in S**55**), the process returns to S**53**. When the voltage values corresponding to all the color numbers are checked (YES in S**55**), the microcomputer **3** sets an abnormal flag indicating the abnormality of the light receiving unit **9**An to the buffer **3**A (S**56**), and the process proceeds to S**59**.

[0089] When the voltage value of the light receiving unit **9**An is included in the range of the voltage value corresponding to the color number m (YES in S**53**), the microcomputer **3** increments the value of the light receiving unit **9**An by 1 (n=n+1) (S**57**). The microcomputer **3** determines whether all the light receiving units **9**A.n are checked (S**58**). When all the light receiving units **9**An are not checked (NO in S**58**), the process returns to S**52**. When all the light receiving units **9**An are checked (YES in S**58**), the process proceeds to S**59**, and a process related to the light receiving units **9**B is performed.

[0090] The microcomputer **3** sets a light receiving unit **9**Bi, which is the object of the color determination process, to **9**B**1** (i=1) (S**59**), and sets the color number m to 1 (m=1) (S**60**). Next, the microcomputer **3** determines whether the voltage value of the light receiving unit **9**Bi is included in the range of the voltage value corresponding to the color number m (S**61**). When the voltage value of the light receiving unit **9**Bi is not included in the range of the voltage value corresponding to the color number m (NO in S**61**), the microcomputer **3** increments the color number m by 1 (m=m+1) (S**62**), The microcomputer **3** determines whether the voltage values corresponding to all the color numbers are checked (S**63**).

[0091] When the voltage values corresponding to all the color numbers are not checked (NO in S**63**), the process returns to S**61**. When the voltage values corresponding to all the color numbers are checked (YES in S**63**), the microcomputer **3** sets an abnormal flag indicating the abnormality of the light receiving unit **9**Bi to the buffer **3**A (S**64**), and the process proceeds to S**67**.

[0092] When the voltage value of the light receiving unit **9**Bi is included in the range of the voltage value corresponding to the color number m (YES in S**61**), the microcomputer **3** increments the value of the light receiving unit **9**Bi by 1 (i=i−1) (S**65**). The microcomputer **3** determines whether all the light receiving units **9**Bi are checked (S**66**). When all the light receiving units **9**Bi are not checked (NO in S**66**), the process returns to S**60**. When all the light receiving units **9**Bi are checked (YES in S**66**), the process proceeds to S**67**, and a process related to the light receiving unit **9**C**1** is performed.

[0093] The microcomputer **3** sets the color number m to 1 (m=1) (S**67**). Next, the microcomputer **3** determines whether the voltage value of the light receiving unit **9**C**1** is included in the range of the voltage value corresponding to the color number m (S**68**), When the voltage value of the light receiving unit **9**C**1** is not included in the range of the voltage value corresponding to the color number m (NO in S**68**), the microcomputer **3** increments the color number m by 1 (m=m+1) (S**69**). The microcomputer **3** determines whether the voltage values corresponding to all the color numbers are checked (S**70**). When the voltage values corresponding to all the color numbers are not checked (NO in S**70**), the process returns to S**68**. When the voltage values corresponding to all the color numbers are checked (YES in S**70**), the microcomputer **3** sets an abnormal flag indicating the abnormality of the light receiving unit **9**C**1** to the buffer **3**A (S**71**), and this process ends.

[0094] When the voltage value of the light receiving unit **9C1** is included in the range of the voltage value corresponding to the color number m (YES in S**68**), this process ends.

[0095] FIG. **14** is a flowchart illustrating the boundary determination process in S**35**.

[0096] The microcomputer **3** determines whether the voltage values of the light receiving units **9A1** to **9A3** are normal values (S**81**). When the voltage value of the light receiving unit **9** is included in the range of the voltage value corresponding to any of the color numbers m, the microcomputer **3** determines that the voltage value of the light receiving unit **9** is the normal value. When the voltage values of the light receiving units **9A1** to **9A3** are normal values (YES in S**81**), the microcomputer **3** determines whether the voltage values of the light receiving units **9B1** to **9B3** are normal values (S**82**). When the voltage value of any of the light receiving units **9B1** to **9B3** is not normal values (NO in S**82**), the microcomputer **3** measures the length using the voltage values of the light receiving units **9M** to **9A3** (S**84**), and this process ends.

[0097] When the voltage values of the light receiving units **9B1** to **9B3** are normal values (YES in S**82**), the microcomputer **3** determines whether the color detected by the light receiving unit **9A1** matches the color detected by the light receiving unit **9B1** (S**83**). When the color detected by the light receiving unit **9A1** matches the color detected by the light receiving unit **9B1** (YES in S**83**), the process proceeds to S**84**. When the color detected by the light receiving unit **9A1** does not match the color detected by the light receiving unit **9B1** (NO in S**83**), the microcomputer **3** determines whether the voltage value of the light receiving unit **9C1** is the normal value (S**85**).

[0098] When the voltage value of the light receiving unit **9C1** is not the normal value (NO) in S**85**), the microcomputer **3** determines that the detection result is abnormal (S**88**), and this process ends. When the voltage value of the light receiving unit **9C1** is the normal value (YES in S**85**), the microcomputer **3** determines whether the color detected by the light receiving unit **9A1** matches the color detected by the light receiving unit **9C1** (S**86**). When the color detected by the light receiving unit **9A1** matches the color detected by the light receiving unit **9C1** (YES in S**86**), the process proceeds to S**84**. When the color detected by the light receiving unit **9A1** does not match the color detected by the light receiving unit **9C1** (NO in S**86**), the microcomputer **3** measures the length using the voltage values of the light receiving units **9B1** to **9B3** (S**87**), and this process ends.

[0099] When any of the voltage values of the light receiving units **9A1** to **9A3** is not the normal value (NO in S**81**), the microcomputer **3** determines whether the voltage values of the light receiving units **9B1** to **9B3** are the normal values (S**89**). When any of the voltage values of the light receiving units **9B1** to **9B3** is not the normal value (NO in S**89**), the microcomputer **3** determines that the detection result is abnormal (S**91**), and this process ends. When the voltage values of the light receiving units **9B1** to **9B3** are the normal values (YES in S**89**), the microcomputer **3** measures the length using the voltage values of the light receiving units **9B1** to **9B3** (S**90**), and this process ends.

[0100] FIG. **15**A is a diagram illustrating a first variation of the measuring instrument according to the first embodiment, and FIG. **15**B is a diagram illustrating a second variation of the measuring instrument according to the first embodiment.

[0101] In the measuring instrument **1** according to the first embodiment, the length X of the pattern is longer than a length required for arranging the light receiving unit **9** and the irradiating unit **8** in the length direction, and hence the plurality of sets of light receiving units **9** are arranged in a row in the length direction of the measure **7**A, as illustrated in FIG. **7**.

[0102] However, when the length X of the pattern is shorter than a length P required for arranging one set of light receiving unit **9** in the length direction, as illustrated in FIG. **15**A, the plurality of sets of light receiving units **9** cannot be arranged in a row in the length direction of the measure **7**A. In this case, the plurality of sets of light receiving units **9** (**9A1** to **9A3**) may be arranged in a plurality of rows by shifting them in the width direction of the measure **7**A. as illustrated in FIG. **15**A. Even in such an arrangement, the length of the measurement object can be measured as in the first embodiment, and the measurement with higher resolution can be performed.

[0103] Further, the single irradiating unit **8** may be arranged within a range **15** where the plurality of light receiving units **9A1** to **9A3** can receive the reflected light, as illustrated in FIG. **15**B. In this case, the light receiving units **9A1** to **9A3** are arranged in the plurality of rows in the width direction of the measure **7**A. Even in such an arrangement, the length of the measurement object can be measured as in the first embodiment, and the number of irradiating units **8** can be reduced. Therefore, power consumption and manufacturing cost of the measuring instrument **1** can be reduced.

[0104] FIG. **16**A is a diagram illustrating a first variation of the measuring instrument **1** according to the second embodiment, and FIG. **16**B is a diagram illustrating a second variation of the measuring instrument **1** according to the second embodiment.

[0105] As illustrated in FIG. **16**A, the plurality of sets of light receiving units **9** (**9A1** to **9A3**, **9B1** to **9B3**, **9C1**) may be arranged in the plurality of rows in the width direction of the measure **7**A. Even in such an arrangement, the length of the measurement object can be measured as in the second embodiment, and the measurement with higher resolution can be performed.

[0106] Further, the single irradiating unit **8** may be arranged in a range **16**A where the plurality of light receiving units **9A1**, **9B1** and **9C1** can receive the reflected light, another single irradiating unit **8** may be arranged in a range **16**B where the light receiving units **9A1**, **9B2** and **9A2** can receive the reflected light, and the other single irradiating unit **8** may be arranged within a range **16**C where the light receiving units **9A2**, **9B3** and **9A3** can receive the reflected light, as illustrated in FIG. **16**B. In this case, the light receiving units **9A1** to **9A3**, **9B1** to **9B3**, and **9C1** are arranged in the plurality of rows in the width direction of the measure **7**A. Even in such an arrangement, the length of the measurement object can be measured, and the number of irradiating units **8** can be reduced. Therefore, the power consumption and the manufacturing cost of the measuring instrument **1** can be reduced.

[0107] As described above, according to the second embodiment, the microcomputer **3** determines whether the light receiving units **9A1** to **9A3** read the boundaries based on the colors read by the light receiving unit **9A1**, the light

receiving unit **9B1** that is away from the light receiving unit **9A1** in the length direction by the interval Y shorter than the interval X, and the light receiving unit **9C1** that is away from the light receiving unit **9A1** in the length direction by the interval Z shorter than the interval X and is opposite to the light receiving unit **9B1** with respect to the light receiving unit **9A1**. Therefore, even if the output value of the light receiving unit **9A1** when reading any pattern is the same as the output value of the light receiving unit **9A1** when reading the boundary between the two patterns, the microcomputer **3** can determine whether the light receiving unit **9A1** reads the boundary between the two patterns, and can accurately measure the length of the measurement object.

[0108] When the light receiving units **9A1** to **9A3** detect the boundaries between the two patterns, the light receiving units **9B1** to **9B3** are used instead of the light receiving units **9A1** to **9A3**, so that the length of the measurement object can be measured accurately.

[0109] In the above embodiment, the single unit pattern is composed of three adjacent patterns, but the number of patterns constituting the single unit pattern may be two or four or more. Further, the plurality of patterns constituting the single unit pattern need not to be adjacent to each other.

[0110] In the above embodiment, the pattern is expressed by the ternary number, but an N-ary number in which N exceeds **3** may be used.

[0111] In the above embodiment, the number of patterns constituting the unit pattern are the same as the number of light receiving units **9A** or light receiving units **9B**, but the number of light receiving units **9A** and the number of light receiving units **9B** may exceed the number of patterns constituting the unit pattern. In this case, it is possible to perform measurement using a plurality of types of measures having different numbers of patterns constituting the unit pattern with a single measuring instrument. Switching between functions can be done by operating a switch or switching/rewriting software,

Third Embodiment

[0112] Next, a description is given of a third embodiment.

[0113] In the above-mentioned measure **7A**, a problem in which the width of the measure **7A** increases and a problem in which the number of light receiving units **9** arranged in the width direction increases are solved by arranging the plurality of patterns in a row in the length direction.

[0114] However, when it is desired to increase the length that can be measured by the measure **7A**, it is necessary to increase the number of patterns read by the light receiving unit **9**, and hence the number of light receiving units **9** arranged in a row in the length direction must be increased. For this reason, when the light receiving units **9** are arranged in a row in the length direction, the measuring instrument **1** may be enlarged in the length direction, which may deteriorate the usability. Therefore, it is desired to reduce the size of the light receiving unit **9** or the measuring instrument **1** in the length direction.

[0115] Therefore, in the third embodiment, the light receiving units **9** are arranged in two or more rows in the width direction and individual color pattern is arranged to each row, so that the size of the measuring instrument **1** in the length direction is reduced.

[0116] The method of reading the pattern of the measure **7A** and the process flow in the third embodiment are the same as those in the first or second embodiment described above, Therefore, software or firmware executed by the microcomputer **3** does not need to be changed from software or firmware in the first or second embodiment, and the arrangement of the pattern of the measure **7A** and the arrangement of the light receiving unit **9** are changed. Here, the structure of the light receiving unit **9** is not changed, and the arrangement of the light receiving units **9** are changed.

[0117] FIGS. **17A** to **17D** are diagrams illustrating a method for converting a plurality of patterns arranged in a row in the length direction into the plurality of patterns arranged in four rows in the width direction in order to read the color pattern using four light receiving units **9** arranged in a row in the width direction. Hereinafter, the color pattern in a row in the length direction may be described as a single-line color pattern or any one of the color patterns in the first to fourth lines.

[0118] The color pattern having a plurality of patterns arranged in a row at regular intervals X in the length direction is printed on the measure **7A** of FIG. **17A**. Each pattern has one of three different colors, and any of 0, 1 or 2 is assigned to the color of each pattern. Although **17A** does not illustrate an example of a pattern to which "**2**" is assigned, each pattern has any one of white, blue, and black, and values of "0", "1", and "2" are assigned to these colors, respectively, as in FIG. **2**. The values of "**0**" to "2" in the pattern of FIG. **17A** are for easy understanding, and it is not necessary to print these values on the measure **7A**. Similarly, the boundaries between the patterns are also illustrated for ease of understanding, but it is not necessary to draw such boundaries on the measure **7A**,

[0119] In the example of FIG. **17A**, four patterns adjacent to each other in the length direction constitute the single unit pattern, and the single ternary value is assigned to the single unit pattern.

[0120] The interval **X1**, which is also the length of the pattern, corresponds to the unit length measurable by the measure **7A**. In the measuring instrument **1**, four light receiving units **9A1** to **9A4** and four irradiating units **8** for detecting the reflected light from the color patterns of the measure **7A** are arranged at the intervals X in the same manner as the patterns. Each light receiving unit **9A** reads the single pattern. In FIG. **17A**, a length **Y1** in the width direction of the pattern is the same as the length of the interval X, but may be larger or smaller than the length of the interval X. The number of sets of the irradiating unit **8** and the light receiving unit **9** may be two or four or more depending on the number of patterns constituting the single unit pattern and the like. As described above, the number of irradiating units **8** does not have to be the same as the number of patterns constituting the single unit pattern.

[0121] In a state of FIG. **17A**, the light receiving units **9A1**, **9A2**, **9A3** and **9A4** read a rightmost pattern in the single unit pattern, a second pattern from the right in the single unit pattern, a third pattern from the right in the single unit pattern, and a fourth pattern from the right in the single unit pattern, respectively.

[0122] When the measure **7A** is moved to the right by the interval X or the measuring instrument **1** is moved to the left. by the interval X from the state of FIG.

[0123] **17A** the light receiving unit **9A1** reads the pattern read by the light receiving unit **9A2** in the state of FIG. **17A**. When the measure **7A** is moved to the right by an interval 2X (i,e., twice the interval X) or the measuring instrument **1** is moved to the left by the interval 2X from the state of

FIG. **17**A, the light receiving unit **9A1** reads the pattern read by the light receiving unit **9A3** in the state of FIG. **17**A. When the measure **7**A is moved to the right by an interval 3X (i,e., three times the interval X) or the measuring instrument **1** is moved to the left by the interval 3X from the state of FIG. **17**A, the light receiving unit **9A1** reads the pattern read by the light receiving unit **9A4** in the state of FIG. **17**A.

[0124] Therefore, when the light receiving units **9A1** to **9A4** are arranged in a row in the width direction of the measure **7**A, the color patterns in the second to fourth lines to be read by the light receiving units **9A2** to **9A4** may be shifted from the color pattern in the first line to be read by the light receiving unit **9A1** by an integer multiple (1, 2, 3 . . .) of the interval X in the longitudinal direction (in the left direction of FIG. **17**A), and arranged in the width direction of the color pattern in the first line.

[0125] FIG. **17**D illustrates an example of four-line color patterns (i.e., the color patterns arranged in four rows in the width direction) on the measure **7**A. The color patterns in second, third, and fourth lines are arranged by shifting the same color pattern as the color pattern in the first line by the intervals X, 2X, and 3X in the left direction of FIG. **17**A, respectively. Thereby, the value read by the light receiving units **9A1** to **9A4** arranged in a row in the width direction of FIG. **17**D are the same as the values read by the light receiving units **9A1** to **9A4** arranged in a row in the length direction of FIG. **17**A.

[0126] FIG. **18** is a flowchart illustrating a method for arranging four-line color patterns of FIG. **17**D using a single-line color pattern of FIG. **17**A,

[0127] First, the color patterns in the second to fourth lines are generated by copying the color pattern in the first line including a plurality of patterns arranged at regular intervals in the length direction of FIG. **17**A, and shifting and pasting the color pattern of the first line in the width direction by integer multiples of the length Y**1** of the pattern in the width direction (S**101**). FIG. **17**B also illustrates a state in which the sets of the irradiation units **8** and the light receiving units **9A1** to **9A3** are virtually shifted in the width direction in order to illustrate a relationship between the pattern of each line and each light receiving unit **9**. In FIG. **17**B, the light receiving unit **9A4** that reads a fourth pattern from the right is arranged on the color pattern in the first line. The light receiving unit **9A3** that reads a third pattern from the right is arranged on the color pattern in the second line. The light receiving unit **9A2** that reads a second pattern from the right is arranged on the color pattern in the third line. The light receiving unit **9A1** that reads a rightmost pattern is arranged on the color pattern in the fourth line.

[0128] Next, as illustrated in FIG. **17**C, the color patterns in the second to fourth lines are arranged at positions shifted from the color pattern in the first line by 1 times, 2 times, and 3 times the interval X in the length direction (i.e., a left direction of FIG. **17**C), respectively (S**102**). On the other hand, each of the light receiving units **9A1** to **9A3** illustrated in FIG. **17**C is shifted in the length direction by an amount in which the color pattern in each line is shifted with respect to the arrangement of the color pattern in each line illustrated in FIG. **17**B. Thereby, the light receiving units **9A1** to **9A4** are arranged in a row in the width direction.

[0129] As described above, the four-line color patterns as illustrated in FIG. **17**D can be obtained from the state of FIG. **17**A. The patterns of "pattern No. **0**" illustrated in FIG. **17**D corresponds to the unit pattern from the rightmost pattern to the fourth pattern from the right in FIG. **17**A, and the patterns of "pattern No. **4**" corresponds to the unit pattern from the fifth pattern to the eighth pattern from the right in FIG. **17**A.

[0130] The measure **7**A of FIG. **171** generated by the conversion method of FIG. **18** includes (1) the color pattern in the first line including the plurality of patterns arranged at intervals X in the length direction, and (2) one or more color pattern in Nth line (N=2 or more integers) arranged at positions that are shifted in the width direction from the color pattern in the first line and shifted in the length direction from the color pattern in the first line by integer multiples (1, 2, 3 . . .) of the interval X. The color patterns in the second to fourth lines of FIG. **17**D are shifted in the width direction from the color pattern in the first line by integral multiples (1, 2, 3 . . .) of the length Y**1**.

[0131] Even when the four-line color patterns and the light receiving units **9A1** to **9A4** arranged in a row in the width direction are used as illustrated in FIG. **17**D, the same measurement process as that in FIG. **5** is executed. That is, the microcomputer **3** converts the patterns read by the light receiving units **9A1** to **9A4** into the Nary value (N is 3 or more), and calculates the scale value of the measure **7**A based on data that defines the relationship between the N-ary value and the scale value of the measure **7**A.

[0132] FIG. **19** is a diagram illustrating a correspondence relationship between the measure of FIG. **17**A, values read by the light receiving units **9A1** to **9A4**, a pattern No., and converted values of the ternary number and the decimal number. Here, the "pattern No." is an identification number of the unit pattern and corresponds to the scale value of the measure **7**A.

[0133] For example, when the light receiving units **9A1** to **9A4** read the pattern No**4**, the light receiving units **9A1** and **9A4** detect the value of "1", and the light receiving units **9A2** and **9A3** detect the value of "0". It can be seen that the values of the pattern No. **4** read by the light receiving units **9A4** to **9A1** of FIG. **19** correspond to the color patterns in the first to fourth lines corresponding to the pattern No. **4** of FIG. **17**D, respectively.

[0134] Therefore, it can be seen from FIG. **19** that the values read by the light receiving units **9A1** to **9A4** arranged in a row in the length direction of FIG. **17**A. are the same as the values read by the light receiving units **9A1** to **9A4** arranged in a row in the width direction of FIG **17**D.

[0135] FIGS. **20**A to **20**D are diagrams illustrating a method for converting the color pattern including the plurality of patterns arranged in a row in the length direction into two color patterns arranged in two rows in the width direction.

[0136] The same method as in FIG. **18** is adopted to convert the light receiving units **9A1-9A4** arranged in a row in the length direction and the single-line color pattern in FIG. **20**A into the light receiving units **9A1-9A4** arranged in two rows in the width direction and the two-line color patterns in FIG. **20**D.

[0137] Specifically, the color pattern in the second line is generated by copying the color pattern of FIG. **20**A, and pasting the color pattern of the first line at a position shifted in the width direction by an integer multiple (one time) of the length Y**1** of the pattern in the width direction from the color pattern of the first line (S**101** in FIG. **19**).

[0138] FIG. **20**B illustrates a state in which the light receiving units **9**A**1** and **9**A**2** are virtually shifted in the width direction. As illustrated in FIG. **2011**, the light receiving units **9**A**3** and **9**A**4** are arranged on the color pattern in the first line without moving in the length direction, and the light receiving units **9**A**1** and **9**A**2** are moved in the width direction and arranged on the color pattern in the second line.

[0139] Next, as illustrated in FIG. **20**C, the color pattern in the second line is arranged at the position shifted in the length direction (left direction of FIG. **20**C) from the color pattern in the first line by an integer multiple of the interval X (S**102** in FIG. **18**). In the example of FIG. **20**, the color pattern in the second line is arranged at a position shifted by the interval 2X from the color pattern in the first line. Each of the light receiving units **9**A**1** to **9**A**2** is arranged at the position shifted by the interval 2X in the length direction (i.e., the left direction of FIG. **20**C) with respect to its position of FIG. **20**B in accordance with the shift of the color pattern in the second line.

[0140] Thereby, the two-line color patterns as illustrated in FIG. **20**D can be obtained from the state of FIG. **20**A. In FIG. **20**D, the color patterns are read by using the light receiving units **9**A**1** to **9**A**4** arranged in 2 lines 2 rows, thereby measuring the length.

[0141] FIGS. **21**A to **2**M are diagrams illustrating a variation of the method for converting the color pattern including the plurality of patterns arranged in a row in the length direction into two color patterns arranged in two rows in the width direction,

[0142] The same method as in FIG. **18** is adopted to convert the light receiving units **9**A**1** to **9**A**4** arranged in a row in the length direction and the single-line color pattern in FIG. **21**A into the light receiving units **9**A**1** to **9**A**4** arranged in two rows in the width direction and the two-line color patterns in FIG. **21**D.

[0143] In FIGS. **21**A to **21**D, a type of the set of the light receiving units **9** to be shifted and a shift amount of the color pattern in the second line are changed, as compared with FIGS. **20**A to **20**D.

[0144] In FIG. **21**C, the color pattern in the second line is shifted in the left direction of FIG. **21**C by the interval 2X with respect to the color pattern in the first line. At this time, the even-numbered light receiving units **9**A**2** and **9**A**4** read the color pattern in the first line, and the odd-numbered light receiving units **9**A**1** and **9**A**3** read the color pattern in the second line. The light receiving units **9**A**2** and **9**A**1** are arranged in the width direction, and the light receiving units **9**A**4** and **9**A**3** are also arranged in the width direction. Further, the light receiving units **9**A**1** and **9**A**3** are separated from each other by the distance 2X in the length direction, and the light receiving unit **9**A**2** and the light receiving unit **9**A**4** are also separated from each other by the distance 2X in the length direction. Other processing of FIGS. **21**A to **21**D is the same as that of FIGS. **20**A to **20**D.

[0145] Three-line color patterns are formed by shifting the single-line color pattern in the same manner as FIG. **18**, and the three-line color patterns may be read by arranging the light receiving units **9**A**1** to **9**A**4** arranged in a row in the length direction, in two rows.

[0146] In the third embodiment, only the light receiving units **9**A**1** to **9**A**4** are used, but the measuring instrument **1** of the third embodiment may include the light receiving units **9**B**1** to **9**B**4** and the light receiving unit **9**C**1** in addition to the light receiving units **9**A**1** to **9**A**4**, in the same manner as the second embodiment and FIG. **9**. In this case, the measuring instrument **1** of the third embodiment can also execute the measurement process of FIG. **11**, the color determination process of FIGS. **12** and **13**, and the boundary determination process of FIG. **14**.

[0147] As described above, according to the third embodiment, the arrangement of the light receiving units **9**A**1** to **9**A**4** and the number of lines of the color pattern can be changed without changing the values read by the light receiving units **9**A**1** to **9**A**4** arranged in a row in the length direction, and hence the widths of the measure **7**A and the light receiving units **9** or the width of the measuring instrument **1** can be changed.

[0148] All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various change, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A measuring instrument comprising:

a plurality of first readers that optically read a. plurality of patterns from a. measure having a color pattern including the plurality of patterns arranged at a regular interval in a length direction, the plurality of first readers being arranged at the regular interval in the length direction;

a converter that converts the plurality of patterns read by the plurality of first readers into a value of an N-ary number (N is 3 or more); and

a calculator that calculates a scale value of the measure based on data that defines a relationship between the value of the N-ary number and the scale value of the measure.

2. The measuring instrument as claimed in claim **1**, further comprising:

a second reader that is arranged at a position away from at least one of the plurality of first readers in the length direction by a distance shorter than the regular interval;

a third reader that is arranged at a position away from any one of the plurality of first readers in a direction opposite to the length direction with respect to the second reader, by a distance shorter than the regular interval; and

a determiner that determines whether each of the first readers reads a boundary between two adjacent patterns based on reading results of the second reader, the third reader and any one of the plurality of first readers.

3. The measuring instrument as claimed in claim **2**, wherein

the second reader includes a plurality of second readers arranged at positions away from the plurality of first readers, respectively, by a distance shorter than the regular interval in the length direction,

when the determiner determines that each of the first readers reads the boundary between the plurality of patterns, the converter measures a length by using the

reading results of the plurality of second readers instead of the reading results of the first readers.

4. The measuring instrument as claimed in claim **1**, wherein

the first readers are arranged in a plurality of rows in the length direction.

5. The treasuring instrument as claimed in claim **2**, wherein

the first readers and the second readers are arranged in a plurality of rows in the length direction.

6. A measure comprising:

a color pattern to be read by the measuring instrument as claimed in claim **1**.

7. A measuring instrument comprising:

a first reader that optically reads a first color pattern from a measure, the measure having the first color pattern arranged at a regular interval in a length direction, and a second color pattern that is shifted from the first color pattern by an integral multiple of the regular interval in the length direction and arranged in a width direction of the first color pattern;

a second reader that is arranged at a position shifted in the width direction from the first reader, and optically reads the second color pattern; and

a calculator that calculates a scale value of the measure based on a plurality of patterns read by the first reader and the second reader.

8. The measuring instrument as claimed in claim **7**, wherein the plurality of patterns read by the first reader and the second reader are the same as patterns read by a plurality of reading units, the plurality of reading units optically reading a plurality of patterns included in the first color pattern and being arranged at the regular interval in the length direction.

9. A measure comprising:

a first color pattern arranged at a regular interval in a length direction; and

a second color pattern that is shifted in a width direction from the first color pattern, and is shifted in the length direction from the first color pattern by an integral multiple of the regular interval in the length direction.

* * * * *