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(54) APPLICATION PROGRAMMING INTERFACE FOR MEASURING DEVICES

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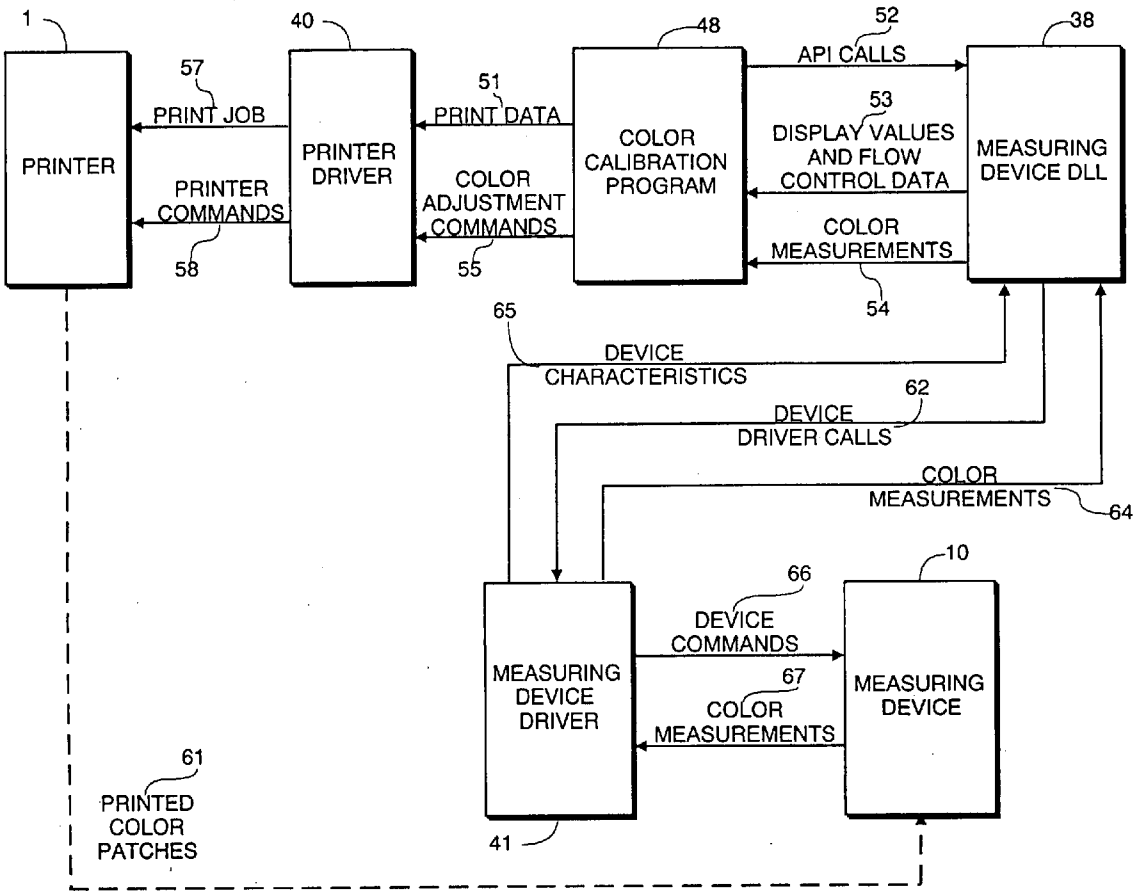
(57) **ABSTRACT**

An application programming interface (API) that provides a common interface between an application program and plural different types of color measuring devices each having at least one color measuring sensor. The API includes plural functions for operating any of the plural different types of color measuring devices. In order to complete an operation performed by at least one of the plural functions, the function that performs the operation must be called a number of times which is different for at least two different types of color measuring devices. For a particular color measuring device, the API provides the application program with flow control data of the number of times that the function must be called. This flow control data preferably can be provided by the function, in the form of a call-again value or as a numerical value, or by a separate function in the API such as a get-device-capabilities function. In some embodiments of the invention, a combination of these methods of providing the flow control data is utilized. Preferred functions for operating any of the plural different types of color measuring devices include a calibrate-position function, a calibrate-sensor function, a move-to-patch function, and a make-measurement function.



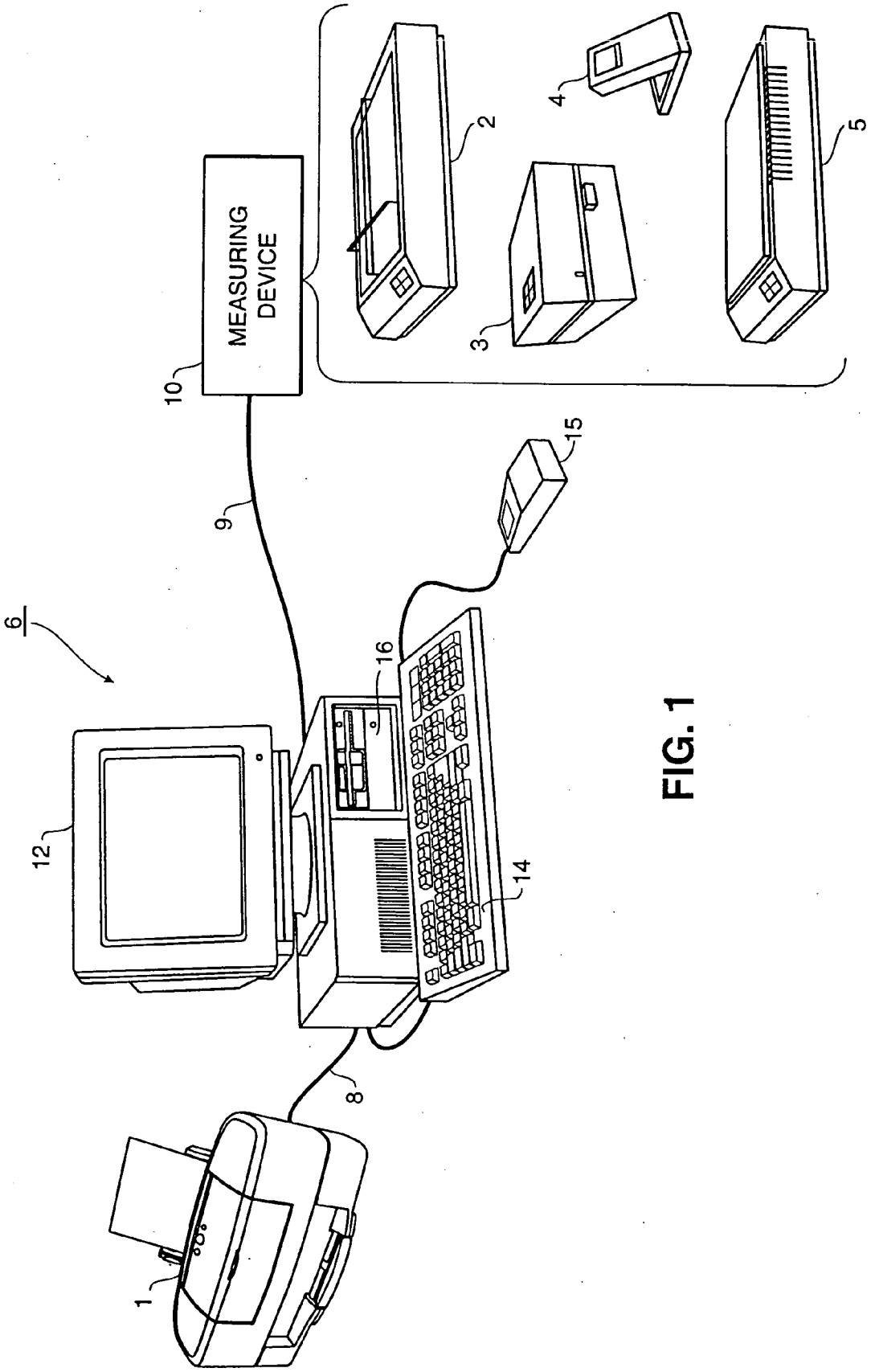


FIG. 1

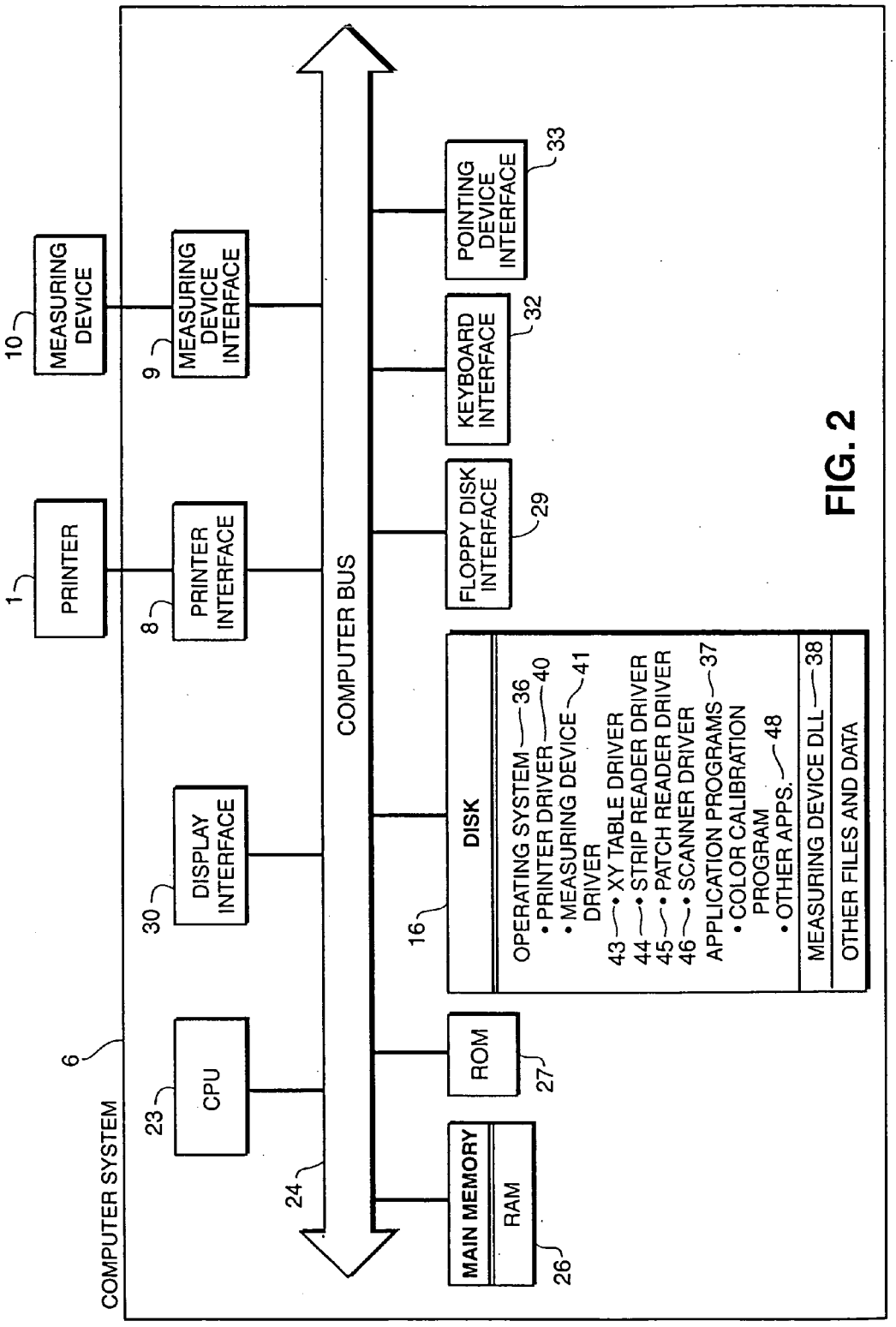

COMPUTER SYSTEM
6
CPU
23
DISPLAY INTERFACE
30
PRINTER INTERFACE
8
PRINTER
1
MEASURING DEVICE INTERFACE
9
MEASURING DEVICE
10
COMPUTER BUS
24
MAIN MEMORY
RAM
26
ROM
27
DISK
16
OPERATING SYSTEM 36
• PRINTER DRIVER 40
• MEASURING DEVICE DRIVER 41
43 • XY TABLE DRIVER
44 • STRIP READER DRIVER
45 • PATCH READER DRIVER
46 • SCANNER DRIVER
APPLICATION PROGRAMS 37
• COLOR CALIBRATION PROGRAM
• OTHER APPS. 48
MEASURING DEVICE DLL 38
OTHER FILES AND DATA
FLOPPY DISK INTERFACE
29
KEYBOARD INTERFACE
32
POINTING DEVICE INTERFACE
33

FIG. 2

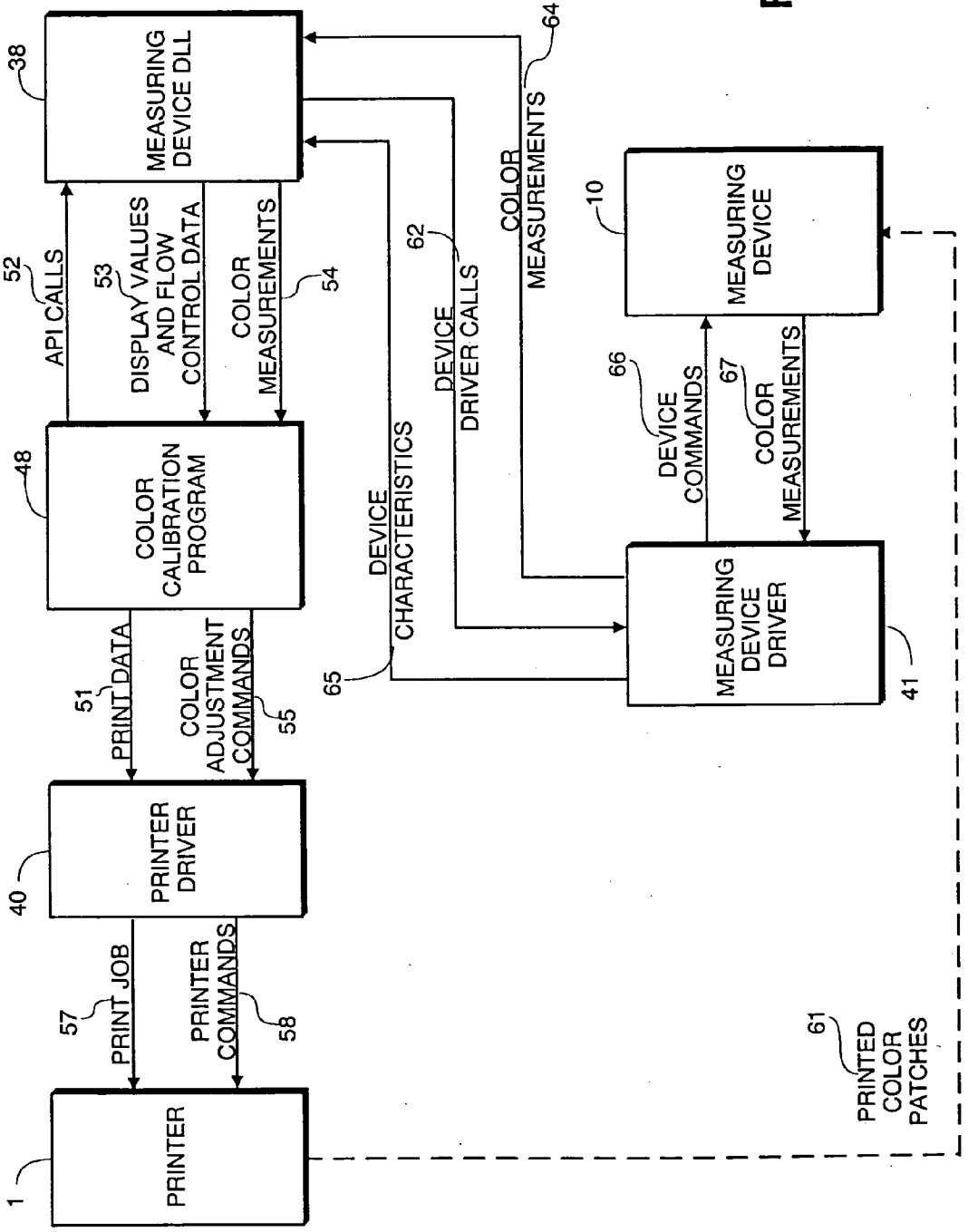

MEASURING DEVICE DLL
38
API CALLS
52
DISPLAY VALUES AND FLOW CONTROL DATA
53
COLOR MEASUREMENTS
54
COLOR CALIBRATION PROGRAM
48
PRINT DATA
51
COLOR ADJUSTMENT COMMANDS
55
PRINTER DRIVER
40
PRINT JOB
57
PRINTER COMMANDS
58
PRINTER
1
DEVICE CHARACTERISTICS
65
DEVICE DRIVER CALLS
62
COLOR MEASUREMENTS
64
MEASURING DEVICE
10
DEVICE COMMANDS
66
COLOR MEASUREMENTS
67
MEASURING DEVICE DRIVER
41
PRINTED COLOR PATCHES
61

FIG. 3

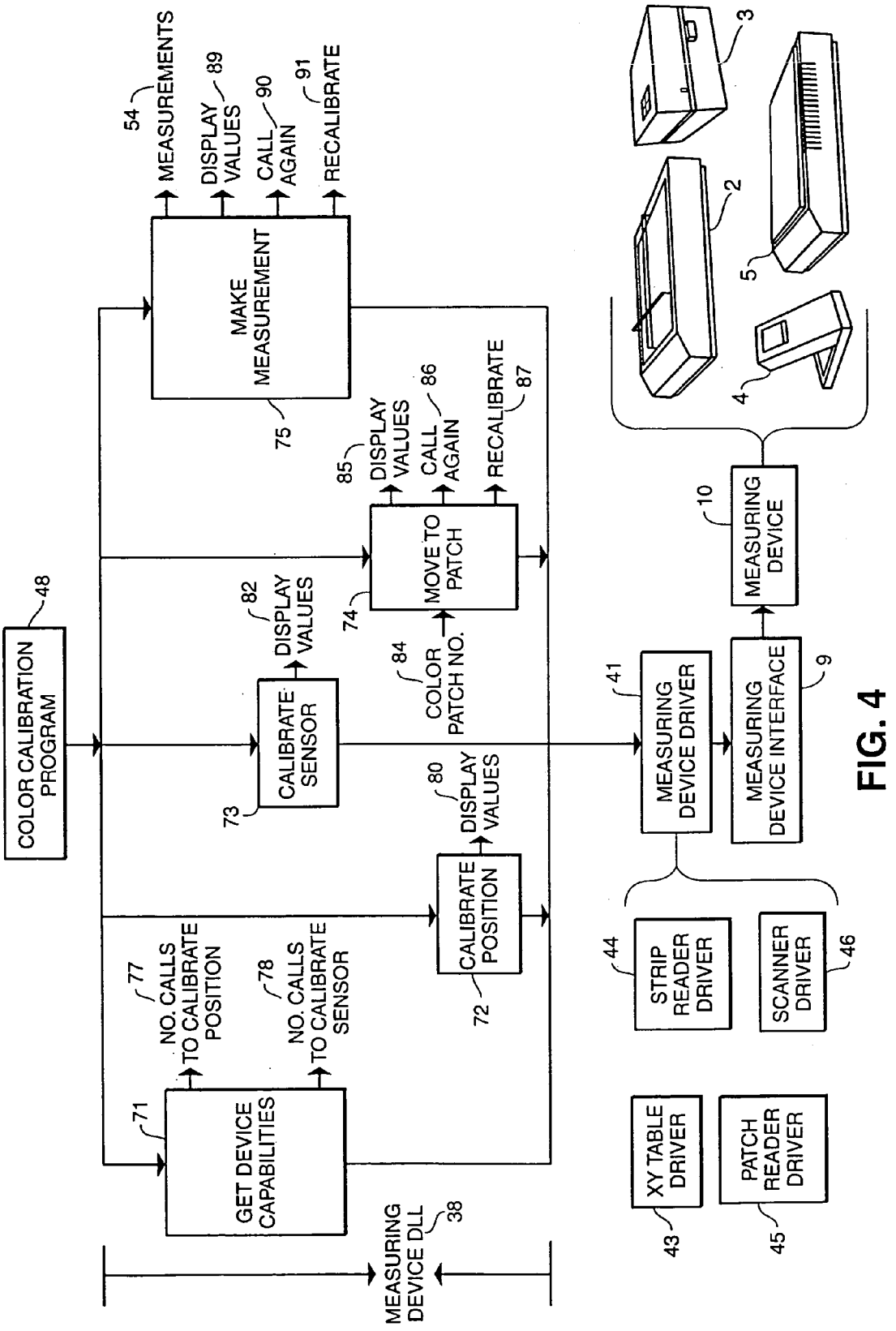

COLOR CALIBRATION PROGRAM
48
MEASURING DEVICE DLL
38
GET DEVICE CAPABILITIES
71
NO. CALLS TO CALIBRATE POSITION
77
NO. CALLS TO CALIBRATE SENSOR
78
CALIBRATE POSITION
72
DISPLAY VALUES
80
CALIBRATE SENSOR
73
DISPLAY VALUES
82
COLOR PATCH NO.
84
MOVE TO PATCH
74
DISPLAY VALUES
85
CALL AGAIN
86
RECALIBRATE
87
MAKE MEASUREMENT
75
54 MEASUREMENTS
DISPLAY VALUES
89
CALL AGAIN
90
91 RECALIBRATE
XY TABLE DRIVER
43
PATCH READER DRIVER
45
STRIP READER DRIVER
44
SCANNER DRIVER
46
MEASURING DEVICE DRIVER
41
MEASURING DEVICE INTERFACE
9
MEASURING DEVICE
10
3
2
5
4

FIG. 4

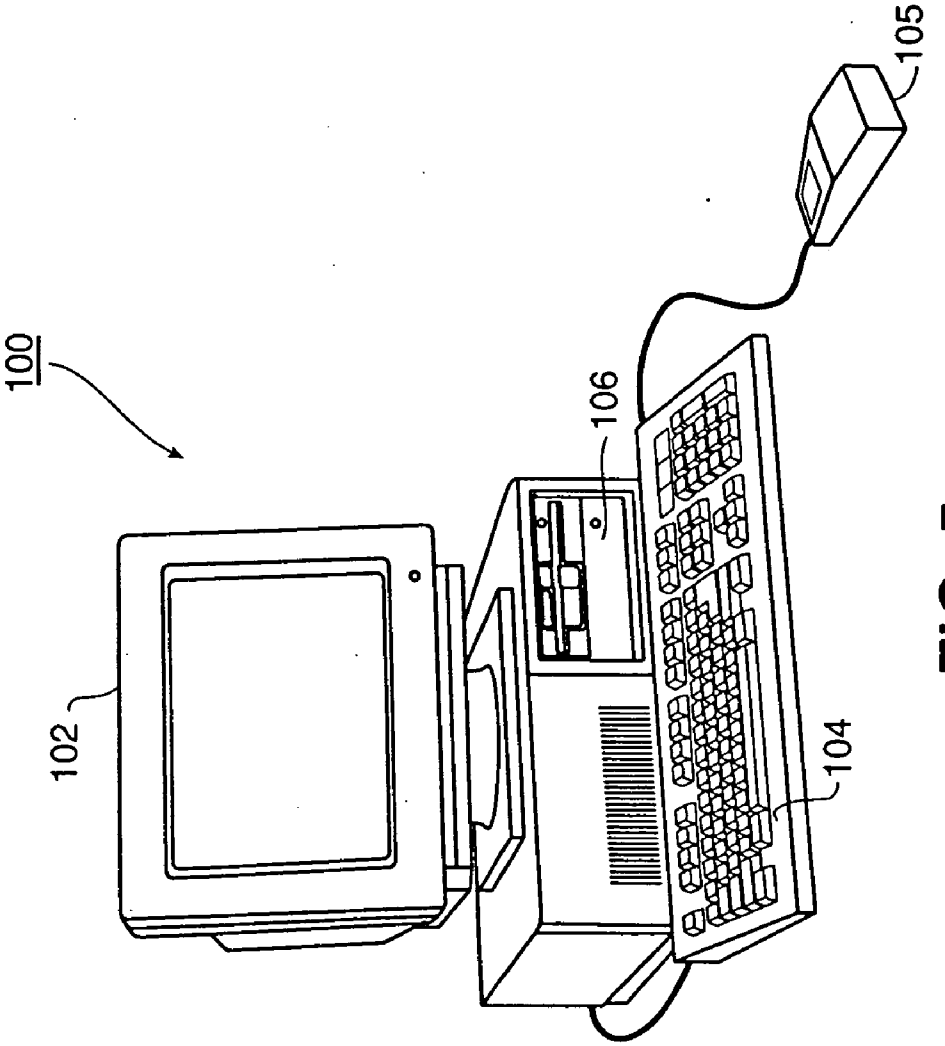


FIG. 5

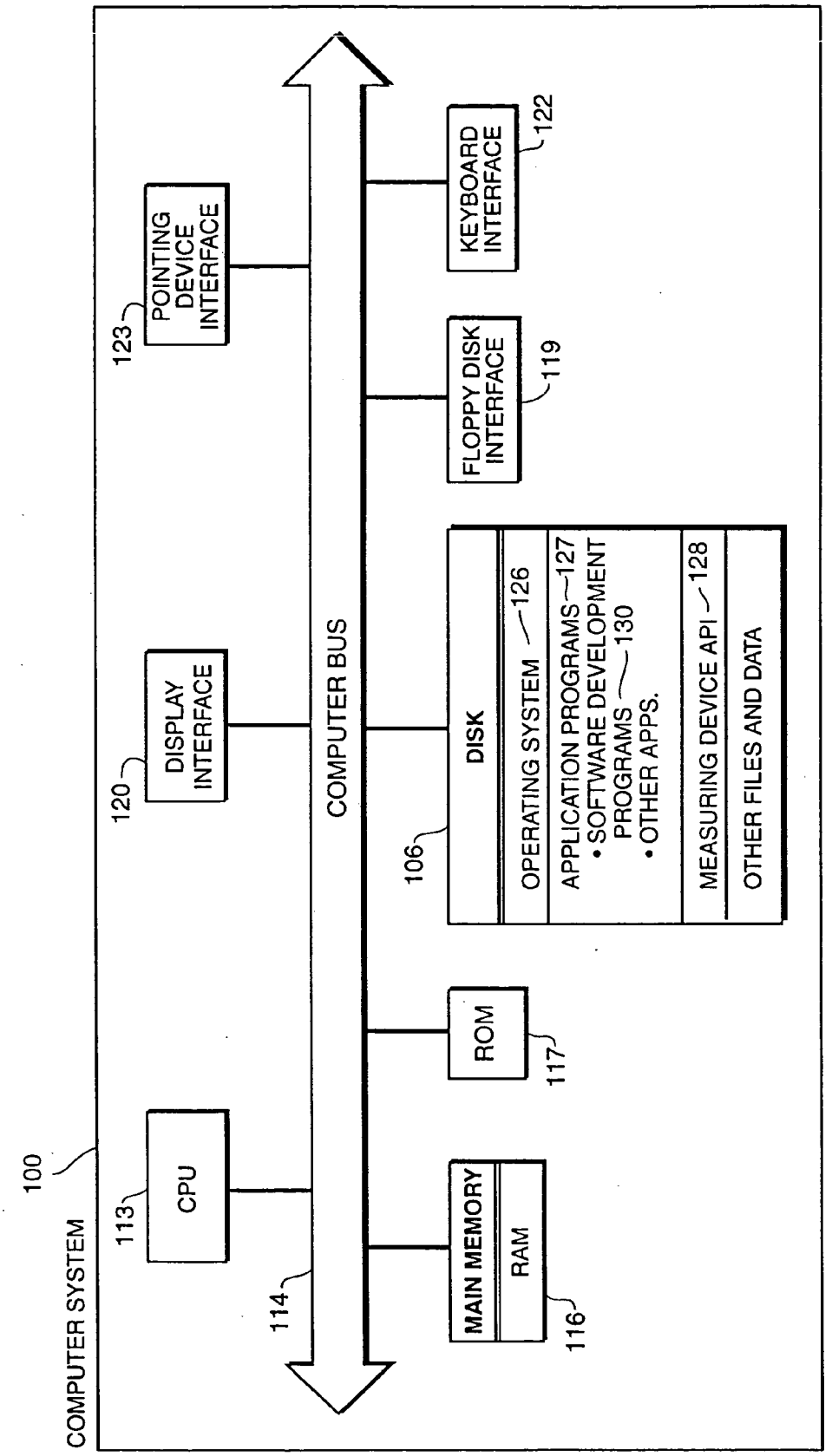

100
COMPUTER SYSTEM
113
CPU
114
COMPUTER BUS
120
DISPLAY INTERFACE
123
POINTING DEVICE INTERFACE
122
KEYBOARD INTERFACE
119
FLOPPY DISK INTERFACE
106
DISK
OPERATING SYSTEM 126
APPLICATION PROGRAMS 127
• SOFTWARE DEVELOPMENT PROGRAMS 130
• OTHER APPS.
MEASURING DEVICE API 128
OTHER FILES AND DATA
117
ROM
116
MAIN MEMORY
RAM

FIG. 6

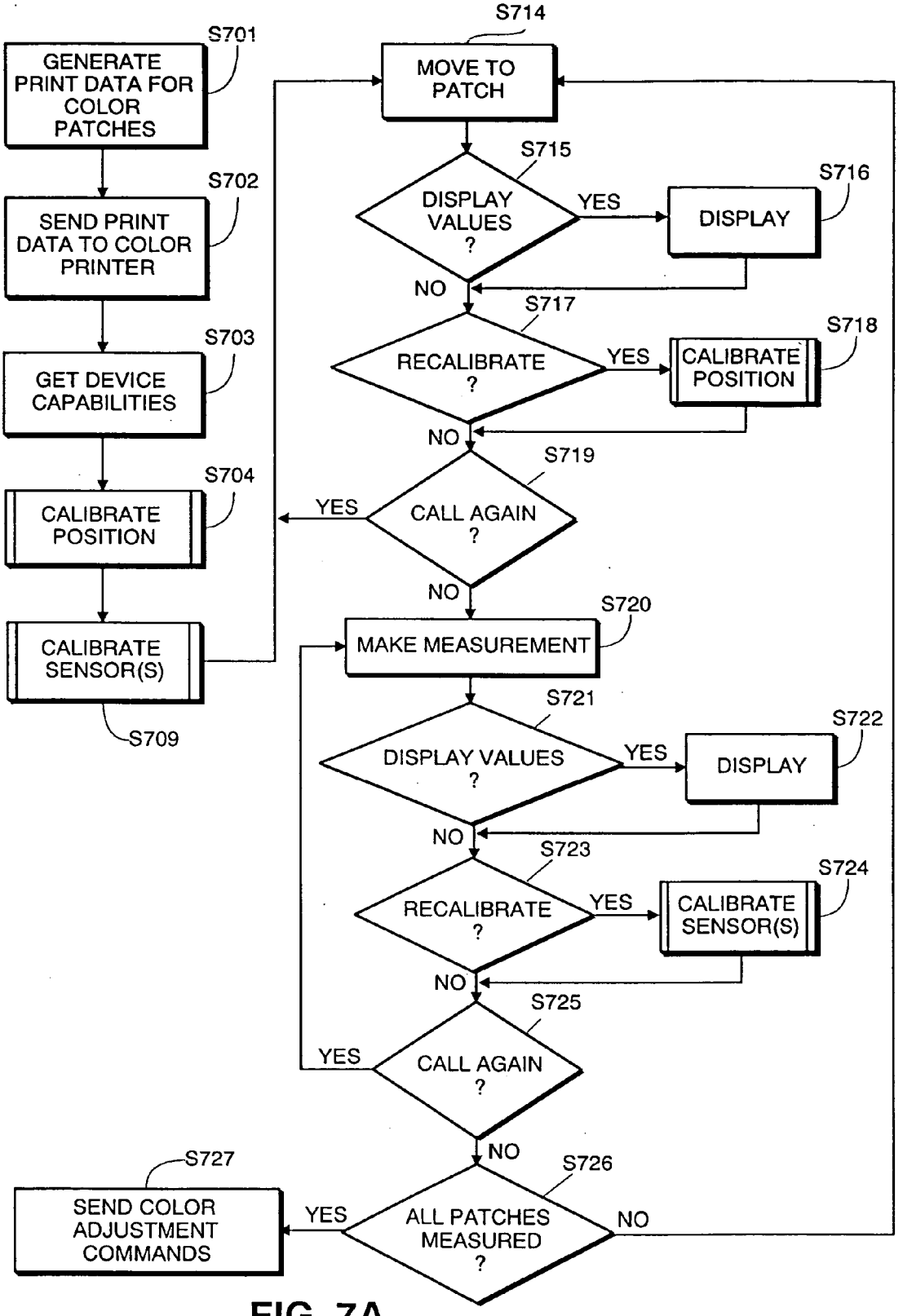

S701
GENERATE PRINT DATA FOR COLOR PATCHES
S702
SEND PRINT DATA TO COLOR PRINTER
S703
GET DEVICE CAPABILITIES
S704
CALIBRATE POSITION
CALIBRATE SENSOR(S)
S709
S714
MOVE TO PATCH
S715
DISPLAY VALUES ?
YES
S716
DISPLAY
NO
S717
RECALIBRATE ?
YES
S718
CALIBRATE POSITION
NO
S719
CALL AGAIN ?
YES
NO
S720
MAKE MEASUREMENT
S721
DISPLAY VALUES ?
YES
S722
DISPLAY
NO
S723
RECALIBRATE ?
YES
S724
CALIBRATE SENSOR(S)
NO
S725
CALL AGAIN ?
YES
NO
S726
ALL PATCHES MEASURED ?
YES
NO
S727
SEND COLOR ADJUSTMENT COMMANDS

FIG. 7A

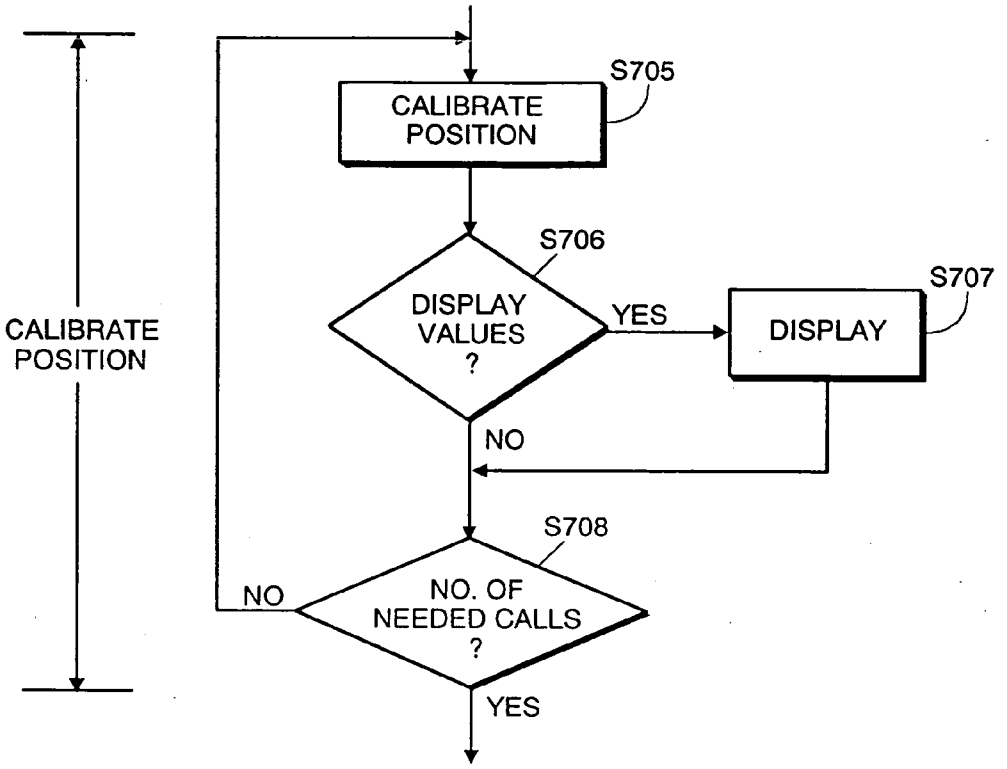

CALIBRATE POSITION
S705
CALIBRATE POSITION
S706
DISPLAY VALUES ?
YES
S707
DISPLAY
NO
S708
NO. OF NEEDED CALLS ?
NO
YES

FIG. 7B

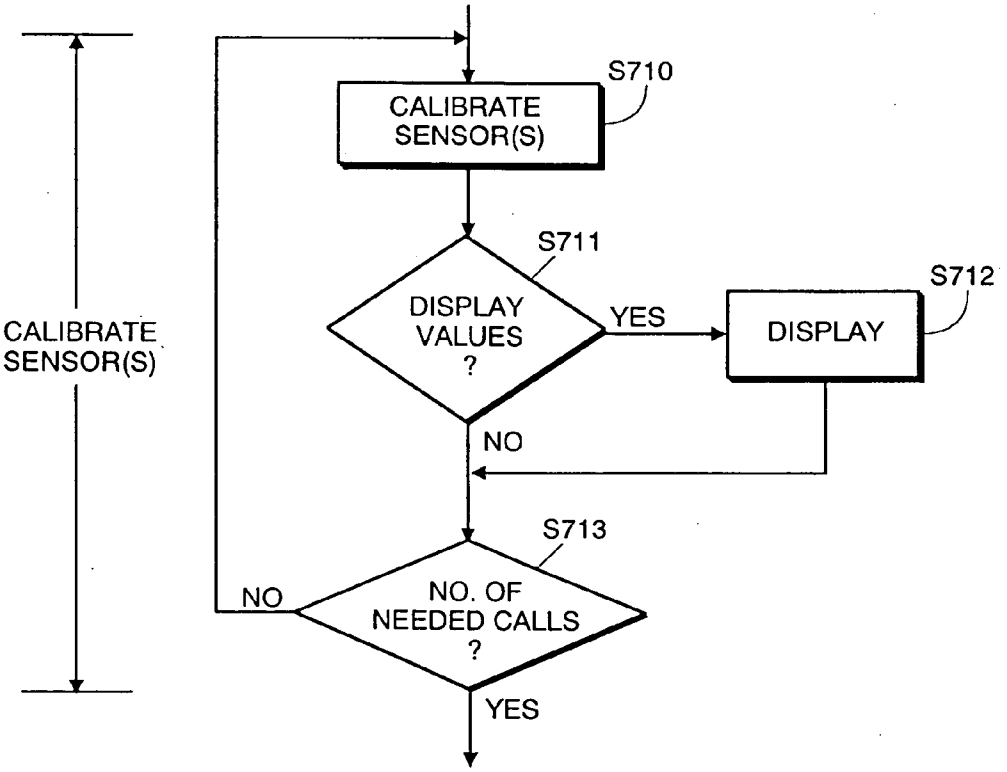

CALIBRATE SENSOR(S)
S710
CALIBRATE SENSOR(S)
S711
DISPLAY VALUES ?
YES
S712
DISPLAY
NO
S713
NO. OF NEEDED CALLS ?
NO
YES

FIG. 7C

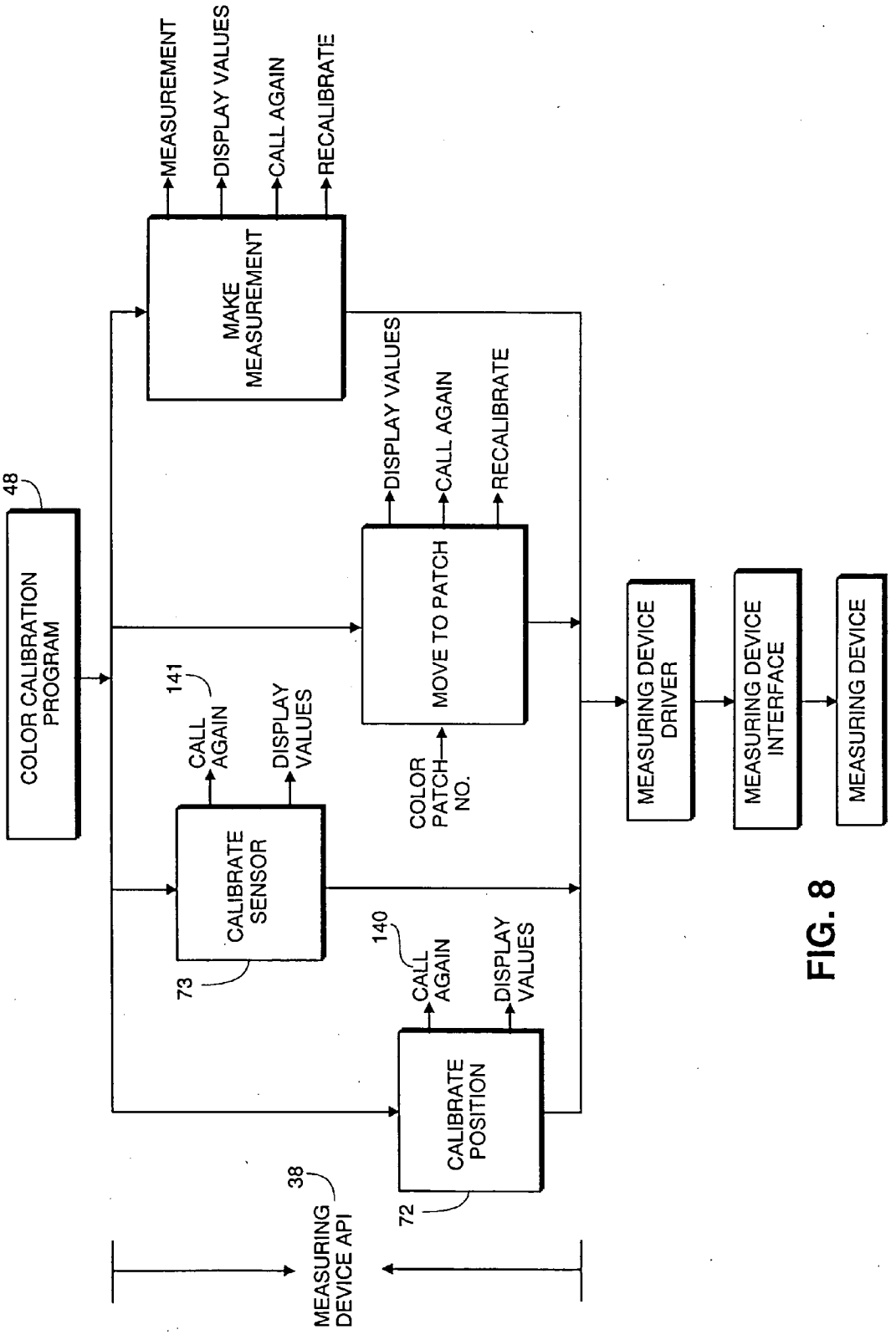

MEASUREMENT
DISPLAY VALUES
CALL AGAIN
RECALIBRATE
MAKE MEASUREMENT
48
COLOR CALIBRATION PROGRAM
DISPLAY VALUES
CALL AGAIN
RECALIBRATE
MOVE TO PATCH
COLOR PATCH NO.
141
CALL AGAIN
DISPLAY VALUES
CALIBRATE SENSOR
73
140
CALL AGAIN
DISPLAY VALUES
CALIBRATE POSITION
72
38
MEASURING DEVICE API
MEASURING DEVICE DRIVER
MEASURING DEVICE INTERFACE
MEASURING DEVICE

FIG. 8

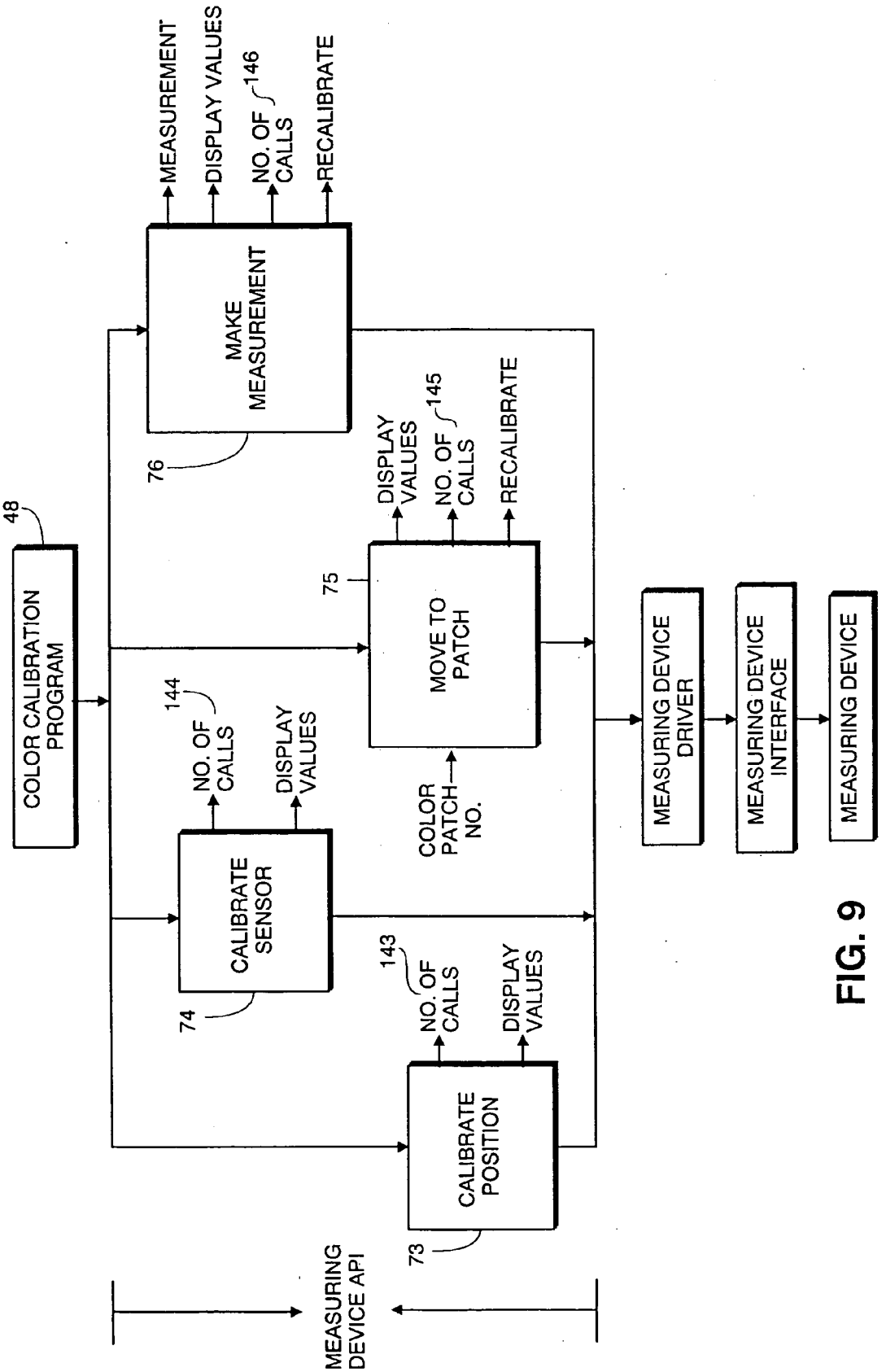

MEASUREMENT
DISPLAY VALUES
NO. OF CALLS
146
RECALIBRATE
MAKE MEASUREMENT
76
48
COLOR CALIBRATION PROGRAM
DISPLAY VALUES
NO. OF CALLS
145
RECALIBRATE
75
MOVE TO PATCH
144
NO. OF CALLS
DISPLAY VALUES
CALIBRATE SENSOR
74
COLOR PATCH NO.
143
NO. OF CALLS
DISPLAY VALUES
CALIBRATE POSITION
73
MEASURING DEVICE API
MEASURING DEVICE DRIVER
MEASURING DEVICE INTERFACE
MEASURING DEVICE

FIG. 9

APPLICATION PROGRAMMING INTERFACE FOR MEASURING DEVICES

BACKGROUND OF THE INVENTION

[0001] This application is being filed with a microfiche appendix of computer program listings consisting of one (1) fiche having fifty-one (51) frames.

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FIELD OF THE INVENTION

[0003] The present invention concerns an application programming interface (API) usable by a software developer when writing an application program, such as a color calibration program, that uses a color measuring device. In particular, the present invention relates to an API that provides a common interface between such an application program and plural different types of color measuring devices.

DESCRIPTION OF THE RELATED ART

[0004] One common use of color measuring devices is to calibrate color fidelity of color recording devices. Typically, the recording device (such as a color laser beam printer or ink jet printer) records color patches on a recording medium. The color values of the patches are measured by the color measuring device, the measured values are compared against expected (or ideal) values, and the comparisons are used to calibrate the recording device.

[0005] Color measuring devices come in many different physical structures, such as XY tables, strip readers, handheld patch readers, and flatbed scanners, and operate in different ways using different numbers and types of sensors. Color patches are input in different ways to color measuring devices which have different physical structures. For example, patches are input to an XY table on a sheet that has an array of patches printed thereon, whereas patches are input to a strip reader on strips that each have one or more rows of patches printed thereon. The sensors that actually perform color measurements are positioned on patches in different ways depending on the physical structures of the color measuring devices.

[0006] In order to make accurate color measurements for use in calibrating a color recording device, the color measuring devices themselves must be calibrated properly. For example, for some color measuring devices to position their sensor(s) accurately, the positioning mechanism in the color measuring devices must be calibrated. In addition, the sensors in some color measuring devices must be calibrated so as to ensure proper color measurements. Depending on the numbers and types of sensors as well as the physical structures of the color measuring devices, calibration of the position of the sensors and calibration of the sensors differ among different types of color measuring devices.

[0007] In addition, application programs that use color measuring devices should provide interfaces to the user. These interfaces should include instructions to the user at various points throughout operations performed using the color measuring devices. The timing and content of these instructions also differ among different color measuring devices.

[0008] As a result of the foregoing differences in operation among the different types of color measuring devices, a different command set is needed for each different type of device. Application programs that use the color measuring devices often must include different numbers of calls to commands in the different command sets in order to perform a same operation with different color measuring devices. In addition, the application programs often must include different interfaces for each different type of color measuring device. These different command sets and interfaces greatly complicate the task of writing application programs that perform color measurements. As a result, conventional application programs for performing color measurements must include separate and often lengthy routines for taking color measurements with each different type of supported device. In addition, once a conventional application program is written, that application program cannot use new types of color measuring devices, because the new device would require calls to commands in a new command set.

SUMMARY OF THE INVENTION

[0009] Accordingly, there is a need for an application programming interface (API) that allows a software developer to write a single set of routines for taking color measurements using plural different types of color measuring devices.

[0010] The present invention addresses the foregoing need by providing an application programming interface that abstracts the operations needed to perform color measurements. An application program only needs to include calls to the functions in this API in order to use any supported type of color measuring device. The API in turn calls the necessary commands for performing color measurement operations.

[0011] In order to allow the application program to provide appropriate instructions during operations performed with a color measuring device, certain functions in the API are called numerous times in order to complete their respective operations. In order to enable the application program to call such a function a correct number of times, the API provides the application program with flow control data of the number of times that the function needs to be called so as to complete its operation with a particular color measuring device. The API also preferably provides the application program with display values for display so as to instruct the user in manipulating the color measuring device.

[0012] By virtue of the foregoing, the application program does not need to include separate routines for each different type of supported color measuring device. Instead, the application program need only include calls to the functions in the API and include mechanisms for handling display values and flow control data provided by the API. Moreover, if the API is implemented in a dynamically linkable library (DLL), an existing application program that calls the functions in the API can use new types of color measuring devices by linking to an updated version of the DLL.

[0013] Accordingly, in one aspect the invention is an API that provides a common interface between an application program and plural different types of color measuring devices each having at least one color measuring sensor. The API includes plural functions for operating any of the plural different types of color measuring devices. In order to complete an operation performed by at least one of the plural functions, the function that performs the operation must be called a number of times which is different for at least two different types of color measuring devices. For a particular color measuring device, the API provides the application program with flow control data of the number of times that the function must be called. This flow control data preferably can be provided by the function, in the form of a call-again value or as a numerical value, or by a separate function in the API such as a get-device-capabilities function. In some embodiments of the invention, a combination of these methods of providing the flow control data is utilized.

[0014] Preferably, the functions in the API also provide the application program with display values which are different for at least two different types of color measuring devices. The display values are for display to a user, preferably by the application program, so as to instruct the user in manipulating the color measuring device that is being operated.

[0015] In another aspect, the invention is an API that provides a common interface between an application program and plural different types of color measuring devices each having at least one color measuring sensor. The API includes plural functions for operating any of the plural different types of color measuring devices. The plural functions include a calibrate-position function, a calibrate-sensor function, a move-to-patch function, and a make-measurement function.

[0016] The calibrate-position function calibrates a relative position of a recording medium with respect to any of the plural different types of color measuring devices. Preferably, the calibrate-position function provides the application program with at least one display value that is to be displayed so as to instruct a user to position the recording medium or to position any of the color measuring sensors.

[0017] The calibrate-sensor function calibrates any of the color measuring sensors of any of the plural different types of color measuring devices. Preferably, the calibrate-sensor function provides the application program with at least one display value that is to be displayed so as to instruct the user in calibrating the sensor.

[0018] The move-to-patch function relatively positions any of the color measuring sensors and a color patch for any of the plural different types of color measuring devices. The move-to-patch function is provided with a logical color patch number by the application program. In order to relatively position the color patch and any of the color measuring sensors for some color measuring devices, the move-to-patch function preferably can provide the application program with a display value which instructs the user to manipulate the color measuring devices or to move the recording medium. In order to relatively position the color patch and any of the color measuring sensors for other color measuring devices, the move-to-patch function preferably causes the color measuring device to move the recording medium or to move the color measuring sensors. In any case, the move-to-patch function preferably provides the application program with a recalibrate value in a case that the relative position of the recording medium needs to be recalibrated, for example when a new recording medium is loaded into the color measuring device.

[0019] The make-measurement function makes a color measurement of the patch at which any of the color measuring sensors is relatively positioned, and the make-measurement function provides the application program with a color measurement value for the color patch. The make-measurement function preferably provides the application program with at least one display value that is to be displayed so as to instruct the user in making the color measurement. In addition, the make-measurement function preferably provides the application program with a recalibrate value in a case that any of the color measuring sensors needs to be recalibrated.

[0020] In order to complete an operation performed by at least one of the plural functions, the function that performs the operation must be called a number of times which is different for at least two different types of color measuring devices. For a color measuring device that is being operated, the API provides the application program with flow control data of the number of times that the function must be called. The flow control data preferably can be provided by the function, either in the form of a call-again value or a numerical value, or by a get-device-capabilities function included in the API.

[0021] The computer-executable process steps for the functions in the API preferably are stored in a dynamically linkable library (DLL). Thus, updated API functions can be used by an application program to access new types of measuring devices simply by linking the application program to the DLL.

[0022] The API according to the invention relieves application programs from the burden of having to include separate routines for taking color measurements with each different type of supported color measuring device. Instead, in order to take color measurements with any type of supported color measuring device, the application program need only include calls to functions in the API. The API itself handles the different interfaces to the different types of color measuring devices. As a result, the application program is far simpler to write.

[0023] This brief summary has been provided so that the nature of the invention may be understood quickly. A more complete understanding of the invention can be obtained by reference to the following detailed description of the preferred embodiments thereof in connection with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] **FIG. 1** is a representational view of a computer system in which color fidelity of a color printer is calibrated using a color measuring device.

[0025] **FIG. 2** is a detailed block diagram showing the internal architecture of the computer system shown in **FIG. 1**.

[0026] **FIG. 3** is a block diagram for explaining a system for calibration of color fidelity of a color printer by a color calibration program according to the invention.

[0027] **FIG. 4** is a block diagram for explaining a structure of a measuring device application programming interface (API) according to the invention.

[0028] **FIG. 5** is a representational view of a development system for development of an application program using a measuring device API according to the invention.

[0029] **FIG. 6** is a detailed block diagram showing the internal architecture of the development system shown in **FIG. 5**.

[0030] **FIGS. 7A** to **7C** are flowcharts for explaining color calibration by a color calibration program using a measuring device API according to the invention.

[0031] **FIG. 8** is a block diagram for explaining a variation of the structure of the measuring device API according to the invention.

[0032] **FIG. 9** is a block diagram for explaining another variation of the structure of the measuring device API according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0033] **FIG. 1** is a representational view of a computer system in which color fidelity of a color printer is calibrated using a color measuring device. Shown in **FIG. 1** are color printer **1** and computer system **6**, together with a variety of color measuring devices, such as XY table **2**, strip reader **3**, hand-held patch reader **4**, and scanner **5**.

[0034] Color printer **1** is depicted in **FIG. 1** as an ink jet printer. However, any printer capable of printing color images on recording media can be utilized by a color calibration program written according to the invention, such as ink jet printers and laser printers. Color printer **1** prints color images in response to print jobs received from computer system **6** over printer interface **8**.

[0035] Measuring device **10** is a color measuring device that is used to generate color measurements of color patches input thereto. The color measurements generated by color measuring device **10** are transmitted over measuring device interface **9** to computer system **6**. Examples of measuring device **10** include XY table **2**, strip reader **3**, and hand-held patch reader **4** for reading individual color patches.

[0036] Color patches are input to each of the different types of color measuring devices in different ways. For example, patches are input to XY table **2** on a sheet that has an array of patches printed thereon, whereas patches are input to strip reader **3** on strips that each have one or more rows of patches printed thereon. The sensors that actually perform color measurements are positioned on patches in different ways depending on the physical structures of the color measuring devices. For example, XY table **2** typically includes motors and gimbals for automatically positioning the sensors, while hand-held patch reader **4** typically must be manually positioned over a patch.

[0037] Flatbed scanner **5** can also serve as a color measuring device, provided that scanner **5** is properly calibrated. Color patches are input to flatbed scanner **5** in a similar manner as the patches are input to XY table **2**, namely on a sheet that has an array of patches printed thereon.

[0038] The different color measuring devices also can use entirely different types and arrangements of sensors for making the color measurements. For example, color measuring device **10** can be a spectrometer (i.e., a spectrophotometer or a spectroradiometer), which uses sensors that preferably measure light intensity for frequencies across the entire visible spectrum. Alternatively, color measuring device **10** can be a colorimeter or densitometer, which uses sensors that measure light intensity for XYZ or RGB components of the spectrum.

[0039] In any case, each of the color measuring devices have at least one color sensor for making color measurements. In order to ensure accurate color measurements, the sensor(s) should be calibrated. In addition, depending on the type of measuring device **10**, a relative position of a recording medium with respect to the device might have to be calibrated. In particular, each time a new recording medium (e.g., strip or sheet) is input to color measuring device **10**, the position of the recording medium should be recalibrated so that the color measuring device can properly locate color patches printed thereon.

[0040] Because of the different ways that color patches are input and measured by the different types of color measuring devices, a different command set is needed to calibrate and to make color measurements with each different type of color measuring device.

[0041] As shown in **FIG. 1**, computer system **6** is connected to printer **1** through printer interface **8** and measuring device **10** through measuring device interface **9**. Provided with computer system **6** are display **12** which may be a color monitor, keyboard **14** for entering user commands, and pointing device **15** such as a mouse for pointing to and for manipulating graphical user interfaces and other objects displayed on display **12**.

[0042] Computer system **6** also includes a mass storage device such as fixed disk **16**. This mass storage device is for storing computer-executable process steps for a color calibration program and a measuring device DLL according to the invention, as well other application programs and an operating system including a printer driver and a measuring device driver. Such storage may also be provided by a CD-ROM (not shown).

[0043] It should be understood that, although a programmable general-purpose computer is shown in **FIG. 1**, a dedicated computer terminal or other type of data processing equipment can utilize the present invention.

[0044] **FIG. 2** is a detailed block diagram showing the internal architecture of computer system **6**. As shown in **FIG. 2**, computer system **6** includes central processing unit **23** which interfaces with computer bus **24**. Also interfacing with computer bus **24** are fixed disk **16**, main memory (RAM) **26**, read only memory (ROM) **27**, floppy disk interface **29**, display interface **30** to display **12** (not shown), keyboard interface **32** to keyboard **14** (not shown), pointing device interface **33** to pointing device **15** (not shown), printer interface **8** to color printer **1**, and measuring device interface **9** to measuring device **10**.

[0045] Main memory **26** interfaces with computer bus **24** so as to provide RAM storage to CPU **23** during execution of software applications. More specifically, CPU **23** loads process steps from fixed disk **16**, another storage device, or

some other source such as a network (not shown), into main memory **26**. CPU **23** then executes the stored process steps from main memory **26** in order to execute application programs. Data such as print data and color measurement data can be stored in main memory **26**, where the data can be accessed by CPU **23** during execution of the process steps.

[**0046**] As shown in **FIG. 2**, fixed disk **16** typically contains operating system **36**, application programs **37**, measuring device DLL **38** according to the invention, and other files and data. Operating system **36** includes printer driver **40** and measuring device driver **41**. Measuring device driver **41** is one of plural different types of measuring device drivers corresponding to the type of measuring device **10** connected to computer system **6**. Examples of measuring device driver **41** include XY table driver **43** for XY table **2**, strip reader driver **44** for strip reader **3**, patch reader driver **45** for hand-held patch reader **4**, and scanner driver **46** for scanner **5**. Some or all of these drivers can be stored on fixed disk **16**.

[**0047**] Application programs **37** include color calibration program **48**. The structure and operation of color calibration program **48** is explained in more detail below with reference to **FIG. 3**.

[**0048**] Measuring device DLL **38** is a library of functions that are called by an application program so as to use any of plural different color measuring devices supported by the DLL. In order to write an application program that calls these functions, a software developer uses a measuring device API according to the invention, as explained below with reference to **FIGS. 5 and 6**.

[**0049**] **FIG. 3** is a block diagram for explaining a system for calibration of color fidelity of a color printer by a color calibration program according to the invention. In **FIG. 3**, color calibration program **48** runs on computer system **6** and sends print data **51** for printing color patches to printer driver **40**. The color patches are for use in calibration of color printer **1**.

[**0050**] Color calibration program **48** makes API calls **52** to functions provided by measuring device DLL **38** in order to make color measurements of the color patches. According to the invention, since the DLL encapsulates the functionality needed to operate many different color measuring device, it is possible for the color calibration program **48** to call exactly the same functions, in exactly the same order, no matter which of plural different types of color measuring devices are connected. Because of the difference in devices, however, the API often needs to have certain functions repeated, or operator interaction performed, in order for the different devices to be usable by a single application. Accordingly, in response to API calls **52**, the functions in the DLL provide color calibration program **48** with information that the application needs to ensure that the API functions are called correctly. Such information might include, for example, display values for display by the application to the user so as to prompt the user for some user intervention (such as to prompt the user to insert a next sheet of patches into the measuring device), and the information might further include flow control data that instruct the application to alter its control flow such as by calling particular DLL functions multiple times until a needed result (such as position calibration) is achieved. Display values and flow control data **53** provided to color calibration program **48** are explained in more detail below with reference to **FIGS. 4, 8** and **9**.

[**0051**] Color calibration program **48** also is provided with color measurements **54** by the DLL. Based on color measurements **54**, color calibration program **48** sends color adjustment commands **55** to printer driver **40** so as to adjust color fidelity of color printer **1**. The operation of color calibration program **48** in printing and measuring the color patches and adjusting the color printer is explained in more detail below with reference to **FIGS. 7A** to **7C**.

[**0052**] In response to print data **51** received from color calibration program **48**, printer driver **40** sends print job **57** to color printer **1**. Likewise, in response to color adjustment commands **55** received from color calibration program **48**, printer driver **40** sends printer commands **58** to color printer **1**.

[**0053**] Color printer **1** prints printed color patches **61** in response to print job **57** received from printer driver **40**. The user inputs these color patches to color measuring device **10**.

[**0054**] Measuring device DLL **38** provides a common interface between color calibration program **48** and plural different types of color measuring devices. As mentioned above, functions in measuring device DLL **38** are called by API calls **52** from color calibration program **48**. The functions in measuring device DLL **38** make device driver calls **62** based on API calls **52** in order to operate measuring device **10**. Device driver calls **62** are calls to a device driver corresponding to the type of color measuring device **10**. For example, if measuring device **10** is an XY table, device driver calls **62** are calls to an XY table driver. In response to device driver calls **62**, measuring device DLL **38** is provided with color measurements **64** by measuring device driver **41**. Measuring device DLL **38** in turn provides color calibration program **48** with display values and flow control data **53** and color measurements **54**. The flow control data preferably is based at least in part on device characteristics **65** received from measuring device driver **41**. The structures of the functions in measuring device DLL **38** according to the invention are explained in more detail below with reference to **FIGS. 4, 8** and **9**, and the operation of the function is explained with reference to **FIGS. 7A** to **7C**.

[**0055**] Measuring device driver **41** is a device driver corresponding to the type of measuring device **10**. Measuring device driver **41** receives device driver calls **62** from the functions in measuring device DLL **38**. In response to these call, measuring device driver **41** sends device commands **66** to measuring device **10**, which provides color measurements **67** to measuring device driver **41**. Color measurements **67** in turn are provided to measuring device DLL **38** as color measurements **64**.

[**0056**] As mentioned above, measuring device **10** receives printed color patches **61** as input. Measuring device **10** makes color measurements **67** of printed color patches **61** in accordance with device commands **66** received from measuring device driver **41**. Measurement device **10** provides color measurements **67** to measuring device driver **41**.

[**0057**] **FIG. 4** is a block diagram for explaining functionality provided in the DLL and accessed from the application through the API.

[0058] Briefly, the measuring device DLL illustrated in **FIG. 4** is accessed through a measuring device API according to the invention. The API provides a common interface between an application program and plural different types of color measuring devices each having at least one color measuring sensor. The interface includes plural functions for operating any of the plural different types of color measuring devices. In order to complete an operation performed by one or more of the functions, the function that performs the operation must be called a number of times which is different for different types of color measuring devices. For a color measuring device that is being operated, the API provides the application program with flow control data of the number of times that the function must be called. In **FIG. 4**, this flow control data is provided for some of the functions by a separate get-device capabilities function. This flow control data is provided for other functions by the functions themselves, in the form of "call-again" values provided by the functions to the color calibration program. The functions in the API also preferably provide the application program with display values which are different for different types of color measuring devices. The values are displayed by the color calibration program to a user so as to instruct the user in manipulating the color measuring device that is being operated.

[0059] In more detail, **FIG. 4** shows measuring device DLL **38** which is accessed by an application program through a measuring device API according to the invention. Thus, the API provides an interface for a software developer to write an application program that calls the functions in the DLL illustrated in **FIG. 4**. The functions provide an interface between color calibration program **48** and measuring device driver **41**. Measuring device driver **41** in turn communicates with measuring device **10** through measuring device interface **9**.

[0060] Measuring device driver **41** is a device driver corresponding to the type of measuring device **10**. Thus, brackets next to measuring device driver **41** in **FIG. 4** indicate that measuring device driver **41** is one of plural different device drivers such as XY table driver **43**, strip reader driver **44**, patch reader driver **45**, and scanner driver **46**. Likewise, brackets next to measuring device **10** in **FIG. 4** indicate that measuring device **10** is one of XY table **2**, strip reader **3**, hand-held patch reader **4** for reading individual color patches, and scanner **5**.

[0061] It should be noted that the various drivers and devices shown in **FIG. 4** are only representative of the possible drivers and devices that can be operated using the API according to the invention.

[0062] In **FIG. 4**, measuring device DLL **38** includes at least the following functions, which are provided to an application program through a measuring device API according to the invention: get-device-capabilities **71**, calibrate-position **72**, calibrate-sensor **73**, move-to-patch **74**, and make measurement **75**. Arrows pointing into blocks for these functions indicate information provided to the functions by color calibration program **48**. Likewise, arrows pointing out of blocks for these functions indicate information provided by the functions to color calibration program. **48**.

[0063] Information can be provided in various different ways to the functions by color calibration program **48** and by the functions to color calibration program **48**. For example, information can be provided to a function as a passed variable, by modification of a shared (e.g., global) variable or data space, by passing a pointer to a memory location that stores the information, or through messages in a message-based environment. Likewise, information can be provided by a function as a returned value, by modification of a shared variable or data space, by modification of a memory location pointed to by a pointer, or through messages. Any or all of these methods, as well as any other additional methods, can be utilized by measuring device DLL **38** according to the invention.

[0064] Get-device-capabilities function **71** according to the invention provides color calibration program **48** with flow control data for calibrate-position function **72** and calibrate-sensor function **73**. In particular, get-device-capabilities function **71** provides color calibration program **48** with number of calls **77**, thereby indicating the number of calls that must be made to calibrate-position function **72** in order to calibrate a position of a recording medium with respect to measuring device **10**. Likewise, get-device-capabilities function **71** provides color calibration program **48** with number of calls **78**, thereby indicating the number of calls that must be made to calibrate-sensor function **73** in order to calibrate the sensor(s) of measuring device **10**.

[0065] The DLL preferably determines the flow control data by querying measuring device driver **41**, or measuring device **10**, for device characteristics **65**. The functions in measuring device DLL determine the flow control data based at least in part on device characteristics **65**. For example, if the device characteristics identify the type of measuring device **10**, the functions can determine the flow control data using a look-up table. Alternatively, device characteristics **65** can include the flow control data directly, for later use by the different functions in the DLL. Get-device-capabilities function **71** preferably queries the device driver or the device for the device characteristics.

[0066] Calibrate-position function **72** is called to calibrate a relative position of a recording medium with respect to any of the plural different types of color measuring devices. In order to calibrate the relative position of the recording medium, calibrate-position function **72** might have to be called more than once. The number of calls depends at least in part on the type of measuring device **10**. As discussed above, get-device-capabilities function **71** according to the invention provides color calibration program **48** with number of calls **77** that must be made to calibrate-position function **72** in order to complete the position calibration operation. Number of calls **77** preferably is based at least in part on device characteristics **65**.

[0067] Each time calibrate-position function **72** is called, the user might be required to perform a task such as positioning the sensor(s), positioning the recording medium, or otherwise manipulating measuring device **10**. Calibrate-position function **72** preferably provides display values **80** to color calibration program **48**, and program **48** displays display values **80** to a user so as to instruct the user to perform these tasks, as necessary.

[0068] Display values **80**, as well as all other display values provided by measuring device DLL **38**, can include text and/or graphics, or any other type of values displayable by computer system **6**. Because the application program

actually displays the display values, the application program can determine the form of the display. For example, the application program can display text or graphics based on the display values. The display values do not necessarily need to be displayed visually. For example, if the application program includes text-to-speech functionality, the program can generate speech based on the display values.

[0069] Calibrate-sensor function **73** is called to calibrate the sensor(s) of any of the plural different types of color measuring devices. In order to calibrate the sensor(s), calibrate-sensor function **73** might have to be called more than once. As discussed above, get-device-capabilities function **71** according to the invention provides color calibration program **48** with number of calls **78** that must be made to calibrate-sensor function **73** so as to complete the sensor calibration operation. Number of calls **78** preferably is based at least in part on device characteristics **65**.

[0070] Each time calibrate-sensor function **73** is called, the user might be required to perform a task such as manipulating measuring device **10**. Calibrate-sensor function **73** preferably provides display values **82** to color calibration program **48** for display by the program to a user so as to instruct the user to perform any such tasks.

[0071] Move-to-patch function **74** is called to relatively position the sensor(s) and a color patch for any of the plural different types of color measuring devices. Move-to-patch function **74** is provided with logical color patch number **84** by color calibration program **48**. In response, move-to-patch function **74** moves the sensor(s) or the recording medium so as to position the sensor(s) at the corresponding color patch, provides color calibration program **48** with display values **85** so as to instruct the user to move the sensor(s) or the recording medium, or both.

[0072] In order to relatively position the sensor(s) at the patch, move-to-patch function **74** might have to be called multiple times, depending on the type of measuring device **10**. For example, if the color patch corresponding to color patch number **84** is on a next sheet or strip of recording medium, move-to-patch function **74** might have to be called a first time so as to instruct a user to change the sheet or strip, a second time so as to recalibrate the position of the recording medium (by providing a recalibrate value), and then a third time so as to move to the first patch on the recording medium. The number of times that move-to-patch function **74** needs to be called preferably is determined by the function based at least in part on device characteristics **65**. If move-to-patch function **74** needs to be called multiple times, move-to-patch function **74** provides color calibration program **48** with flow control data indicating whether the function has been called the necessary number of times. As shown in **FIG. 4**, this flow control data takes the form of call-again value **86**, which is provided if move-to-patch function **74** has not been called the necessary number of times.

[0073] In some situations, and in particular when a new recording medium is input to measuring device **10**, the relative position of the recording medium and measuring device **10** might have to be recalibrated. Move-to-patch function **74** provides color calibration program **48** with recalibrate value **87** in such situations.

[0074] Make-measurement function **75** is called to make a color measurement of the patch at which the sensor(s) are relatively positioned. Make-measurement function **75** provides color calibration program **48** with color measurement **54** for the color patch. In addition, make-measurement function **75** preferably provides color calibration program **48** with display values **89** for display by the program to instruct the user to perform any necessary tasks for making the color measurement.

[0075] As with move-to-patch function **74**, make-measurement function **75** might have to be called multiple times in order to complete its operation. The number of times that make-measurement function **75** needs to be called preferably is determined by the function based at least in part on device characteristics **65**. If make-measurement function **75** needs to be called multiple times, make-measurement function **75** provides color calibration program **48** with flow control data indicating whether the function has been called the necessary number of times. As shown in **FIG. 4**, this flow control data takes the form of call-again value **90**, which is provided if make-measurement function **75** has not been called the necessary number of times.

[0076] If the sensor(s) need to be recalibrated after a color measurement, for example after a certain number of color measurements, make-measurement function **75** provides color calibration program **48** with recalibrate value **91**.

[0077] **FIG. 5** is a representational view of a development system for development of an application program using a measuring device API according to the invention. As shown in **FIG. 5**, development system **100** is provided with display **102** which may be a color monitor, keyboard **104** for entering user commands and for entering code for an application program, and pointing device **105** such as a mouse. Development system **100** also includes a mass storage device such as fixed disk **106**. This mass storage device is for storing computer-executable process steps for an operating system, software development programs, and a measuring device API according to the invention. Such storage may also be provided by a CD-ROM (not shown).

[0078] It should be understood that, although development system **100** is shown as a programmable general-purpose computer in **FIG. 5**, a dedicated computer terminal or other type of data processing equipment can be used to write application programs utilizing the API according to the present invention.

[0079] **FIG. 6** is a detailed block diagram showing the internal architecture of development system **100**. As shown in **FIG. 6**, development system **100** includes central processing unit **113** which interfaces with computer bus **114**. Also interfacing with computer bus **114** are fixed disk **106**, main memory (RAM) **116**, read only memory (ROM) **117**, floppy disk interface **119**, display interface **120** to display **102** (not shown), keyboard interface **122** to keyboard **104** (not shown), and pointing device interface **123** to pointing device **105** (not shown).

[0080] Main memory **116** interfaces with computer bus **114** so as to provide RAM storage to CPU **113** during execution of software applications. More specifically, CPU **113** loads process steps from fixed disk **106**, another storage device, or some other source such as a network (not shown), into main memory **116**. CPU **113** then executes the stored process steps from main memory **116** in order to execute application programs. Data such as code for an application

program utilizing a measuring device API according to the invention can be stored in main memory **116**, where the data can be accessed by CPU **113** during execution of the process steps.

[**0081**] As shown in **FIG. 6**, fixed disk **106** typically contains operating system **126**, application programs **127**, and measuring device API **128** according to the invention. Operating system **126** typically is a windowing operating system and preferably is compatible with operating system **36** of computer system **6**. Application programs **127** preferably includes software development programs **130** for developing application programs for making color measurements with color measuring devices.

[**0082**] A software developer uses software development programs **130** to write code for an application program such as color calibration program **48**. The software developer includes calls to functions provided by measuring device API **128** in order to have the application program make color measurements with any color measuring device supported by the API.

[**0083**] The API preferably includes headers corresponding to the functions in measuring device DLL **38**. When the software developer compiles the code for application program using software development programs **130**, these headers allow the application program to access the functions in measuring device DLL **38**. These functions provide a common interface to any of the plural supported color measuring devices. Therefore, as long as the application program includes code for handling flow control data and display values returned by the functions in the DLL, as described above with reference to **FIGS. 3 and 4**, the application program is able to make color measurements with any of the plural supported color measuring devices.

[**0084**] **FIGS. 7A** to 7C are flowcharts for explaining a representative color calibration application using a measuring device API according to the invention.

[**0085**] In step S**701** in **FIG. 7A**, color calibration program **48** generates print data **51** for color patches for calibration of color fidelity of color printer **1**. In step S**702**, color calibration program **48** sends print data **51** to printer driver **40**, which in turn sends print job **57** to color printer **1** based on print data **51**. Color printer **1** prints the print job onto a recording medium, resulting in printed color patches **61**.

[**0086**] In step S**703**, color calibration program **48** makes API call **52** to get-device-capabilities function **71** in measuring device DLL **38**. In response, get-device-capabilities function **71** provides flow control data to calibration program **48**. This flow control data preferably includes number of calls **77** and number of calls **78**, which indicate the number of times calibrate-position function **71** and calibrate-sensor function **72** need to be called in order to perform their respective operations.

[**0087**] In step S**704**, the relative position of the sensor(s) with respect to the recording medium is calibrated. **FIG. 7B** is a flowchart for explaining position calibration according to the invention.

[**0088**] In step S**705** of **FIG. 7B**, color calibration program **48** calls calibrate-position function **72**. This function sends device driver calls **62** to measuring device driver **41**, which in turn sends device commands **66** to measuring device **10** so as to calibrate the relative position of the sensor(s).

[**0089**] In step S**706**, color calibration program **48** determines if calibrate-position function **72** provided display values **80**. If calibrate-position function **72** did provide display values **80**, color calibration program **48** displays the display values to the user, such as on display **12**, in step S**707**.

[**0090**] In step S**708**, color calibration program **48** determines if calibrate-position function **72** has been called the number of times indicated by number of calls **77**. If calibrate-position function **72** has not been called number of calls **77** times,flow returns to step S**705**. Once calibrate-position function **72** has been called number of calls **77** times, flow returns to **FIG. 7A**.

[**0091**] In **FIG. 7A**, flow proceeds to step S**709**, where the sensor(s) are calibrated. **FIG. 7C** is a flowchart for explaining sensor calibration according to the invention.

[**0092**] In step S**710** of **FIG. 7C**, color calibration program **48** calls calibrate-sensor function **72**. This function sends device driver calls **62** to measuring device driver **41**, which in turn sends device commands **66** to measuring device **10** so as to calibrate the sensor(s).

[**0093**] In step S**711**, color calibration program **48** determines if calibrate-sensor function **73** provided display values **82**. If calibrate-sensor function **73** did provide display values **82**, color calibration program **48** displays the display values to the user in step S**712**.

[**0094**] In step S**713**, color calibration program **48** determines if calibrate-sensor function **73** has been called the number of time indicated by number of calls **78**. If calibrate-sensor function **73** has not been called number of calls **78** times, flow returns to step S**710**. Once calibrate-sensor function **73** has been called number of calls **78** times, flow returns to **FIG. 7A**.

[**0095**] Returning to **FIG. 7A**, flow proceeds to step S**714**, where move-to-patch function **74** is called. Color calibration program **48** provides move-to-patch function **74** with color patch number **84**, which is a logical patch number corresponding to the next patch that needs to be measured. Preferably, color patch number **84** is incremented every time a color patch is measured. Based on color patch number **84** and the type of measuring device **10**, move-to-patch function **74** of measuring device DLL **38** sends device driver calls **62** to device driver **41**. Device driver **41** in turn sends device commands **66** to measuring device **10**, which moves the sensor(s) or the recording medium, if appropriate, in order to relatively position the patch.

[**0096**] In step S**715**, color calibration program **48** determines if move-to-patch function **74** provided display values **85** to the program. If move-to-patch function **74** did provide display values **85**, color calibration program **48** displays the display values to the user in step S**716**.

[**0097**] With some color measuring devices, move-to-patch function **74** cannot move the sensor(s) or the recording medium. For example, hand-held patch reader **4** has no mechanism for moving its sensor(s) or a recording medium. Rather, the user must move the sensor(s) or the recording medium. In that case, display values **85** sent in step S**716** instructs the user to perform this task, as necessary.

[0098] In step S717, color calibration program 48 determines if move-to-patch function 74 has indicated that position of the recording medium needs to be recalibrated. If the position does need to be recalibrated, flow proceeds to step S718, where the position is recalibrated as explained above with reference to FIG. 7B.

[0099] Flow proceeds to step S719, where color calibration program 48 determines if move-to-patch function 74 needs to be called again so as to complete positioning of the sensor(s). Color calibration program 48 makes this determination by checking for flow control data from move-to-patch function 74 in the form of call-again value 86. If move-to-patch function 74 needs to be called again, flow returns to step S714. Otherwise, flow proceeds to step S720.

[0100] In step S720, color calibration program 48 calls make-measurement function 75. This function sends device driver calls 62 to measuring device driver 41, which in turn uses device commands 66 to instruct measuring device 10 to make a color measurement. Once the measuring operation is complete, measuring device 10 generates color measurement 67 based on this measuring operation and sends color measurement 67 to measuring device driver 41. Measuring device driver 41 sends this color measurement to make-measurement function 75 in measuring device DLL 38 in the form of color measurement 64, and the make-measurement function provides the measurement to color calibration program 48 as color measurement 54.

[0101] In step S721, color calibration program 48 determines if make-measurement function 75 provided display values 89 to the program. If make-measurement function 75 did provide display values 89, color calibration program 48 displays the display values to the user in step S722.

[0102] In step S723, color calibration program 48 determines if make-measurement function 75 has indicated that the sensor(s) need to be recalibrated. If the sensor(s) do need to be recalibrated, flow proceeds to step S724, where the sensor(s) are recalibrated as explained above with reference to FIG. 7C.

[0103] Flow proceeds to step S725, where color calibration program 48 determines if make-measurement function 75 needs to be called again so as to complete making the color measurement. Color calibration program 48 makes this determination by checking for flow control data from make-measurement function 74 in the form of call-again value 90. If make-measurement function 75 needs to be called again, flow returns to step S720. Otherwise, flow proceeds to step S726.

[0104] In step S726, color calibration program 48 determines if all color patches for calibrating color printer 1 have been measured. If more color patches need to be measured, flow returns to step S714. Otherwise, flow proceeds to step S727.

[0105] In step S727, color calibration program 48 generates color adjustment commands 55 based at least in part on color measurements 54. Color calibration program 48 sends these commands to printer driver 40, which in turn sends print commands 58 to color printer 1 so as to adjust the color fidelity of the printer.

[0106] Because each of the function in measuring device DLL 38 accessed through measuring device API 128 makes device driver calls 62 to measuring device 41 for the type of color measuring device 10, color calibration program 48 is insulated from the differences between different types of color measuring devices. Furthermore, the flow control data for multiple calls provided to color calibration program 48 allows the program to call the functions the necessary number of times for each operation without knowing the type of the actual device. The display values provided to the program allow the program to display the display values appropriate for the type of measuring device 10 that is being used. Moreover, since the application program generates displays based on the display values rather than the DLL, the application program can package a message however it wants so as to permit each developer to give his application a unique and internally-consistent GUI. As a result, a block of code that accesses color measuring device DLL 38 can make color measurements with any type of color measuring device supported by the API, despite the different device driver commands needed to calibrate and operate the different types of devices.

[0107] Included in a microfiche appendix submitted herewith is sample code that operates generally as described above. This code includes code for a portion of a color calibration program that makes color measurements using an API according to the invention, the API itself, and a DLL accessed through the API. This code is provided for illustrative purposes only. Other implementations of the color measurement code, measuring device API, and measuring device DLL exist that are within the scope and spirit of the invention.

[0108] FIG. 8 is a block diagram for explaining a variation of the structure of the measuring device DLL according to the invention and of the API used to access the DLL. As shown in FIG. 8, both calibrate-position function 72 and calibrate-sensor function 73 can provide call-again values 140 and 141, respectively, to color calibration program 48. These call-again values are provided by these functions when they need to be called more than once in order to complete their respective operations.

[0109] Because the calibration functions can return these call-again values to facilitate multiple calls, there is no need for get-device-capabilities function 71 to provide number of calls 77 and number of calls 78 to the calibration functions of course, get-device-capabilities function 71 can still be included in the API, if desired.

[0110] FIG. 9 is a block diagram for explaining another variation of the structure of the measuring device API according to the invention. In this variation, each of the functions in the API provides flow control data in the form of a "number of calls" value to indicate how many times that function should be called in order to complete its respective operation. Thus, calibrate-position function 72 provides number of calls 143, calibrate-sensor function 73 provides number of calls 154, move-to-patch function 74 provides number of calls 155, and make-measurement function 75 provides number of calls 156. These values can be a total number of calls that need to be made to each function. For example, if three calls need to be made to calibrate-position function 72, then that function would provide a value of "three" each time it was called. Alternatively, each function can maintain an internal state variable and provide the application program with a number of remaining calls that

must be made in order to complete an operation. For example, calibrate-position function **72** would return a value of "three" the first time it was called to perform a position calibration, a "two" the next time, and a "one" the next time. Again, because each function provides the number of times that function needs to be called, there is no need for get-device-capabilities function **71**.

[**0111**] Various combinations of the foregoing flow control techniques illustrated in **FIGS. 4, 8** and **9** can be used for facilitating multiple calls of the function in measuring device DLL **38**.

[**0112**] While the invention is described above with respect to what is currently considered its preferred embodiments, it is to be understood that the invention is not limited to that described above. To the contrary, the invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

1.-**90**. (canceled)

91. Computer-executable process steps to provide a software application programming interface (API) comprising a common interface between an application program and plural different types of color measuring devices, and plural functions for operating the plural different types of color measuring devices, the process steps comprising the steps of:

receiving a call to a function from the application program, and

calling a measuring device driver based on the called function to operate a color measurement device;

wherein, for the color measuring device that is being operated, the API provides the application program with flow control data of the number of times that the function must be called.

92. Computer-executable process steps according to claim 91, wherein the flow data is provided by the function which must be called a number of times in order to complete the operation.

93. Computer-executable process steps according to claim 92, wherein the flow control data is provided in the form of a call-again value.

94. Computer-executable process steps according to claim **2**, wherein the flow control data is provided in the form of a numerical value.

95. Computer-executable process steps according to claim **1**, wherein the flow control data is provided by a separate function other than the function which must be called the number of times in order to complete the operation.

96. Computer-readable memory medium in which computer-executable process steps are stored, the process steps provide a software application programming interface (API) comprising a common interface between an application program and plural different types of color measuring devices, and plural functions for operating the plural different types of color measuring devices, the process steps comprising the steps of:

receiving a call to a function from the application program, and

calling a measuring device driver based on the called function to operate a color measurement device;

wherein, for the color measuring device that is being operated, the API provides the application program with flow control data of the number of times that the function must be called.

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