US00RE36620E

United States Patent [19]

Costello, Jr.

[11] E **Patent Number: Re. 36,620**

[45] **Reissued Date of Patent: Mar. 21, 2000**

[54] **PULSE OXIMETRY TESTING**

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[73] Assignee: **Clinical Dynamics Corporation**, Wallingford, Conn.

[21] Appl. No.: **09/172,586**

[22] Filed: **Oct. 14, 1998**

Related U.S. Patent Documents

Reissue of:

[64] Patent No.: **5,783,821**
Issued: **Jul. 21, 1998**
Appl. No.: **08/962,149**
Filed: **Oct. 31, 1997**

U.S. Applications:

[63] Continuation of application No. 08/556,749, Nov. 2, 1995, abandoned.

[51] **Int. Cl.**[7] **G01L 25/00**

[52] **U.S. Cl.** **250/252.1**

[58] **Field of Search** 250/252.1, 343; 356/40, 41, 42; 128/633

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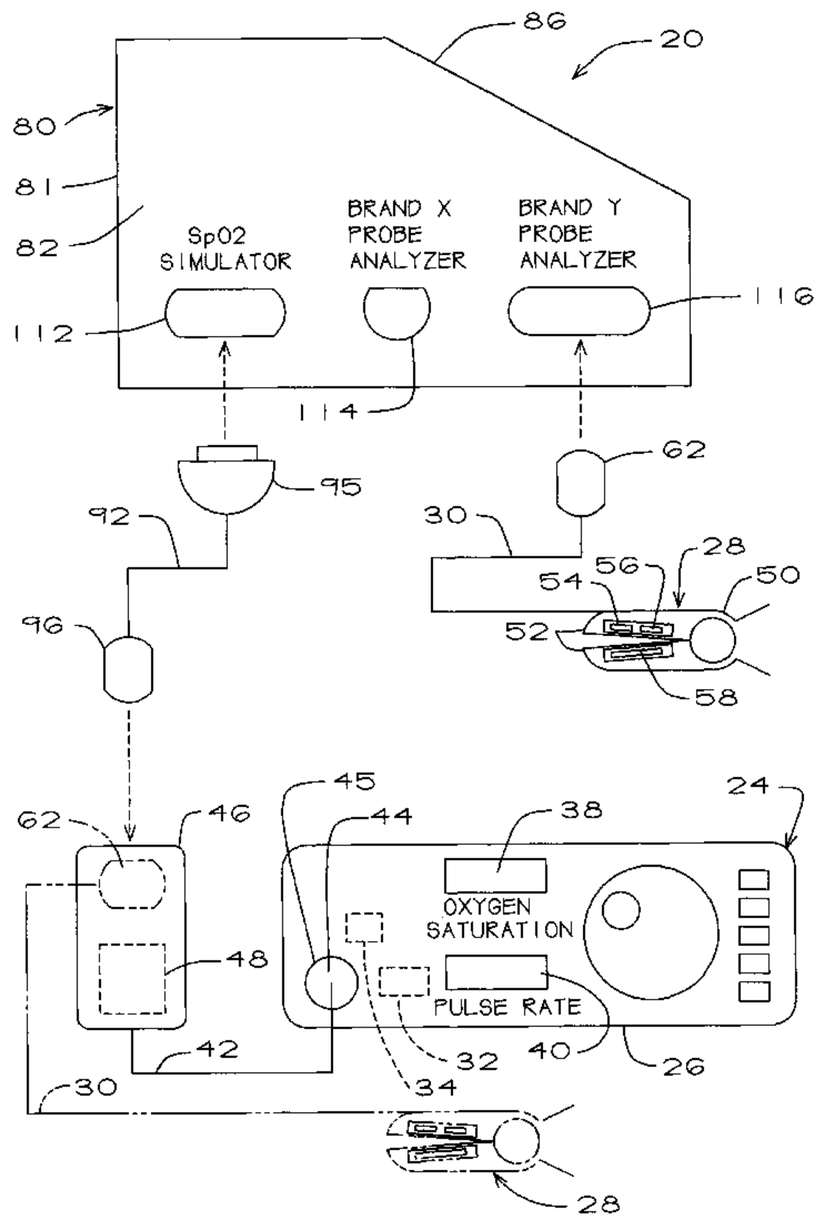
Primary Examiner—David P. Porta
Attorney, Agent, or Firm—Leo F. Costello

[57] **ABSTRACT**

A method and apparatus for testing a pulse oximeter which is based on the concept of an electrical interface between the testing instrument and the oximeter rather than an optical interface. The pulse oximeter signal processor is tested separately from the probe, and still further, the optical elements, that is, the LEDs and the photodiode, of the probe are tested separately from the probe cable. With the probe disconnected from the oximeter, a modulated electrical test signal representative of SpO_2 values and other parameters is generated in response to an electrical signal from the oximeter, and the test signal is applied to the oximeter signal processor, whereby the display of the oximeter shows a value of SpO_2 which is compared with the SpO_2 value represented by the test signal. Independently, the probe including the probe cable, the LEDs and the photodiode are respectively and separately subjected to continuity and optical sensitivity tests. Each of the main components of the oximeter is thereby separately analyzed, and the source of a defect is isolated.

83 Claims, 12 Drawing Sheets



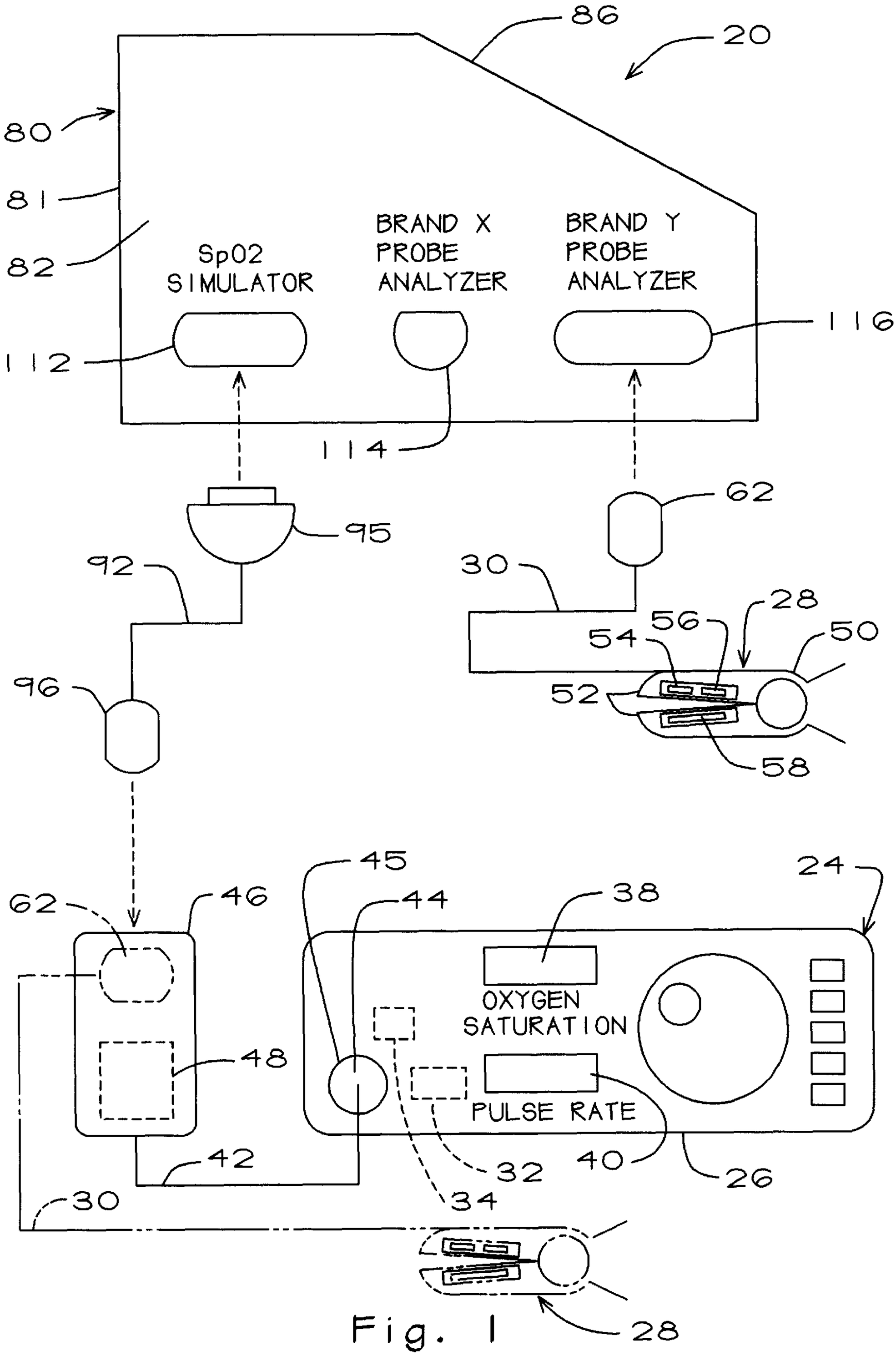

86
20
80
81
82
SpO2 SIMULATOR
BRAND X PROBE ANALYZER
BRAND Y PROBE ANALYZER
116
112
114
95
92
62
30
28
56
54
50
52
58
96
45
24
46
62
44
38
48
OXYGEN SATURATION
PULSE RATE
42
32
40
26
30
34
28

Fig. 1

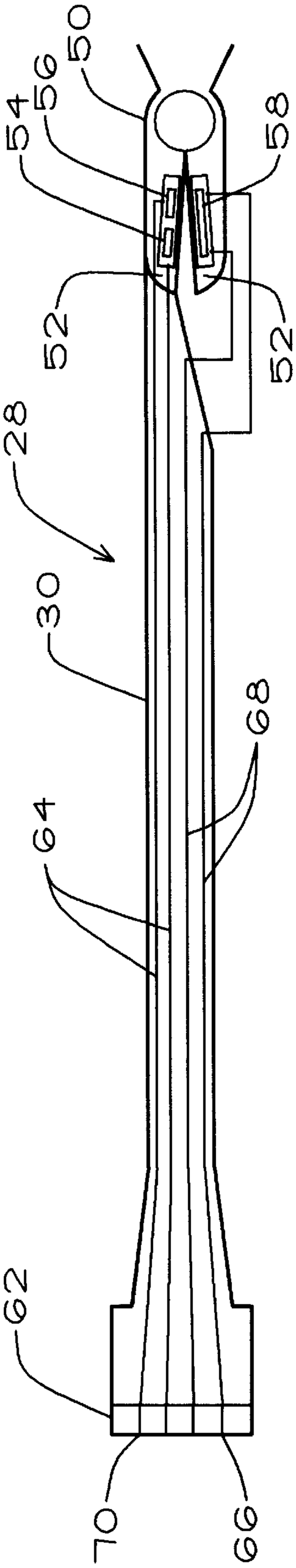


Fig. 2

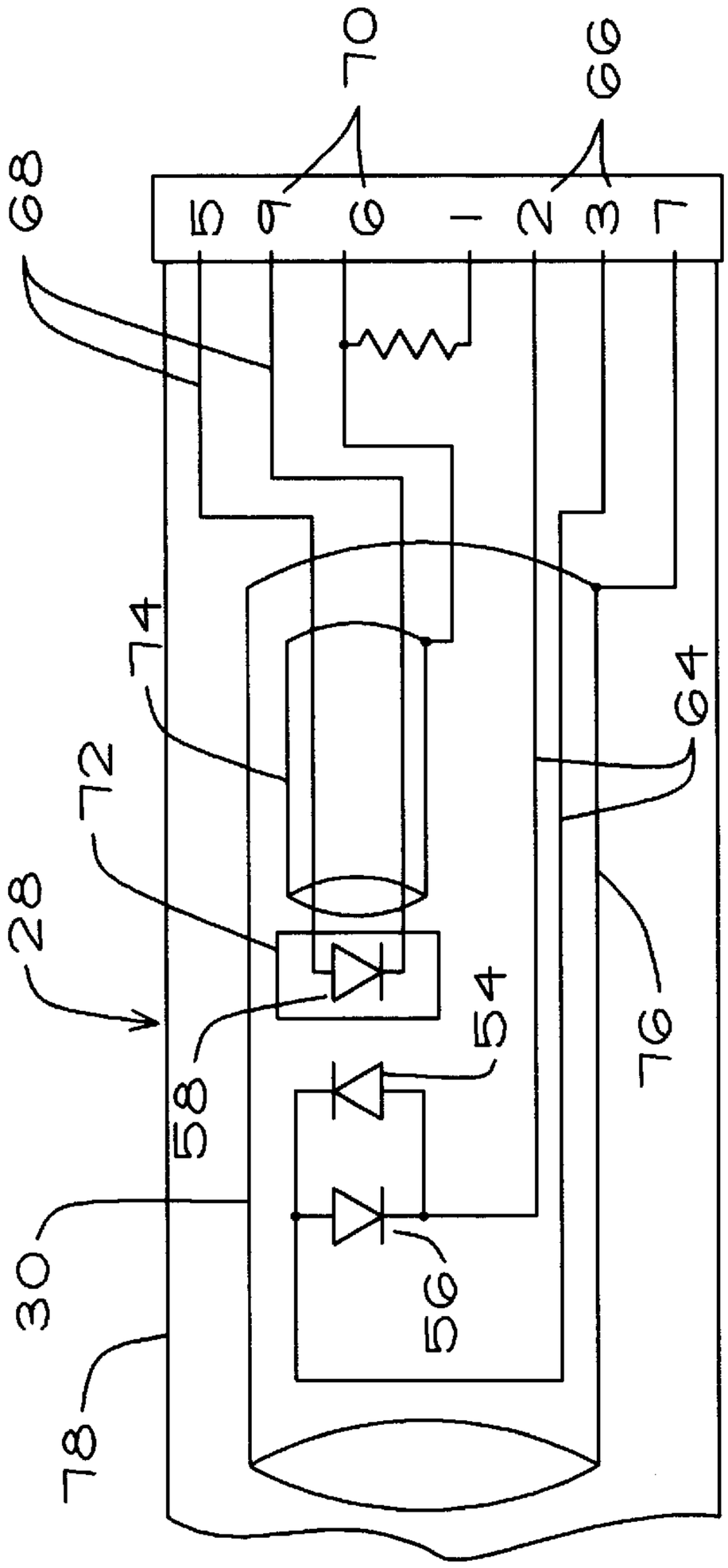


Fig. 4

Fig. 3

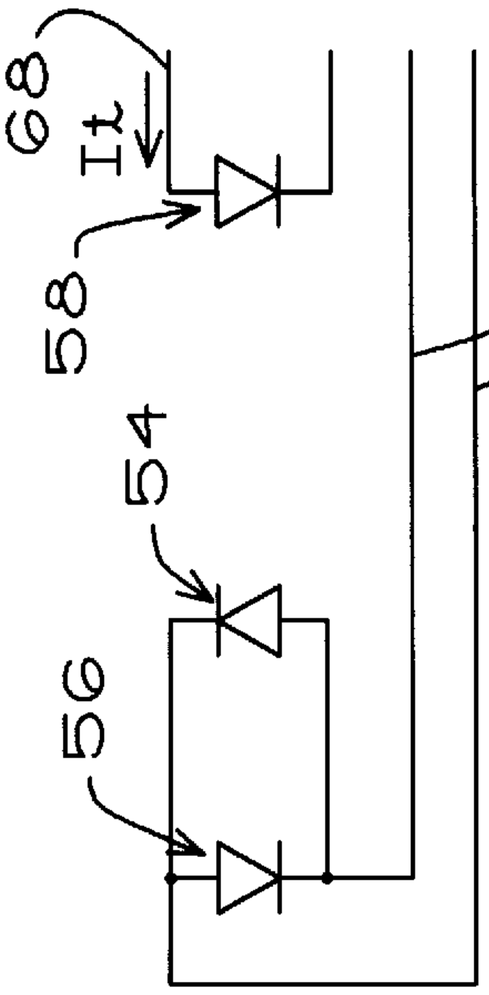


Fig. 5

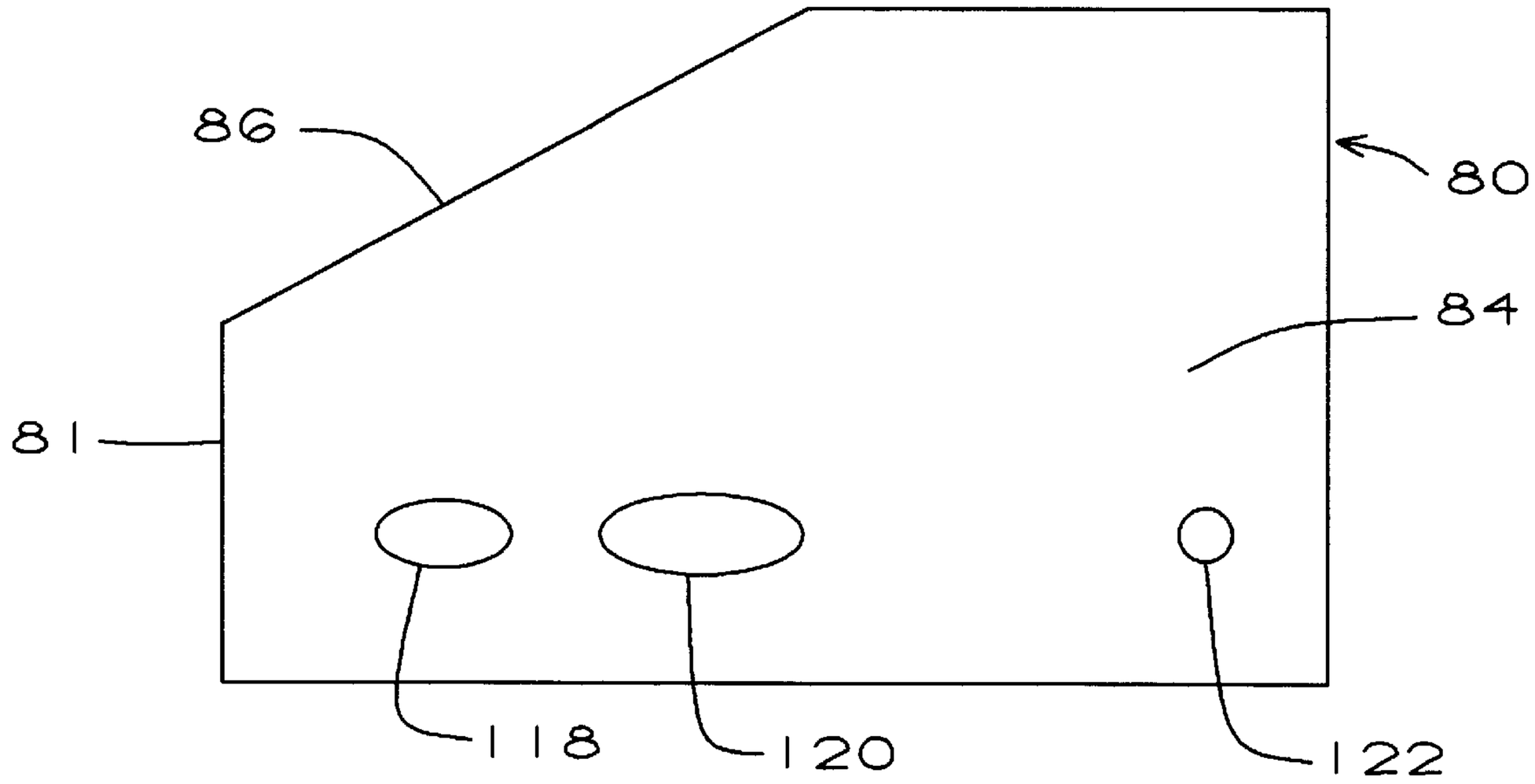

86
80
84
81
118
120
122

Fig. 6

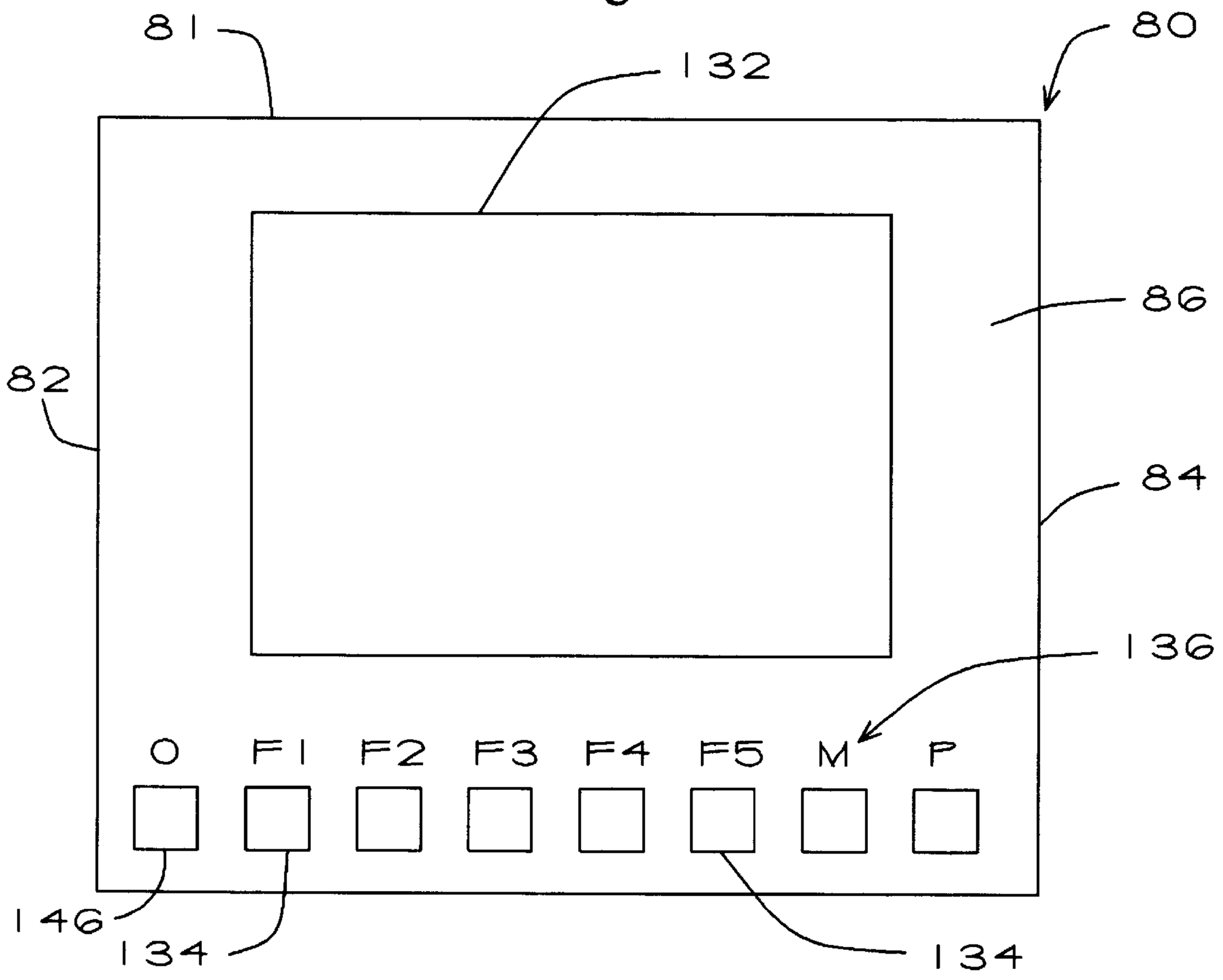

81
80
132
86
82
84
136
0
F1
F2
F3
F4
F5
M
P
146
134
134

Fig. 7

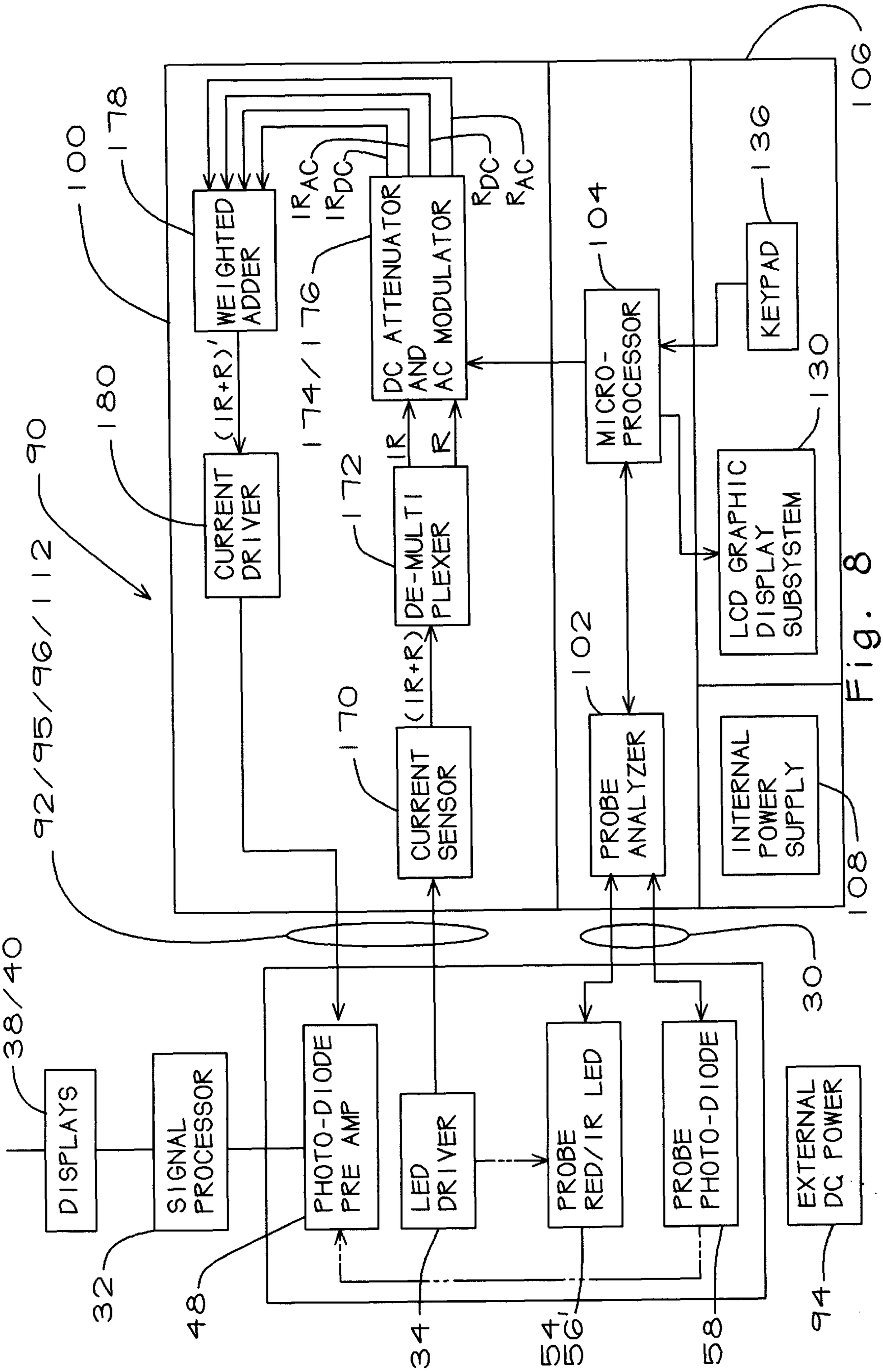

100
178
106
136
IR AC
IR DC
R DC
R AC
WEIGHTED ADDER
(IR+R)'
180
CURRENT DRIVER
174/176
DC ATTENUATOR AND AC MODULATOR
104
MICRO-PROCESSOR
KEYPAD
90
96/112
172
IR
R
DE-MULTI PLEXER
(IR+R)
102
LCD GRAPHIC DISPLAY SUBSYSTEM
130
170
CURRENT SENSOR
PROBE ANALYZER
INTERNAL POWER SUPPLY
108
92/95/98
30
38/40
DISPLAYS
SIGNAL PROCESSOR
PHOTO-DIODE PRE AMP
LED DRIVER
PROBE RED/IR LED
PROBE PHOTO-DIODE
EXTERNAL DC POWER
32
48
34
54
56
58
94

Fig. 8

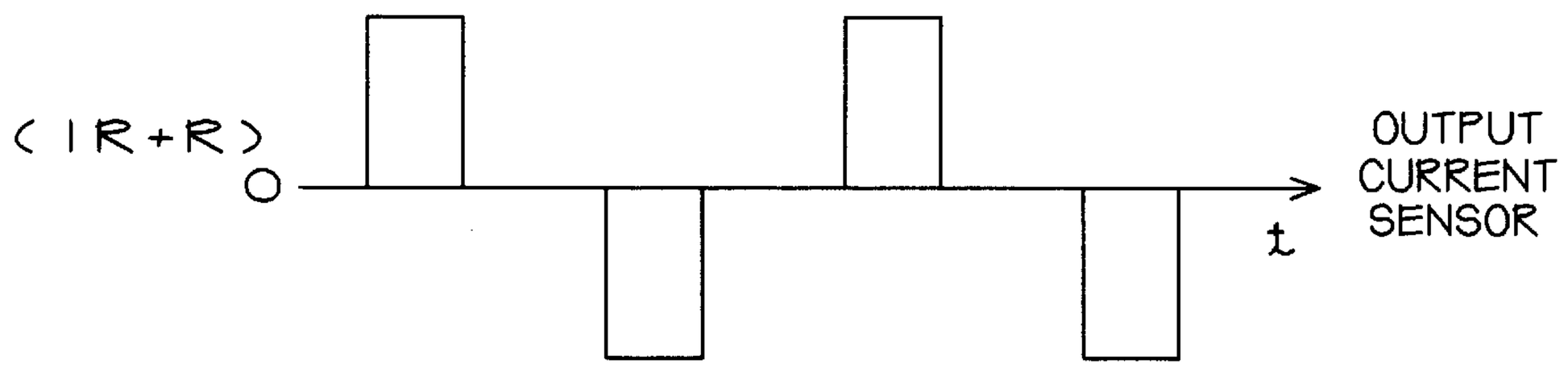


Fig. 8A

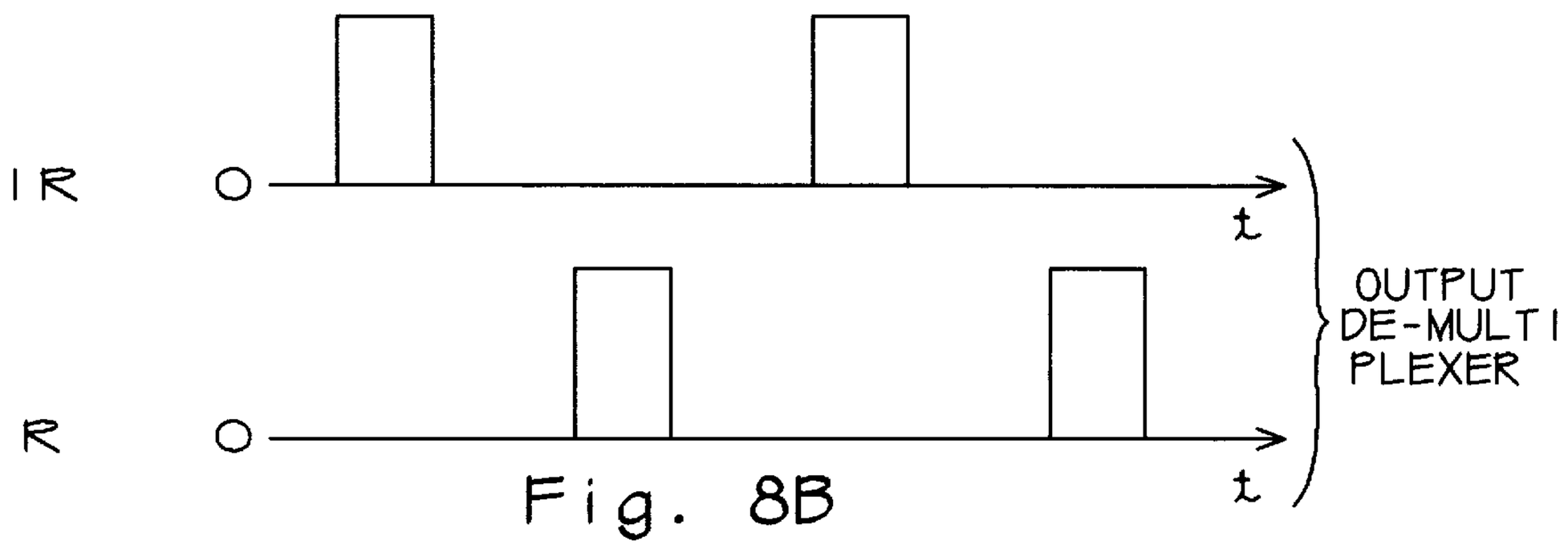


Fig. 8B

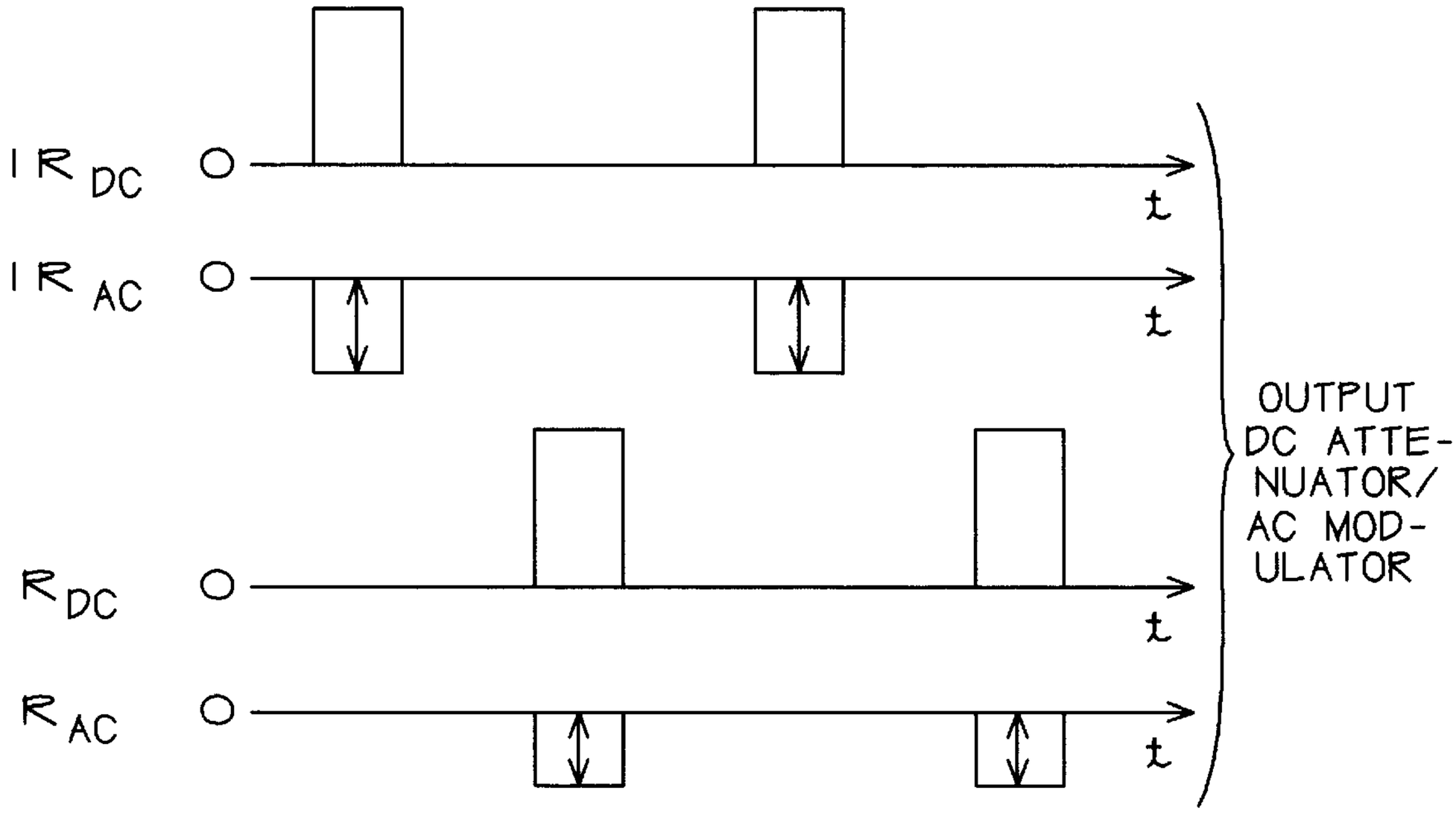


Fig. 8C

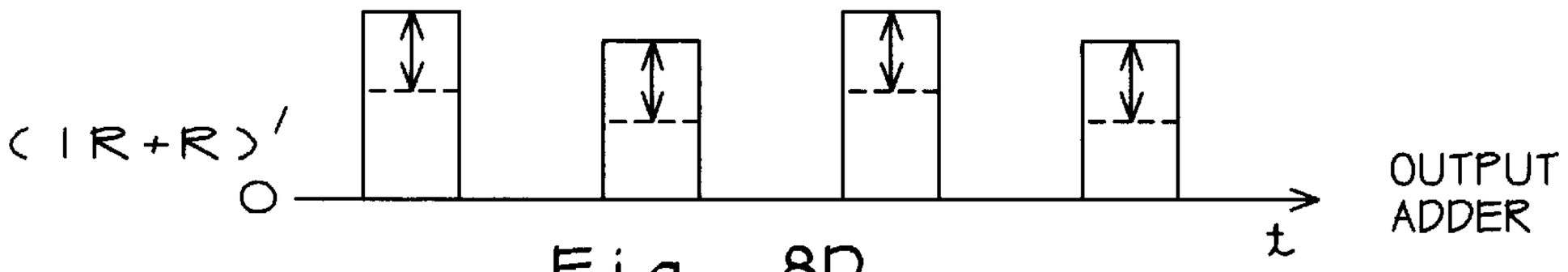


Fig. 8D

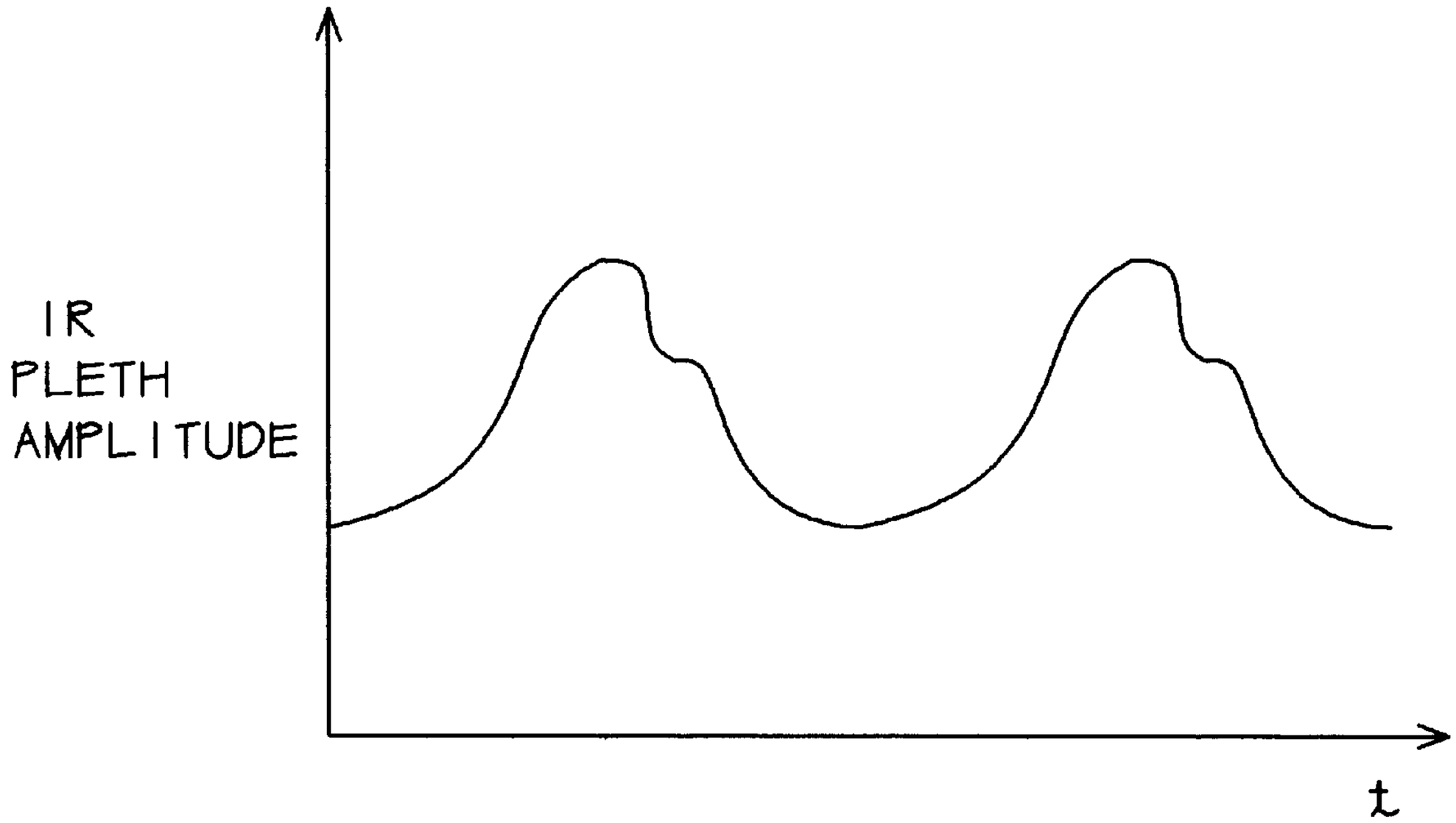


Fig. 8E

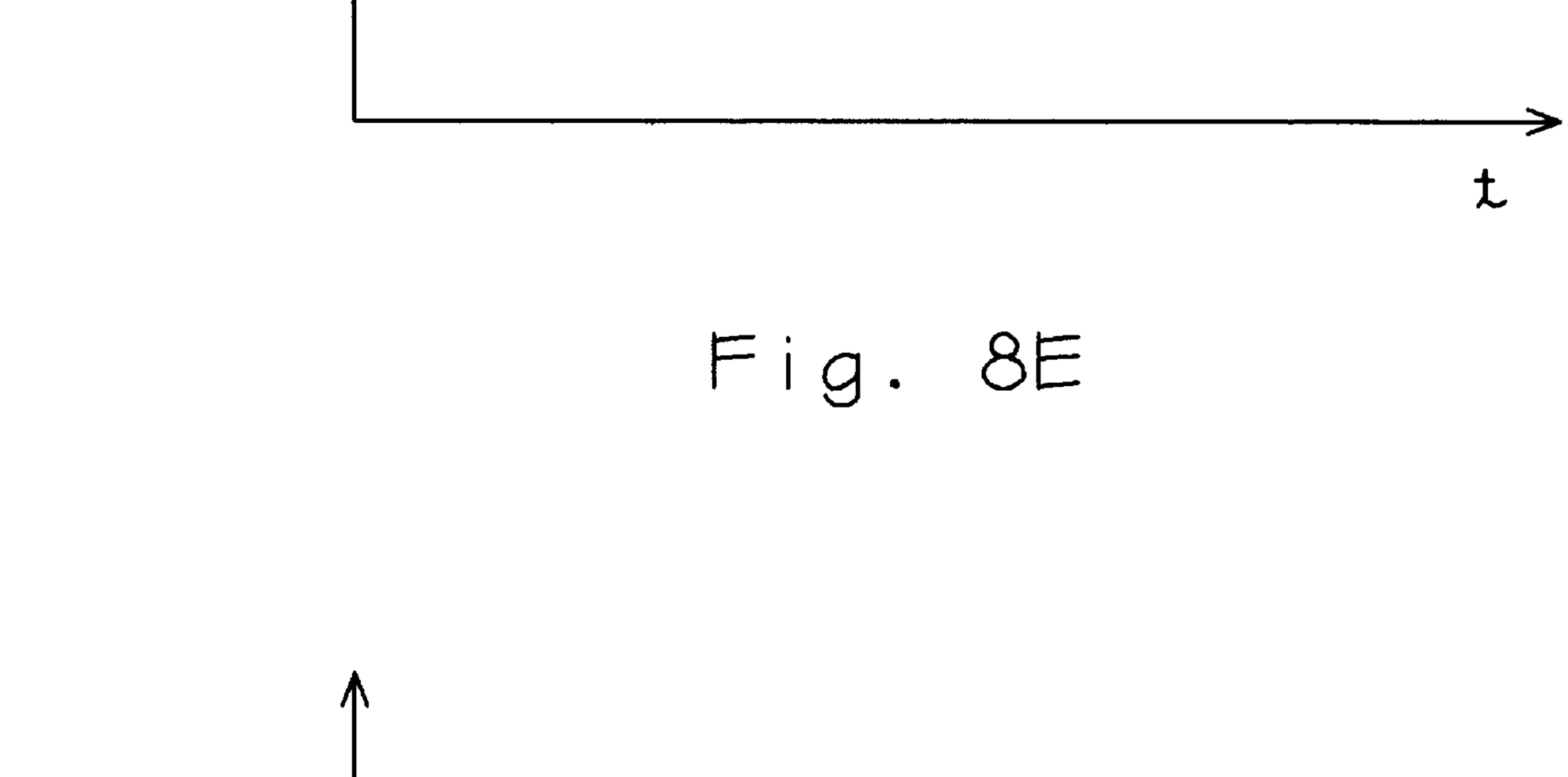


Fig. 8F

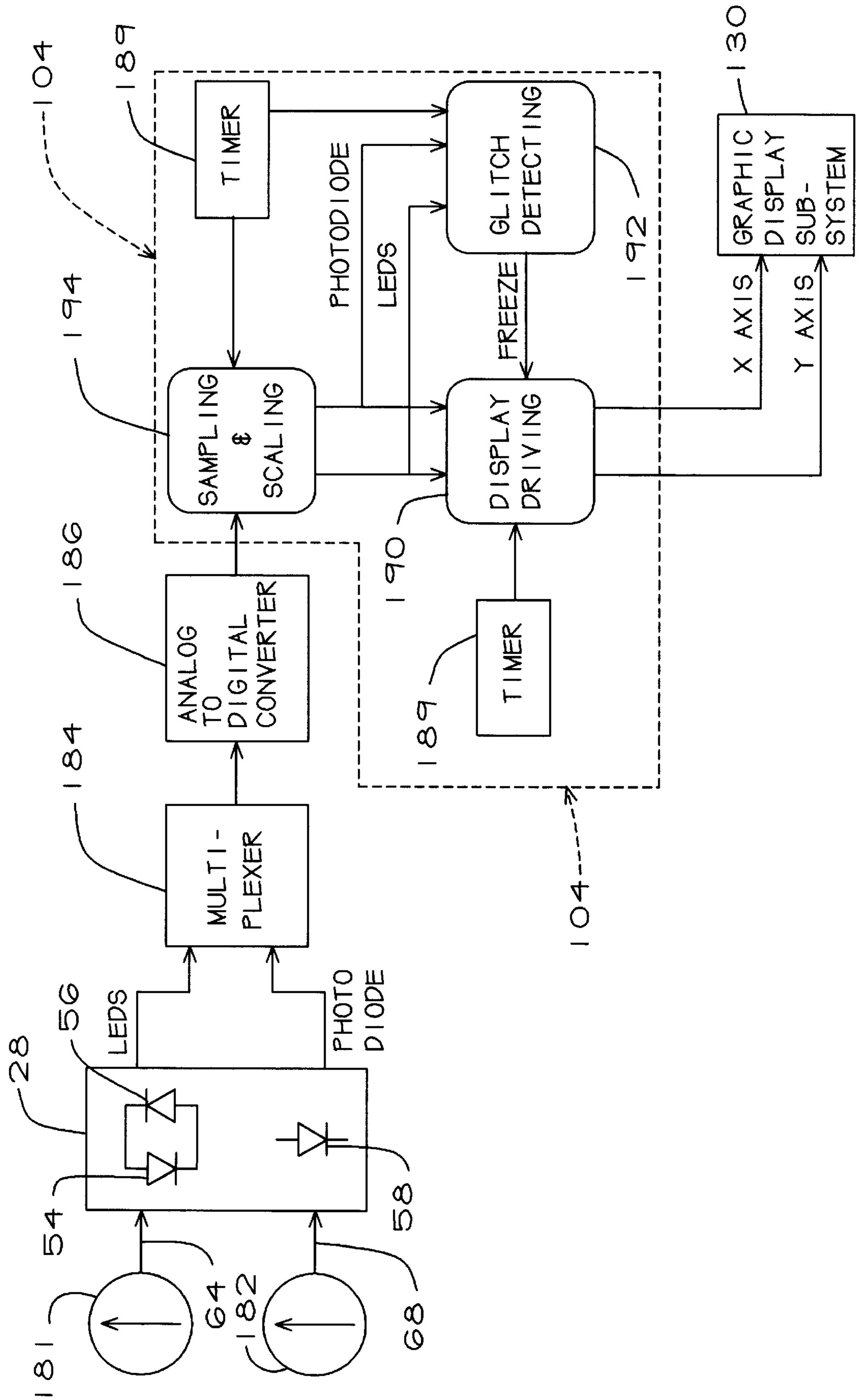

104
189
TIMER
194
SAMPLING & SCALING
186
ANALOG TO DIGITAL CONVERTER
184
MULTI-PLEXER
28
56
LEDS
PHOTO DIODE
54
58
64
68
181
182
PHOTODIODE
LEDS
GLITCH DETECTING
192
FREEZE
190
DISPLAY DRIVING
189
TIMER
104
130
GRAPHIC DISPLAY SUB-SYSTEM
X AXIS
Y AXIS

Fig. 9

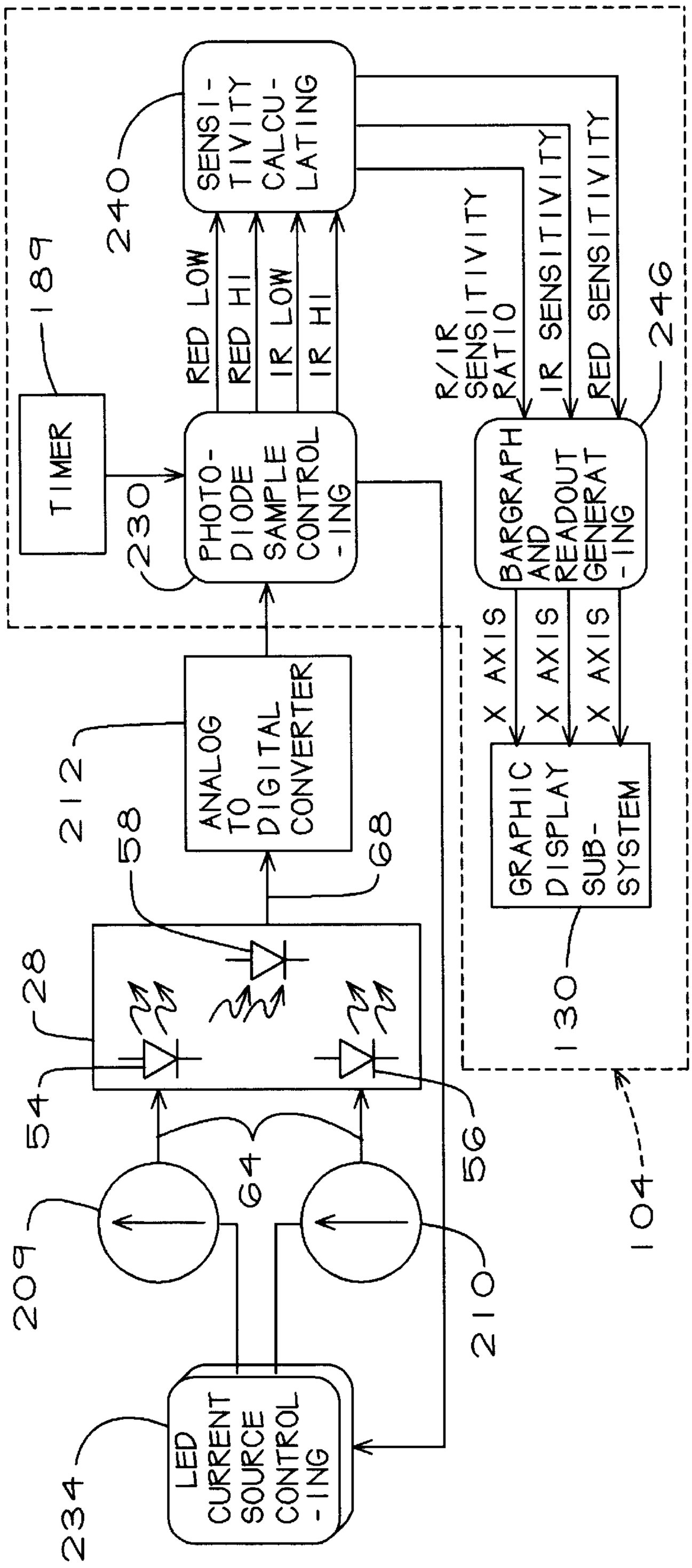


Fig. 10

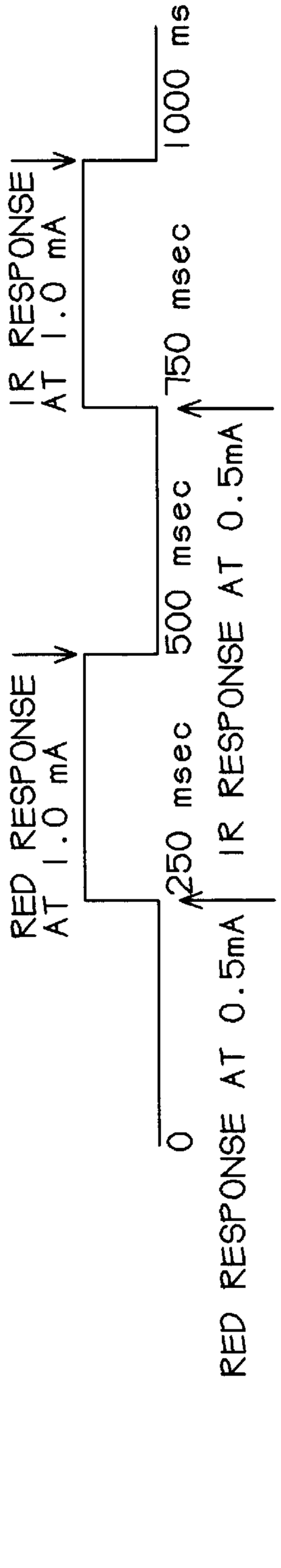


Fig. 10A

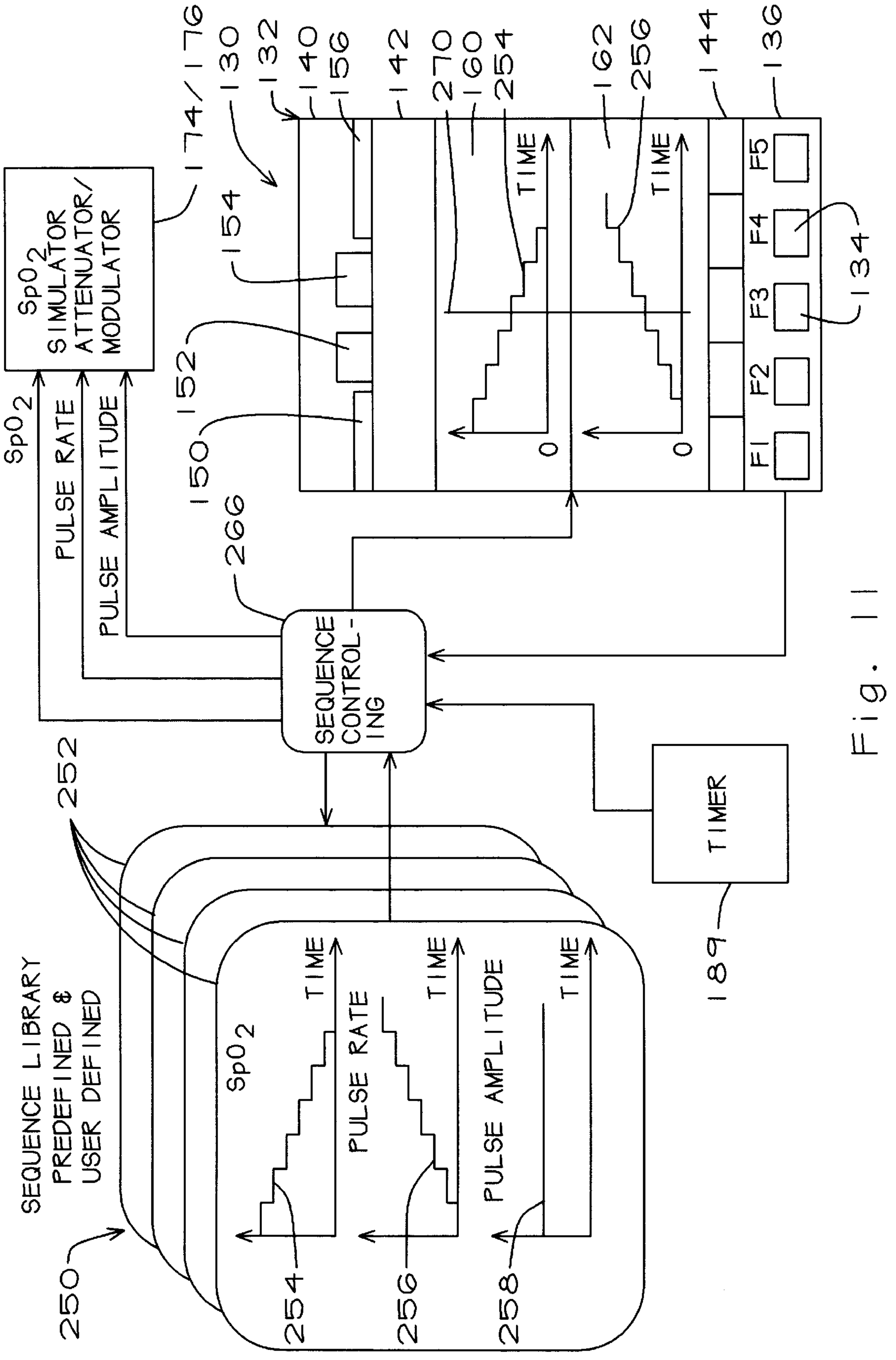

174/176
130
132
140
156
142
270
160
254
162
256
144
136
154
152
150
266
252
250
SpO_2
PULSE RATE
PULSE AMPLITUDE
SpO_2 SIMULATOR ATTENUATOR/ MODULATOR
SEQUENCE CONTROLLING
TIME
0
F1
F2
F3
F4
F5
134
TIMER
189
SEQUENCE LIBRARY
PREDEFINED &
USER DEFINED
254
256
258

Fig. 11

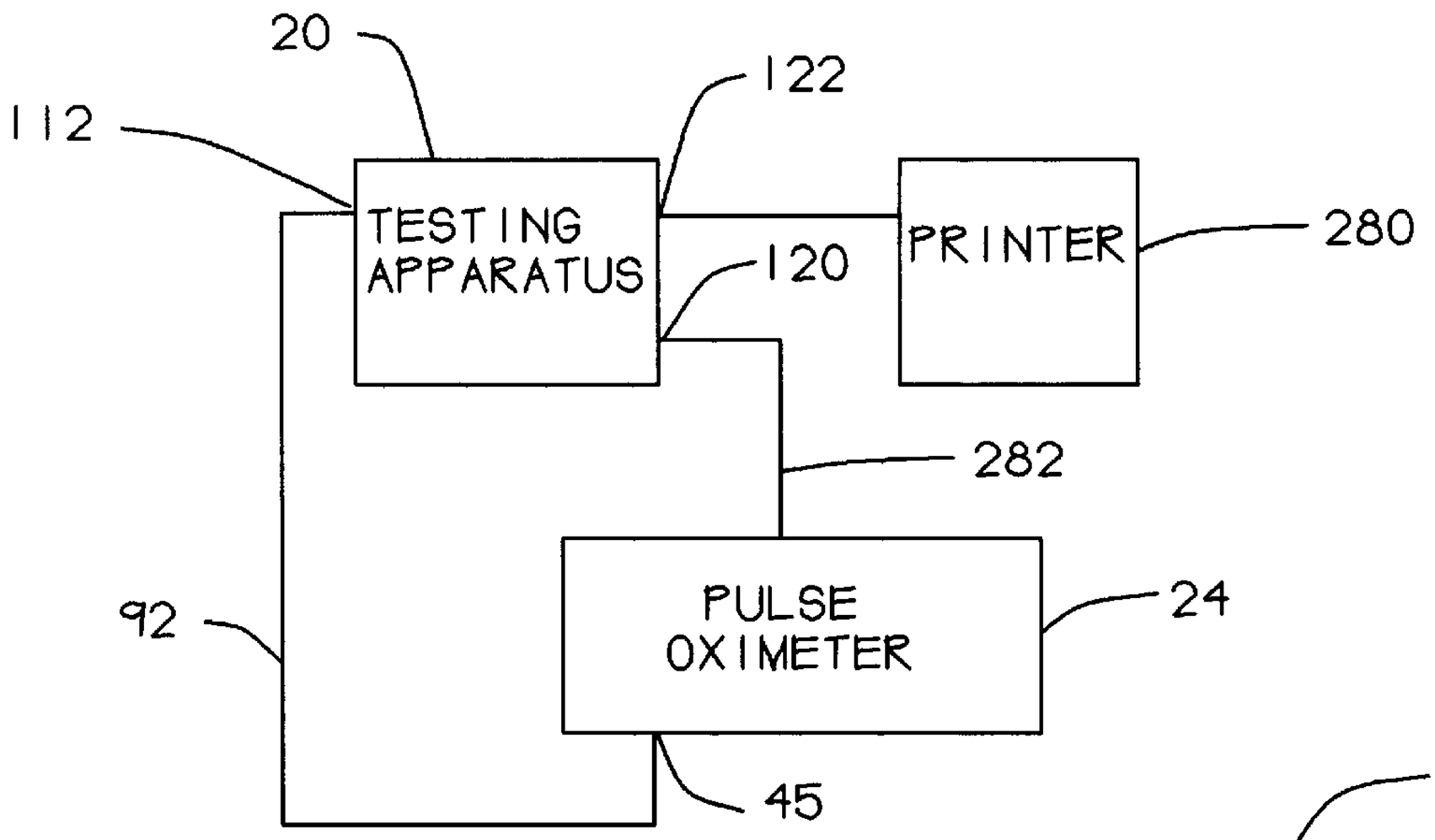

20
112
122
TESTING APPARATUS
120
PRINTER
280
282
PULSE OXIMETER
24
92
45

Fig. 12

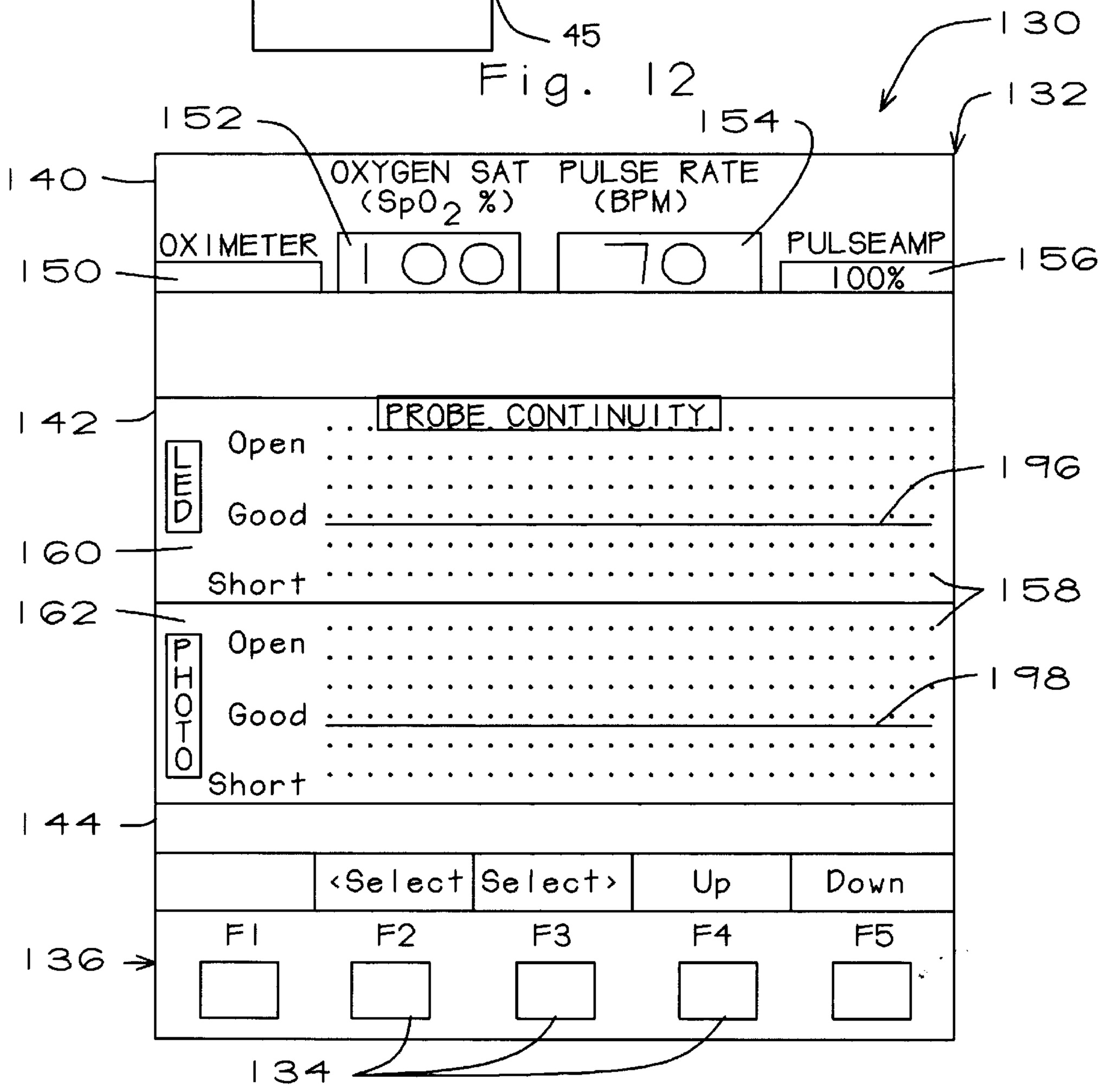

130
132
152
154
140
OXYGEN SAT (SpO_2 %)
PULSE RATE (BPM)
OXIMETER
100
70
PULSEAMP
100%
150
156
142
PROBE CONTINUITY
LED
Open
Good
Short
160
196
158
162
PHOTO
Open
Good
Short
198
144
<Select
Select>
Up
Down
F1
F2
F3
F4
F5
136
134

Fig. 13

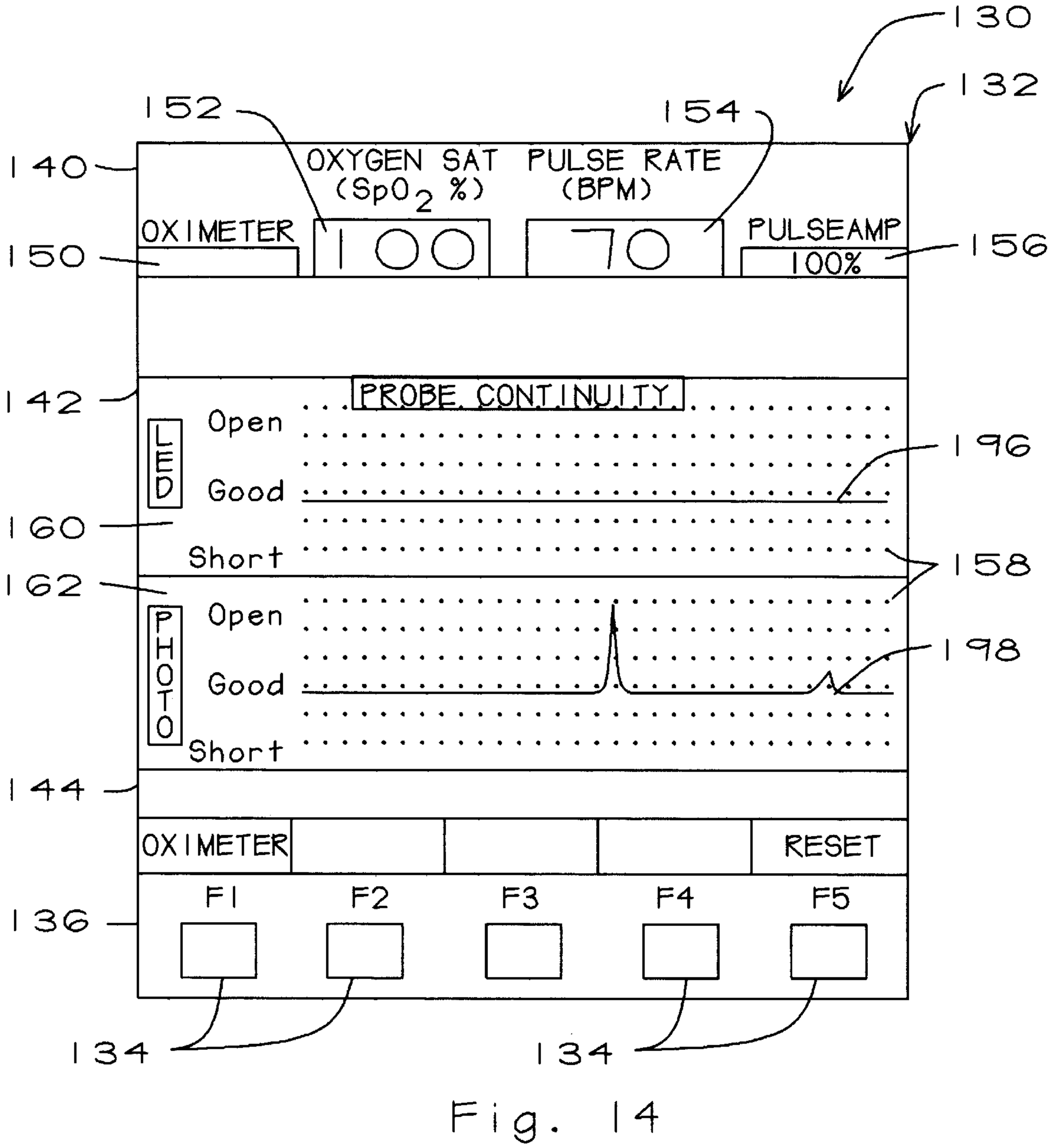

130
132
152
154
140
OXYGEN SAT
(SpO2 %)
PULSE RATE
(BPM)
OXIMETER
PULSEAMP
150
100
70
100%
156
142
PROBE CONTINUITY
LED
Open
Good
196
160
Short
158
162
PHOTO
Open
Good
198
Short
144
OXIMETER
RESET
F1
F2
F3
F4
F5
136
134
134

Fig. 14

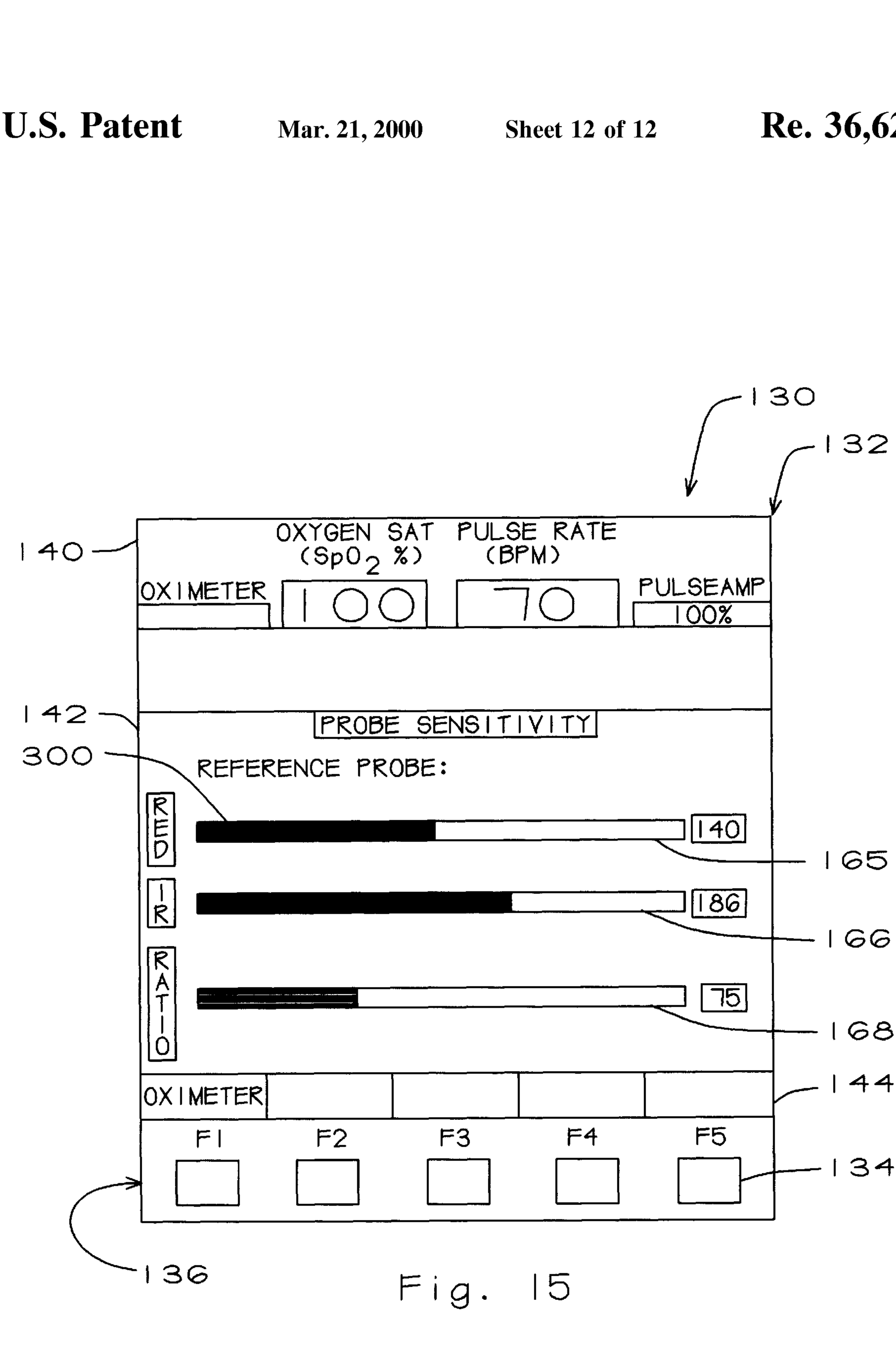

130
132
140
OXYGEN SAT (SpO2 %)
PULSE RATE (BPM)
OXIMETER
100
70
PULSEAMP
100%
142
PROBE SENSITIVITY
300
REFERENCE PROBE:
RED
140
165
IR
186
166
RATIO
75
168
144
OXIMETER
F1
F2
F3
F4
F5
134
136

Fig. 15

PULSE OXIMETRY TESTING

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This application is a *REISSUE of Ser. No. 08/962,149 filed Oct. 31, 1997 U.S. Pat. No. 5,783,821, which is a* continuation of application Ser. No. 08/556,749, filed Nov. 2, 1995, now abandoned.

FIELD OF THE INVENTION

This invention pertains to pulse oximeter testing and more particularly to a method and apparatus for testing pulse oximeters.

BACKGROUND

Pulse oximeters are commonly used in hospitals and other patient-care facilities for monitoring the blood oxygen level of a patient in a non-invasive, continuous manner. The basis of operation of these instruments is the fact that blood absorbs red (R) and infrared (IR) light in different amounts depending on the level of oxygen in the blood (SpO_2) and that a known relationship exists between the ratio of red to infrared light (R/IR) and blood oxygen level (SpO_2).

Thus, a pulse oximeter functions by detecting the amount of red and infrared light transmitted through a part of the body, usually a finger, to establish the R/IR ratio. It then compares this ratio with an internally stored database giving the relationship between R/IR ratios and SpO_2 levels, determines the SpO_2 level for the detected ratio, and displays the SpO_2 value. Pulse rate and other parameters may also be detected and displayed.

The popular pulse oximeters provide an optical sensor, typically called a probe, which is an alligator- or clamshell-clip that clamps on the index finger of a patient. One jaw of the probe clip contains red and infrared light-emitting diodes (LEDs), and the other jaw contains a light detector such as a photodiode. The probe cable is connected to the main unit or instrument of the oximeter. Certain of the conductors in the cable connect the LEDs to a driver circuit in the instrument which produces a signal to activate the LEDs, and other conductors connect the photodiode to an amplifier for amplifying the small signal generated by the photodiode when light is transmitted through a finger and for transmitting it to the signal processor of the oximeter.

Like any instrument for monitoring physiological functions, a pulse oximeter needs to be tested on a regular basis to determine if it is providing accurate readings. Although test equipment has been developed for testing the accuracy of pulse oximeters, such equipment has been based on a particular testing philosophy which imposes certain undesirable limitations on the test results. This philosophy is to provide a simulated finger, clamp this "finger" in the oximeter probe, operate the oximeter to test the simulated finger just as if it were a real finger, and determine if the display provides a reading consistent with the simulation.

An example of this testing approach is disclosed in the Merrick et al. U.S. Pat. No. 5,348,005. In this patented device, the artificial finger is a long, narrow, finger-shaped object made of steel and having slots on opposite sides respectively receiving an LED bar and a pair of photodiode detectors. To test an oximeter, the Merrick et al. artificial finger is placed in the oximeter probe, and the oximeter is operated just as if it were monitoring a human subject. That is, the red and IR LEDs of the oximeter emit flashes of light

that are detected in the "finger" by the photodiodes which convert the light pulses into electrical pulses. These pulses are modulated in the tester to provide signals which simulate the signals that would be developed from a human finger. The modulated electrical signals are then transmitted to the LEDs in the artificial finger which converts them to light flashes that activate the photodiode in the oximeter probe. Thus, the artificial finger is an optical interface between the oximeter under test and the test equipment.

The described testing approach is certainly the straightforward approach in that it simply replaces a real finger with an artificial finger and allows the oximeter to be used for the test in a manner similar to its use in monitoring a patient. The only difference appears to be the use of an electro-optical finger instead of a real finger. Such an approach, however, has not proved to be fully effective since the reliability of the testing can be compromised or indeterminate and desired testing flexibility is lacking, as hereinafter explained.

First, the testing accuracy of an oximeter tester using an optical interface, as described above, depends on proper placement of the simulated finger in the probe to allow the optical elements to interact properly. With a human finger, exact placement of the finger in the probe is not critical since the entire circumference of a finger presents human tissue to the LEDs. With an artificial finger, however, the photodiodes and the LEDs in the artificial finger must be placed exactly opposite the LEDs and photodiode, respectively, of the probe or else the light flashes will not be detected by the photodiodes. Thus, if this placement is not exact, inaccurate readings will occur.

Before discussing other deficiencies of oximeter test equipment employing an optical interface, it is important initially to understand the construction of commonly used oximeter cables and their normal use in a hospital. The cable referred to in one popular brand of oximeter is actually two cables, namely, a preamp cable and a probe cable. Although interconnected, these two cables are of different construction; the preamp cable is relatively strong and durable, whereas the probe cable is not as strong or durable. The preamp cable is a thicker, somewhat flexible, heavy duty cable, usually about 12 feet long, whereas the probe cable is a thinner, very flexible, lightweight cable, usually about 3 feet long. Whether or not the oximeter has a preamp cable, extension cables (also referred to as patient cables) are often provided and for the purpose of the present invention are equivalent to a preamp cable. In referring to the preamp cable hereinafter, it will be understood that such an extension cable is included.

The preamp cable is normally attached to and kept with its oximeter instrument as the latter is moved about the hospital, whereas the probe cable is normally kept separate from the oximeter instrument and is not associated with any particular instrument since it can be attached to any instrument of the same manufacture. The probe cable may even be a disposable item.

In a hospital room, the preamp cable is long enough to serve as an extension cord so that the oximeter instrument can be placed in a convenient position and the preamp cable stretched to the bedside of the patient. In contrast, the probe cable is clamped to the bed or bedclothes of the patient's bed and coupled to the preamp cable. The probe cable is made light and flexible so that it moves easily and folds as the patient moves about and is less of an annoyance to the patient. Thus, probe cables can easily fall on the floor by the bedside and be subjected to abuse. Moreover, they are

normally folded, wound, or otherwise compressed and stored in a drawer, sometimes rather haphazardly.

Because of the described construction, use and treatment of probe cables and their probes, they are very vulnerable to damage and defects. Field studies with hospital biomedical technicians have shown that the majority of oximeter defects have been probe defects and that these defects are caused by frayed probe cable wires, that is, breaks or shorts, many of which occur intermittently. Compounding this problem is the fact that as indicated above, specific oximeter probes are not paired with specific oximeter instruments, that is, the probes are interchangeable among different oximeters and as stated above, the entire probe including the cable and the clip may be disposable.

Using the above described testing approach with an optical interface, i.e., inserting an artificial finger in the clamshell probe of the pulse oximeter, the testing device performs the test through the probe cable, that is, with the probe cable connected to the preamp cable, just as if the oximeter were being used on a human patient. If there is a defect in the probe cable, this testing approach may miss it or fail to isolate it.

For example, if the probe cable has frayed wires, front end circuitry in the oximeter may filter out the noise spikes caused by the fraying, and the display will indicate normal functioning, whereas in fact the probe cable is damaged and may later fail completely at a critical time. Moreover, if the display on the tester indicates an erroneous reading, it may not be possible to determine if the problem is in the probe including the probe cable, or in the signal processing circuitry. Furthermore, if the source of the problem is suspected to be in the probe, the tester provides no way of separately testing the probe cable and optics on the one hand, and the signal processing circuitry on the other hand, to isolate the problem area.

Thus, testing the oximeter as an integral entity, i.e., the probe and signal processing circuitry together, as the optical-interface approach requires, does not afford an unqualified independent assessment of these main parts, and especially of the parts most likely to fail. In fact, this testing methodology may introduce other problems as explained above. In contrast, the oximeter testing approach of the present invention differs from optical interface concept described above and, as a result, avoids the resultant problems.

SUMMARY

Pulse oximeter testing according to the present invention is based on the concept of an electrical interface between the testing instrument and the pulse oximeter rather than an optical interface. Thus, the subject method and apparatus involve testing a pulse oximeter signal processor separately from the probe, and still further, testing the continuity of the probe, particularly the probe cable, separately from the sensitivity of optical elements of the probe.

For testing according to the present invention, the probe is disconnected from the pulse oximeter. Then, a modulated electrical test signal representative of blood oxygen saturation values is generated in response to the electrical LED drive signal from the oximeter and is electrically applied to the oximeter signal processor. This signal causes the display of the oximeter to show a value of blood oxygen saturation which is compared with the saturation values represented by the test signal. Other parameters, such as pulse rate and pulse amplitude, may also be tested. Independently of the signal processor test, but simultaneously therewith if necessary, the probe is subjected to continuity and sensitivity tests and the

results displayed. In this manner, each of the main components of the pulse oximeter is separately analyzed, and the source of a defect, if any, is isolated.

An object of the present invention is to test and verify the basic operation of pulse oximeters used in hospitals and other patient care facilities.

It is another object to test pulse oximeters in a more efficient, effective, safe, and reliable manner than heretofore known.

Another object of the subject invention is to avoid the errors which may be introduced into the testing of a pulse oximeter when the oximeter is tested by clamping its probe onto a simulated finger containing optical elements, thus requiring precise positioning of the simulated finger in the probe.

Another object is to use an electrical, instead of an optical, interface between the pulse oximeter and an instrument for testing the oximeter.

A still further object is to be able to test the main components of a pulse oximeter, namely, the oximeter electronic unit and the optical sensor, separately from each other.

Yet another object is to test a pulse oximeter so as to isolate the source of defects among the main parts of the oximeter.

Still another object is to facilitate testing both the continuity of the probe and the optical functions of the probe independently of each other and of the signal processing circuitry of a pulse oximeter.

Another object is to eliminate doubts about the integrity of testing a pulse oximeter which tests good although its probe cable may have a emerging discontinuity causing intermittent noise spikes which are filtered out by the oximetry circuitry but which could eventually degrade and cause inaccurate or no readings during critical use of the oximeter.

A further object is to be able to test oximeter probes, which are interchangeable among different oximeters, independently of the main oximeter test instrument.

A still further object is to be able to test an oximeter probe, which are the source of most of the defects in an pulse oximeter.

An additional object is to display waveforms representative of the tests performed on the continuity of the probe of a pulse oximeter and on sensitivity of the optical elements of the probe alone while at the same time displaying digital readouts of blood oxygen level, pulse rate and other parameters being tested.

Yet another object is to provide an apparatus for testing a pulse oximeter which is able to test the most commonly used pulse oximeters.

A still further object is to simplify the task of biomedical equipment technicians and other trained healthcare personnel in testing the basic operation of pulse oximeters used in hospitals and other patient-care facilities.

Another object is to be able to subject a pulse oximeter to a manually or automatically controlled sequence of test signals including predetermined combinations of blood oxygen saturation and other parameters, such as pulse rate and pulse amplitude, representing either arbitrary test values or patient profiles, and to determine the response of the oximeter.

A feature of this invention is to allow defects in the probe cable of a pulse oximeter to be analyzed to determine if the

cable can be used, should be disposed of, or should be set aside for repair.

An additional feature of this invention is to allow the optical elements of the probe cable of a pulse oximeter to be analyzed to determine if the probe can be used, should be disposed of, or should be set aside for repair.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic drawing showing a left side elevation of a main unit or instrument of the pulse oximeter testing apparatus of the present invention and showing the apparatus in readiness to be connected to a commonly used pulse oximeter, with the probe disconnected from the oximeter and in position to be connected to the subject testing apparatus but also showing in phantom lines the probe as it is normally connected to the pulse oximeter through the preamp cable.

FIG. **2** is a diagrammatic view of the probe of FIG. **1** which includes a probe connector, a probe cable and a finger clamp.

FIG. **3** is a detailed face view of the probe connector.

FIG. **4** is another diagrammatic view of the probe and its components.

FIG. **5** is a schematic diagram of the red and IR LED circuit and the photodiode circuit in the probe of FIGS. **2–4**.

FIG. **6** is a right side elevation of the main unit of the pulse oximeter testing apparatus of FIG. **1**.

FIG. **7** is a front elevation of the main unit shown in FIGS. **1** and **6**.

FIG. **8** is a functional block diagram showing the major components of the subject testing apparatus and their connections to a pulse oximeter under test.

FIGS. **8**A–**8**D are pulse timing diagrams showing IR and red voltage pulses occurring in the circuits of FIG. **8**, and FIGS. **8**E and **8**F are Pleth diagrams which are illustrated to assist in explaining the circuits of FIG. **8**, it being noted that, for illustrative purposes, the scale of the pulses in FIG. **8**D differs from FIGS. **8**A–**8**C.

FIG. **9** is a functional block diagram of the continuity testing section of the probe analyzer of the subject testing apparatus, the probe analyzer being shown connected to the probe LEDs and photodiode, it being noted in this Fig. and other Figs. herein that the diagram boxes with square corners indicate functions implemented in hardware, whereas the boxes with rounded corners indicate functions implemented in software.

FIG. **10** is a functional block diagram of the sensitivity testing section of the probe analyzer, the probe analyzer being shown connected to the probe LEDs and photodiode.

FIG. **10**A is a photodiode waveform occurring in the circuit of FIG. **10**.

FIG. **11** is a functional block diagram and partially diagrammatic view of a sequencing feature of the subject testing apparatus.

FIG. **12** is a functional block diagram showing how the testing apparatus is connected to an oximeter and a printer for automatically logging the results of a test.

FIGS. **13**, **14**, and **15** are diagrammatic views of the display screen and part of the keypad of the subject testing apparatus showing different displays and different menus which are available on the display screen with the method and apparatus of the present invention.

DETAILED DESCRIPTION OF THE APPARATUS

The pulse oximeter testing apparatus or analyzer of the present invention is generally represented by the numeral **20** in FIG. **1**, which is a schematic drawing showing how the testing apparatus is connected to a pulse oximeter **24**. Since reference will made herein to certain aspects of the pulse oximeter itself, it will be helpful at the outset to provide a brief general description of a typical pulse oximeter.

Thus, the pulse oximeter **24** (FIG. **1**) includes a main unit **26** and a probe **28** which includes a probe cable **30**. The main unit includes a signal processor **32**, an LED driver **34**, and upper and lower displays **38** and **40** for displaying the blood oxygen saturation SpO_2 as a percentage and pulse rate in beats per minute. The main unit of the brand of oximeter shown and described herein also includes a preamp cable **42**. The preamp cable terminates at one end in a proximal preamp connector **44** coupled to an interface connector **45** in the main unit **26** and at the opposite end in a distal. preamp connector **46**. A photodiode amplifier **48** is located in the distal preamp connector. Some brands of oximeter do not employ an external photodiode amplifier but incorporate all the necessary functions in the main unit. The principles of the present invention are equally applicable whether or not the oximeter uses an external preamplifier and cable.

The probe **28** including the probe cable **30** is shown in greater detail in FIGS. **2–5** to which reference is now made. The probe includes a clamshell- or alligator-clamp or clip **50** which has hinged upper and lower jaws **52**. Red and infrared light-emitting diodes (LEDs) **54** and **56**, respectively, are mounted in the upper jaw, and a photodiode **58** is mounted in the lower jaw. The LEDs are electrically connected in inverse parallel relationship as shown in FIGS. **4** and **5** and are positioned in the clamp so as to direct light toward the photodiode. As is well-known, when the oximeter **24** is used to monitor the blood oxygen level (SpO_2) of a patient, the probe clamp is clipped onto the index finger of the patient so that light from the LEDs can be transmitted through the finger and be detected by the photodiode.

A probe connector **62** (FIGS. **2** and **3**) is attached to the probe cable **30** at the opposite end from the probe clamp **50**. In the normal operation of the oximeter, the probe connector **62** is connected to the distal preamp connector **46**, as shown in phantom in FIG. **1**, thereby to connect the probe **28** to the main unit **26**. In accordance with the principles of the present invention, however, the probe connector **62** connects the probe to the subject testing apparatus **20**, as will be subsequently described in detail.

The probe cable **30** (FIGS. **2–5**) includes LED conductors **64** interconnecting the LEDs **54**, **56** and terminals **66** in the probe connector **62**, thereby constituting an LED circuit, and photodiode conductors **68** interconnecting the photodiode **58** and other terminals **70** in the connector, thereby constituting a photodiode circuit. The probe cable also includes electromagnetic shields **72**, **74**, and **76** (FIG. **4**) and outer insulation **78**, all of which are well-known and thus not described in greater detail.

With the foregoing brief description of a typical oximeter **24** as background, reference is now made to the testing apparatus **20** (FIGS. **1** and **6–8**) of the present invention. The testing apparatus provides a main instrument **80** which includes a housing **81** that has a left panel **82**, a right panel **84**, and a front panel **86**, and which encloses an electronic testing system generally identified by the numeral **90** in FIG. **8**. The testing apparatus also includes a simulator adapter cable **92** (FIGS. **1** and **8**) and an external DC power supply **94**. The simulator adapter cable has connector plugs **95** and **96** at opposite ends thereof.

The electronic testing system **90** (FIG. **8**) provides an SpO_2 simulator or signal processor **100**; a probe analyzer

102; a microprocessor **104**; a user interface **106**; an internal power supply with battery **108**; and interface connectors **112**, **114** and **116** (FIG. **1**) in the left panel **82**. Interface connector **112** is connected to the SpO_2 simulator, and interface connectors **114** and **116** are connected to the probe analyzer respectively for brand X and brand Y pulse oximeter probes **28**. The interface connector **112** is designed to receive the plug **95** of the simulator adapter cable **92**, and interface connectors **114** and **116** are designed to receive the connectors **62** of the probe cables **30** of the manufacturers of brand X and brand Y oximeters, as **24**. Interface connectors **118**, **120**, and **122** (FIG. **6**) are mounted in the right panel **84** respectively for the external DC power supply **94**, for serial communication, and for a printer (FIG. **12**).

To best understand the testing functions of the subject apparatus **20**, it will be helpful first to explain the user interface **106** (FIGS. **7**, **8** and **13–15**). The user interface includes an LCD graphic display subsystem **130** (FIG. **8**) which provides an LCD display screen or panel **132** (FIG. **7** and **12–15**) in the front panel **86** of the housing **81** and a plurality of keys **134** in a keypad **136** below the screen. The display screen is divided into an upper SpO_2 simulator window **140**, a middle graphing window **142**, and a lower soft-key menu window **144**. In the disclosed embodiment, there are five soft keys F1–F5, two hard keys M and P, and an on/off key O (FIG. **7**).

The LCD graphic display subsystem **130** (FIGS. **8** and **13–15**) provides several menus to be displayed in the lower menu window **144**, and these menus are selected by pressing the hard keys M and P. In the disclosed embodiment, there is one root menu and four sub-menus, namely, an SpO_2 simulator sub-menu (FIG. **13**), a sequencing sub-menu, a probe continuity sub-menu (FIG. **14**), and a probe sensitivity sub-menu (FIG. **15**). For each menu displayed, each soft key F1–F5 has a different function which is displayed in the lower menu window above the key, as shown in FIGS. **13**, **14** and **15**. The root menu is not shown, but it is the default menu in which the names of the four sub-menus are displayed in the lower menu window above the keys F1 through F4. The sub-menus correspond to the different modes of operation of the subject testing apparatus **20**, namely, SpO_2 simulator mode, sequencing mode, probe continuity mode and probe sensitivity mode and relate to the displays in the upper and middle windows **140** and **142**. The SpO_2 simulator menu relates to the upper or SpO_2 simulator window **140**, whereas the sequencing, probe continuity, and probe sensitivity submenus all relate to the middle or graphing window **142**.

Considering first the SpO_2 simulator mode using the SpO_2 simulator sub-menu and its related upper, SpO_2 simulator window **140** (FIG. **13**), the latter displays the parameter settings selected and then generated by the SpO_2 simulator **100** (FIG. **8**). The SpO_2 window includes an oximeter brand or status box **150**, which displays the brand of oximeter under test; an oxygen saturation display box **152**, which displays SpO_2 as a percentage; a pulse rate display box **154**, which displays pulse rate in beats per minute; and a pulse amplitude display box **156**, which displays pulse amplitude as a percentage. Examples of typical values are shown in boxes **152**, **154**, and **156**.

Using the SpO_2 simulator sub-menu (FIG. **13**), the display boxes **152–156** are sequentially highlighted and thus selected by pressing soft keys F2 or F3. When the SpO_2 box **152** is selected, the desired SpO_2 percentage can be chosen by pressing the keys F4 or F5 which causes the percentage displayed s to increase or decrease in increments of one percent. The SpO_2 percentage displayed corresponds to a particular R curve (relationship between R/IR and SpO_2) stored in the microprocessor and selected when keys F4 or F5 are pressed. Similarly, the pulse rate and pulse amplitude are selected and displayed in the boxes **154** and **156**.

As previously indicated, the sequencing, probe continuity and probe sensitivity modes all share the middle or graphing window **142**. Each of these modes, along with its sub-menu, is selected by pressing the hard keys M or P. For the probe continuity mode, the key M or P is pressed until the probe continuity sub-menu appears in the lower window **144** (FIGS. **13** and **14**) and the probe continuity display **158** appears in the middle window **142** (also FIGS. **13** and **14**). The probe continuity display provides an upper LED channel **160** and a lower photodiode channel **162**, both extending across the window. The graphic display subsystem **130** provides a static graphic background for the probe continuity display including: a matrix of dots or graticules (FIG. **13**) spaced horizontally in time preferably by five milliseconds; the indicia "LED" and "PHOTO" along the ordinate margins of the upper and lower channels, respectively; the indicia "OPEN", "GOOD", and "SHORT" along the ordinate margin of each channel; and the label "PROBE CONTINUITY" along the top of the window. For the probe sensitivity mode, one of the keys M or P is pressed until the probe sensitivity display **164** shown in FIG. **15** appears in the middle or graphing window **142** and the probe sensitivity sub-menu appears in the lower window **144**. For the probe sensitivity mode, the graphic display subsystem **130** provides a static graphic background in the middle window including: upper, middle and lower bargraph channels **165**, **166**, and **168** which, although not shown, are empty when no test is being conducted; the indicia "RED," "IR," and "RATIO" along the left margin; the label "PROBE SENSITIVITY" along the top of the window; the name of the probe **28** being tested just below the label; and areas at the right ends of the bargraph channels to display numbers respectively representative of the amplitudes of the values displayed in the bargraph channels.

As for the sequencing mode and sub-menu, more detailed reference is made under the subsequent heading "Test the Main Unit-Sequencing Mode." With the foregoing understanding of the user interface **106**, the SpO_2 simulator **100** (FIG. **8**) of the subject testing apparatus **20** includes a current sensor **170** as its input stage. When the testing apparatus is being used to test the pulse oximeter **24**, the connector **62** of the probe cable **30** (FIG. **1**) is disconnected from the preamp connector **46**, and instead, the simulator adapter cable **92** is connected to the preamp connector and also to the interface connector **112**, thereby establishing an electrical connection between the input of the current sensor and the output of the LED driver **34** of the pulse oximeter under test.

When the testing apparatus **20** is thus connected to the pulse oximeter **24** under test (FIG. **1**) and the oximeter **24** is powered up, the LED driver **34** (FIG. **8**) will then feed red and IR current pulses to the current sensor **170** instead of to the probe LEDs **54** and **56**. The current sensor receives these red and IR current pulses and converts them into IR and red voltage pulses (IR and R), as shown in FIG. **8A**, whose amplitudes represent the IR and red light intensity that would have been produced by the probe LEDs in the normal operation of the oximeter.

The SpO_2 simulator **100** (FIG. **8**) also includes a de-multiplexer **172** which is connected to the output of the current sensor **170**. In general, the polarity of the red and IR pulses from the oximeter's LED driver **34** is different, and thus the polarity of the voltage pulses (FIG. **8A**) from the

current sensor is different, for example, the IR pulses are positive and the red pulses are negative. The de-multiplexer detects this polarity and thus distinguishes between red and IR pulses and splits the red and IR voltage pulses into separate IR and red voltage pulse signals IR and R (FIG. **8**B) and feeds these signals to a DC attenuator **174** from where they are transmitted to an AC modulator **176**.

The attenuator and modulator **174/176** vary the IR and red pulse signals IR and R in accordance with values of parameters stored in databases in the memory of the microprocessor **104** and as displayed in the boxes **152, 154** and **156**. This attenuation/modulation simulates what is caused by a real finger placed in the clamp **50** of the probe **28** and thus simulates SpO_2 levels, pulse rates and pulse amplitudes such as those occurring when the oximeter **24** is being used to monitor a patient.

For example, the DC attenuator **174** under the control of the microprocessor **104** (FIG. **8**) first modifies the IR and R pulse signals (FIG. **8**B) from the de-multiplexer **172** to simulate the average component of the SpO_2 simulation, that is, constant physiological parameters caused by such factors as skin, bone and venous blood as attenuated by a human finger. The DC attenuator thus outputs IR_{DC} and R_{DC} voltage pulses, as shown in FIG. **8**C, to the AC modulator **176** and to a weighting adder **178**.

Mathematically, these pulses are defined as:

$$IR_{DC}=K_{IR}\times IR, \text{ and}$$

$$R_{DC}=KR\times R,$$

where IR and R represent the voltage levels of the IR and R pulse signals (FIG. **8**B) from the de-multiplexer **172**, and K_{IR} and K_R are the attenuation constants for IR and red signals respectively. Next, the AC modulator **176** under the control of the microprocessor **104** (FIG. **8**), modifies the IR_{DC} and R_{DC} pulse signals (FIG. **8**C—the arrows indicating modulation) from the DC attenuator **174** to simulate the pulsatile or variable component of the SpO_2 simulation. This pulsatile component is the variable physiological parameter of arterial blood, i.e., the pulse, as attenuated by a human finger, and as represented by the waveforms shown in FIGS. **8**E and **8**F which are based on Pleth diagrams of arterial blood flow. The information represented by these waveforms is stored in the memory of the microprocessor and relates to the well known R-curves which give the relationship between the R/IR ratios and SPO_2 values. A user of the testing apparatus selects an R curve and in so doing selects the waveforms of FIGS. **8**E and **8**F to be used.

The AC modulator **176** (FIG. **8**) outputs IR_{AC} and R_{AC} voltage pulse signals, as shown in FIG. **8**C, to the weighting adder **178**. These signals are mathematically defined as:

$$IR_{AC}=IR_{DC}\times IR_{PLETH(t)}, \text{ and}$$

$$R_{AC}=R_{DC}\times R_{PLETH(t)},$$

where IR_{DC} and R_{DC} are calculated as indicated above and $IR_{PLETH(t)}$ and $R_{PLETH(t)}$ are samples taken at predetermined intervals, preferably 5 msec in the preferred embodiment, from the Pleth waveforms of FIGS. **8**E and **8**F which, as stated, are stored in the memory of the microprocessor.

As referred to above, the SpO_2 simulator **100** (FIG. **8**) includes the weighting or scaling adder **178** which receives the four output signals IR_{DC}, IR_{AC}, R_{DC}, and R_{AC} (FIG. **8**C) from the DC attenuator **174** and the AC modulator **176** and recombines these signals into attenuated and modulated IR and red voltage pulse signals (IR+R)', as shown in FIG. **8**D, the arrows indicating modulation. In so doing, the adder also applies weighting or scaling factors to the IR_{DC}, IR_{AC}, R_{DC}, and R_{AC} voltage pulse signals. In the disclosed embodiment, these weighting factors are 1 for IR_{DC} and R_{DC} and 0.20 for IR_{AC} and R_{AC}. That is, the level of the IR_{AC} and R_{AC} signals is reduced to ⅕th of the level of the IR_{DC} and R_{DC} signals. The output of the weighting adder is mathematically defined as:

$$\text{Adder Output}=IR_{DC}+\tfrac{1}{5}IR_{AC}+R_{DC}+\tfrac{1}{5}R_{AC}.$$

The output of the weighting adder **178** is fed to a current driver **180** that converts the modulated IR and red voltage pulse signals (FIG. **8**D) into modulated IR and red current pulse signals. These current pulse signals are conducted to the photodiode preamplifier **48** by the simulator adapter cable **92** and then to the signal processor **32** and the displays **38** and **40** of the pulse oximeter **24**. The modulated IR and red current pulse signals are thus processed by the signal processor **32** just as if the current pulse signals had come from the photodiode **58** as a result of the probe **28** being attached to a real finger.

It is emphasized that the interface between the pulse oximeter **24** and the oximeter tester **20** is an electrical interface, with no optics involved. That is, the LED driver **34** and the current sensor **170** and the photodiode preamplifier **48** and the current driver **180**, respectively, are electrically interconnected by the simulator adapter cable **92**. At this time, the probe **28** is disconnected from the oximeter and is not involved in the testing of the oximeter's ability to process detected signals and to display accurate SpO_2 and pulse measurements.

The probe **28**, having been disconnected from the pulse oximeter **24** to allow electrical testing of the oximeter's signal processing capabilities, is subjected to its own test by the probe analyzer **102** (FIGS. **8**–**15**). The probe analyzer is part of the electronic testing system **90** of the subject testing apparatus **20** and operates under the control of the microprocessor **104** and the user interface **106**. The probe analyzer tests the continuity of the probe circuits and the sensitivity of the probe optics. Continuity testing is described below with particular reference to FIGS. **5**, **9**, **13** and **14**, and sensitivity testing is described below with particular reference to FIGS. **5**, **10**, **10**A, and **15**.

Considering continuity testing first, the probe analyzer **102** (FIGS. **8** and **9**) includes LED and photodiode continuity current sources **181** and **182** which are connected to certain terminals in the interface connectors **114** and **116**. When the probe connector **62** is connected to its matching interface connector **114** or **116**, the continuity current sources are respectively connected to the LED and photodiode circuits through the conductors **64** and **68**, respectively, at terminals **2**, **3** and **5**, **9** FIGS. **4** and **5** to supply testing current to these circuits and thereby to generate continuity testing voltages across the LEDs **54**, **56** and the photodiode **58**. The probe analyzer also includes a multiplexer **184** which receives the separate LED and photodiode continuity voltages, combines them into a single voltage signal with alternating LED and photodiode pulses, and feeds the combined signal to an analog-to-digital converter **186**. The A/D converter transforms the signal into a series of discrete voltage pulses representative of the alternating LED and photodiode continuity voltages.

With continued reference to FIG. **9** in addition to FIGS. **13** and **14**, the microprocessor **104** circuitry includes a timer

189 which, in general, generates clocking signals which call upon and cause various sub-routines to be executed. For probe **28** continuity testing, the timer executes the following software sub-routines: display driving **190** (including sweep generation), glitch or spike detecting **192**, and sampling and scaling **194**. The timer provides hardware interrupts of preferably from 1 to 5 milliseconds during which it executes the above-stated and subsequently described service routines. The display driving routine activates the x-axis of the LCD display screen **132** to provide horizontal sweep or time lines **196** and **198** (FIGS. **13** and **14**) in the upper and lower channels at the "Good" level. The sampling and scaling routine samples and scales the output of the A/D converter **186** at predetermined time intervals, and the display driving routine applies these signal samples to the display screen.

More specifically, the display driving routine **190** applies signal samples representative of the continuity voltages from the LED circuit **54**, **56**, **64** to the y-axis in upper LED channel **160** and signal samples representative of the continuity voltages from the photodiode circuit **58**, **68** to the y-axis in lower photodiode channel **162**. The glitch detecting routine **192** senses when a glitch or spike of a predetermined threshold is sampled by the sampling and scaling routine and causes the display driving routine to freeze the display on the screen, as more fully described below.

Reference is now made to FIGS. **5**, **8**, **10**, **10**A and **15** for a description the probe sensitivity testing features of the probe analyzer **102** (FIG. **8**). As shown in FIG. **10**, the probe analyzer includes red and IR sensitivity current sources **209** and **210** respectively connected to the red and IR LEDs **54** and **56**. These current sources are connected to certain terminals in the interface connectors **114** and **116** so that when the probe connector **62** is connected to its matching interface connector, the sensitivity current sources are connected to their corresponding red and IR LEDs.

The red and IR LEDs **54** and **56** are alternately activated by these current sources **209** and **210** (FIGS. **5** and **10**) to produce red and IR light flashes. These flashes activate the photodiode **58** to generate a voltage signal across the photodiode having alternating red and IR pulses. The probe analyzer also includes an analog-to-digital converter **212** which receives the voltage signal from the photodiode **58** and transforms the signal into a series of discrete voltage pulses representative of the alternating red and IR sensitivity voltages.

Referring to FIGS. **10** and **15**, for probe **28** sensitivity testing, the timer **189** of the microprocessor **104** executes the following software routines: photodiode sample controlling **230**, LED current source controlling **234**, sensitivity calculating **240**, and bargraph and readout generating **246**. The photodiode sample controlling routine activates the LED current source controlling routine alternately to apply current to the red and IR LEDs. The sample controlling routine also samples the IR and red pulses from the A/D converter **212** and develops red (R) low and red (R) high pulses and IR low and IR high pulses.

From the pulses developed by the photodiode sample controlling routine **230** (FIG. **10**), the sensitivity calculating routine **240** generates a red sensitivity pulse from the red low and red high pulses, an IR sensitivity pulse from the IR low and IR high pulses, and an R/IR sensitivity ratio pulse from the red and IR sensitivity pulses. The bargraph and readout generating routine **246** applies the red sensitivity, the IR sensitivity and the R/IR sensitivity pulses to the x-axis of the LCD display screen in the upper, middle and lower bargraph channels **165**, **166**, and **168**, respectively. Thus, horizontal bargraphs representative of the response of the photodiode **58** to the light flashes from the red and IR LEDs **54** and **56** are created.

DETAILED DESCRIPTION OF THE METHOD

Before describing the method for testing a pulse oximeter, as **24**, according to the present invention, the status of the oximeter prior to the test, that is, the normal status of the oximeter is summarized, as shown in the lower part of FIG. **1**. The probe connector **62** is normally connected to the preamp connector **46**, as shown in phantom lines in FIG. **1**, so that the probe clamp **50** is connected by the probe cable **30** and the preamp cable **42** to the main unit **26** of the oximeter. To monitor a patient, the probe clamp is clipped on the index finger of the patient whose SpO_2 level, pulse rate, and perhaps other parameters are to be checked. The oximeter is then turned on, causing the LEDs **54** and **56** to flash light at the finger and causing the photodiode **58** to receive the light that is transmitted through the finger.

To test the pulse oximeter **24** in accordance with the present invention, the first step is to disconnect the probe **28** (FIG. **1**) from the oximeter's main unit **26**. Specifically, the probe connector **62** is disconnected from the preamp connector **46**, thus disconnecting the probe clamp **50** (including of course the LED and photodiode circuits) and the probe cable **30** from the main unit, shown in the center right in FIG. **1**. At this point, the probe and the main oximeter unit are ready to be tested.

Hospital technicians often wish to test only the probe **28** (FIG. **1**) center right including its cable **30**, LEDs **54**, **56** and photodiode **58**, and not the oximeter **24** as a whole. They wish to confirm probe continuity and sensitivity, since the probe is often stored separately from the main unit **26** and is more likely to be defective than the remainder of the oximeter, as has been fully explained in the Background, above. Of course, it is also desirable and necessary to test the rest of the oximeter. The present method and apparatus readily enables such testing versatility. Thus, following disconnection of the probe connector **62** from the preamp connector **46**, the next step of the method depends on what the technician wants to test: the main unit **26**; the probe **28**; or both.

To test the main unit **26**, the plug **96** of the simulator adapter cable **92** is attached to the preamp connector **46**, and the connector plug **95** is inserted into the interface connector **112**. Testing is then continued as described below.

To test the probe **28**, the probe connector **62** (FIG. **1**) on the probe cable **30** is plugged into the interface connector, either **114** or **116**, which matches the brand of oximeter **24** under test. It will be recalled that the testing apparatus is programmed to test various brands of oximeters having different probes **28**, and an interface connector, as **114**, **116**, is provided for each brand to be accommodated. In the embodiment of the apparatus shown, however, only two brands, namely, brands X and Y, are capable of being tested since currently these two brands are the most commonly used. It will readily be understood, however, that the subject apparatus **20** could be modified to test additional brands without departing from the scope of the present invention.

To test both the probe **28** (FIG. **1**) and the main unit **26** at the same time, the simulator adapter cable **92** and the probe cable **30** are both connected to the testing apparatus **20** in the manner described above. Even if only the probe or the main unit is to be tested to the exclusion of the other, both cables may be connected to the testing apparatus while either test is being conducted.

The description of the method of the present invention is continued now with a description of the steps for testing the main unit **26** (FIG. **1**) and thereafter the steps for testing the probe **28**. Using the keypad **136**, the user turns on the testing

apparatus **20** by pressing the on-off key O (FIG. **7**) whereupon the electronic testing system **90** is activated and the default menu, that is the root menu, appears in the soft-key menu window **144** (FIG. **13**). The testing apparatus as used to test the main unit is thereafter operated either in a basic manual mode or in a sequencing mode, the latter having both an automatic option and a manual option. The basic manual mode is first described.

TESTING THE MAIN UNIT **26**—BASIC MANUAL MODE

In the basic manual mode, the technician first chooses individual values of SpO_2 percentage together with values of pulse rate and possibly pulse amplitude. To make this choice, the technician presses the hard keys M or P (FIG. **7**) to select the SpO_2 submenu, as appears in FIG. **13**. Then, using the keys F**2** or F**3**, the SpO_2 display box **152** is selected, and with the keys F**4** or F**5**, the desired value of SpO_2 percentage is set. Testing values of pulse rate and/or pulse amplitude, if desired, are similarly set and displayed in their respective boxes **154** and **156**.

Next, the technician turns on the pulse oximeter **24**, thereby causing the LED driver **34** (FIG. **8**) alternately to generate IR and red current pulses which are directly fed to the current sensor **170** of the signal processor **100** of the testing apparatus **20**. Again it is noted that these red and IR current pulses, in the normal operation of the pulse oximeter, would cause the red and IR LEDs in the probe **28** to flash. Since the probe **28** is disconnected from the oximeter **24**, however, no such flashing occurs. Although believed understood, the fact that the probe may be connected to the testing apparatus at this time does not cause activation of the IR and red LEDs by the LED driver since the oximeter's normal connection of the LED driver to the probe is broken.

In response to the IR and red current pulses from the LED driver **34** (FIGS. **1**, **8** and **8**A) and as previously described, modulated IR and red i current pulse signals are generated by the signal processor **100** under control of the microprocessor **104**. This modulated current represents the blood oxygen saturation (SpO_2) level, pulse rate, and pulse amplitude selected and displayed in the boxes **152**, **154**, and **156** (FIG. **13**) and being used to test the oximeter **24**. The modulated IR and red current is transmitted to the photodetector amplifier **48** (FIG. **8**) by the simulator adapter cable **92** and is processed by the pulse oximeter just as if the current had come from the probe **28** attached to a real finger. The values of SpO_2 and pulse rate are read on the displays **38** and **40** of the pulse oximeter and compared with the settings displayed in boxes **152** and **154** of the display screen **132** to determine whether the oximeter is reading correctly.

TESTING THE MAIN UNIT **26**—SEQUENCING MODE

In the sequencing mode of the testing apparatus **20**, the subject method and apparatus test the pulse oximeter **24** with a sequence of programmed values of desired parameters (SpO_2 , pulse rate, and pulse amplitude in the disclosed embodiment). With reference to FIG. **11**, the sequencing mode includes a library **250** of profiles or combinations **252** of parameters, each profile including a set of parameter curves, for example, SpO_2 curves, as **254**: pulse rate curves, as **256**; and pulse amplitude curves, as **258**, all of which are loaded into the memory of the microprocessor **104**. As suggested above, more or fewer parameters could be included if desired.

These profiles **252** are user-defined and preferably include both actual patient profiles from clinical studies and arbitrary, user-created profiles. The front profile diagrammatically illustrated in FIG. **11** is an arbitrary profile and includes an SpO_2 curve **254** declining in steps; a pulse rate curve **256** rising in steps, and a constant pulse amplitude curve **258**. The patient profiles, not shown, typify the various conditions that are expected to be encountered in use of the oximeter, and for example, include constant values, that is, straight lines, like the pulse amplitude of FIG. **11**, with intermittent deviations representative of physiological irregularities, such as desaturation dips, arrhytmia's, or the like deviations from the normal.

The sequencing mode (FIG. **11**) can be operated either manually at an operator-controlled rate (the manual option) or automatically at a programmed rate (the automatic option). For this purpose, the timer **189** of the microprocessor **104** executes a sequence controlling sub-routine **266** which is initiated from the keypad **136**. The sequence controlling subroutine feeds signals representing the selected profile data to the AC/DC modulators **174**/**176** of the SpO_2 simulator **100** (FIGS. **8** and **11**) and to the graphic display subsystem **130** (FIGS. **8** and **11**). In the disclosed embodiment, the sequence controlling routine feeds only the SpO_2 and pulse rate curves **254** to the upper and lower channels **160** and **162**, respectively, of the display screen **132**. Because of preferred space limitations on the display screen, the pulse amplitude curve **258** is not included, although it could be if desired.

Each profile **252** (FIG. **11**) provides a cursor **270** (FIG. **12**) which is contained in the memory of the microprocessor **104** as part of the profile data. The cursor is developed by the sequence controlling routine as a vertical sweep in the middle window **142** of the display screen **132** and its position at any given time corresponds with, that is, indicates on the curves, the values of the parameters being fed to the attenuator/modulator **174**/**176** and shown in the displays **152**, **154**, and **156**. The cursor is programmed in memory to start at zero time base and to advance horizontally across the screen at timed intervals depending on whether the manual option or the automatic option is selected. If the manual option is selected, the cursor advances from one step to the next upon pressing one of the keys **134** and remains there until the key is pressed again, so the timing of the intervals is under the immediate control of the operator. If the automatic option is selected, the cursor advances from one step to the next at a rate programmed into the particular profile selected.

In use of the sequencing mode, the technician selects the desired profile **252** (FIG. **11**) and the manual or automatic option with the keypad **136** and then turns on the pulse oximeter **24**. As with the basic manual mode, the LED driver **34** (FIG. **8**) alternately generates red and IR current pulses which are directly fed to the current sensor **170** of the signal processor **100** of the testing apparatus **20**. The sequence controlling routine **266** feeds signals representing the profile data to the DC attenuator/ AC modulator **174**/**176** and feeds the same profile signals plus the cursor signal to the graphic display subsystem **130**. The modulated red and IR current is transmitted to the photodiode preamplifier **48** (FIG. **8**) by the simulator adapter cable **92** and is processed by the pulse oximeter as in the basic manual mode.

TESTING THE MAIN UNIT **26**—SEQUENCING MODE

Manual or Interactive Option

In the manual, that is, interactive, option of the sequencing mode, the technician controls the advance of the cursor **270** across the screen **132** by pressing the appropriate key **134** of the keypad **136** each time the technician elects to step to the next set of values in the profile **252** selected. After each advance of the cursor, the technician compares the values of SpO_2, pulse rate, and pulse amplitude at the location of the cursor, which are being fed to the oximeter

24 and which are displayed in the display boxes **152**, **156**, and **158**, with the readings on the displays **38** and **40** of the oximeter. Additionally, the technician may keep a datalog of the test by entering the values read on the oximeter's displays into the memory of the microprocessor **104** by pressing appropriate keys **134**. Subsequently or at the same time, the test results stored in memory can be printed-out by connecting a printer **280** to the printer port **122** (FIG. **12**).

TESTING THE MAIN UNIT **26**—SEQUENCING MODE

Automatic Option

The automatic option of the sequencing mode allows two types of tests especially useful for testing pulse oximeters, as **24**, namely a sweep test and a trend test. In the sweep test, a sequencing profile **252** is selected and the automatic sequencing mode is activated with the keypad **136** causing the cursor **270** to sweep in steps across the screen automatically from one value to the next and at a predetermined rate, preferably from about four to thirty second intervals but slower or faster is of course possible, as controlled by the timer **189**. The interval depends on the characteristics of the oximeter, e.g., the specified amount of delay time needed by the oximeter to process and display the readings after each successive input, and as explained above, is built into the profile. Thus, the ability of the oximeter to respond within the delay time specified by the oximeter manufacturer can be tested. The results of the test are logged by connecting a cable **282** (FIG. **12**) from the oximeter to the serial port **120** of the main unit **80** of the testing apparatus **20** whereby the readings on the oximeter's displays are fed into the memory of the microprocessor **104**. Thereafter or simultaneously, and as described above, these results can be printed by connecting the printer **280** to the printer port **122**.

The trend test is similar to the sweep test except that the intervals between each stepped advance of the cursor **270** are much longer, so that one complete cycle through the profile, as **254**, i.e., one pass across the screen, may be as long as an hour or more. Here, it is first to be understood that certain pulse oximeters, as **24**, have the capability of running trend tests on patients. For a trend test on a patient, the oximeter is connected to the patient and readings are taken and recorded over an extended period, up to an hour or more, to determine if there is a trend in the patient's condition. Thus, it is desirable to test the trend-taking capabilities of the oximeter. The subject method and apparatus **20** allow such a test.

To conduct a trend test on the oximeter **24**, a patient profile **252** that incorporates parameters having deviations that show a trend is preferably selected. Alternatively, an arbitrary profile with a built-in trend may be selected. For example, the profile might include an SpO_2 curve that is essentially flat but has momentary desaturation dips which increase over time. The purpose of the trend test is to determine if the oximeter can detect these momentary dips and the trend thereof accurately.

In summary of the testing of the main unit **26**, it is again emphasized that the optical interface of the pulse oximeter **24** is changed to an electrical interface. There is a direct electrical connection between the LED driver **34** and the current sensor **130** and a direct electrical connection between the current driver **142** and the photodiode amplifier **48**. The probe **28** is out of the loop. Since the electrical interface of the subject testing apparatus bypasses the probe, the probe is not involved in the test of the oximeter's signal processor **32**, LED driver **34**, displays **38**, **40**, and photodiode amplifier **48**.

TESTING THE PROBE **28**—CONTINUITY TEST

The analysis of the probe **28** usually starts with a continuity test since field experience shows that the majority of probe defects are caused by frayed wires in the probe cable **30**, many of which are intermittent defects. The testing apparatus **20** is turned on by pressing the on-off key **146**. Then, the keys M or P are pressed to select the probe continuity sub-menu, as shown in FIGS. **13** and **14**, thereby to display the continuity signals on the screen **132**. The continuity current sources **181** and **182** (FIG. **9**) deliver current to the LED and photodiode circuits while the probe cable is manually wiggled back and forth by the technician in an effort to reveal intermittent defects in the conductors **64** and **68**.

Specifically, current of about 0.5 ma is sent through the conductors **64** and just one of the LEDs, as **54** (FIG. **9**), by the current source **181**. In the normal operation of the red and IR LEDs **54** and **56** as part of the pulse oximeter **24**, current is caused to flow first in one direction and then in the other through the conductors **64**, thereby alternately to excite the LEDs. For this continuity test, however, only one of the LEDs is excited since the principle objective is to check the continuity of the conductors where defects are more likely to occur.

The other continuity current source **182** (FIGS. **2–5** and **9**) supplies a relatively low amperage current It, for example 0.5 ma, through the conductors **68** and the photodiode **58** (FIG. **5**). It is significant here, and a feature of this invention, that the continuity current It flows through the photodiode in the opposite direction, as indicated by the arrow in FIG. **5**, from the direction in which current flows when the photodiode is excited by flashes of light. This is a very practical feature since it causes the photodiode continuity signal, which would ordinarily be sensitive to ambient light, to be completely unresponsive to light. In this manner, the probe **24** and cable **30** can be freely wiggled during the test without any chance of artifact resulting from light sensitivity.

As shown in FIG. **9**, and as previously described and under the control of the timer **189**, the LED and photodiode voltage samples are applied by the display driving routine **190** of the microprocessor **104** to the y-axes of the LED and photodiode channels **160** and **162** of the display screen **132**. In a properly functioning probe **30**, there are no opens or shorts in the LED or photodiode circuits, so no voltage spikes or glitches will be developed, thereby causing the waveforms of the horizontal sweeps to be in the middle of their channels **160** and **162**, that is, along the levels marked "Good," as shown in FIG. **13**. If either circuit has a discontinuity, that is, a broken conductor or wire, as **64** or **68**, a positive voltage sample, that is representing a glitch, will be fed to the screen **160** and the waveform will rise to the position marked "Open," such as shown in FIG. **14** with regard to the circuit for the photodiode **58**. Similarly, although not shown, if the circuit is shorted, a negative sample also representing a glitch will be delivered to the screen, causing the waveform to drop to the position marked "Short."

What makes the probe continuity test according to the present invention so valuable is its ability to detect intermittent opens and shorts in the probe's red/IR circuit **54**, **56**, **64** and the probe's photodiode circuit **58**, **68** (FIG. **5**). A simple static test of probe continuity, such as a numeric display from a digital multi-meter, is not able to detect these open or short circuit conditions referred to as glitches that are characteristic of intermittently defective probes **24** and particularly the probe cables **30**. The subject testing apparatus **20** provides simultaneous waveform displays of both the red/IR circuit and the photodiode circuit so that a single mechanical, i.e., manual, stress test, or wiggle test, of the probe cable will reveal any intermittent opens or shorts. In

addition, any time a glitch is detected by the subject apparatus, the waveforms are frozen on the screen, as more fully described below, thereby eliminating any chance that the operator may overlook a glitch.

In the probe continuity testing mode, with the continuity sub-menu displayed as shown in FIG. **14**, the soft key F**3** toggles between an auto trigger mode and a glitch trigger mode. In the auto trigger mode, which is the typical operating mode, the waveforms (FIGS. **14**) sweep continuously across the screen **132** until a glitch is detected. With reference to FIG. **9**, when the glitch detecting routine **192** detects a glitch, it sends a signal to the display driving routine that causes the waveform, as **198** (FIG. **14**), to freeze on the screen at the end of the current sweep across the screen. This captures or freezes the glitch waveform on the screen so that it can not be missed by the technician.

By toggling the key F**3** into the glitch trigger mode, with the display screen **132** showing the probe continuity sub-menu (FIG. **14**), the waveforms **196** and **198** do not sweep across the screen until a glitch is detected. This provides for maximum amount of glitch signature or pattern on the screen and allows the technician an opportunity carefully to examine the glitch. Another key F**5** is used to clear the screen after a glitch has been detected and frozen and to re-enable continuous waveform sweeping.

TESTING THE PROBE **28**—SENSITIVITY TEST

If the probe **28** tests "Good" for continuity, it is next subjected to the probe sensitivity test to evaluate the IR and red optical performance of the probe. By pressing the hard keys M or P, the probe sensitivity sub-menu is selected, as shown in FIG. **15**. The probe sensitivity test provides a quantitative method of evaluating the probe's red, IR and red/IR ratio optical performances. It is important to test this ratio because the ratio has a direct bearing on how the oximeter works. If there is too much or too little red (or too much or too little IR), there will be an imbalance so the signal to noise ratio will be compromised and an inaccurate reading will result.

With reference to FIGS. **10**, **10**A and **15**, the bargraph and readout generating routine **246** provides horizontal bargraphs, as **300**, in the bargraph channels **165**, **166**, and **168**, together with corresponding numerical readouts at the ends of the bargraph channels. These bargraphs and readouts occur in response to activation of the LEDs **54**, **56** by the sensitivity current sources **209** and **210** which in turn activate the photodiode **58**. The bargraghs and readouts provide three measures of probe sensitivity, namely, (a) red channel sensitivity, i.e., the sensitivity of the photodiode to red light flashes; (b) IR channel sensitivity, i.e., the sensitivity of the photodiode to IR light flashes; and (c) the red/IR ratio sensitivity. The formulas for these sensitivities are:

(a) red channel sensitivity=[red response @ 1 mA]—[red response @ 0.5 mA]

(b) IR channel sensitivity=[IR response @ 1 mA]—[IR response @ 0.5 mA]

(c) red/IR ratio sensitivity=red sensitivity/IR sensitivity,

where red response @ x mA is the response of the photodiode when the red LED is energized with x mA of current, and IR response @ x mA is the response of the photodiode when the IR LED is energized with x mA of current.

Based on the foregoing formulas, the photodiode sample controlling routine **230** (FIG. **10**) measures four photodiode responses, which are taken across the photodiode **58** by the A/D converter and fed to the sample controlling routine **230** as digital pulses, so that in effect, the sample controlling routine is sampling the output of the photodiode. These four responses are: [red response @ 1 mA], [red response @ 0.5 mA], [IR response @ 1 mA], and [IR response @ 0.5 mA]. From these responses, the sample controlling routine produces the waveform shown in FIG. **10**A, which also shows when the four responses are sampled. The sample controlling routine produces this waveform using the method set forth in the following paragraph.

First, under the control of the timer **189**, the sample controlling routine **230** (FIG. **10**) through the current source controlling routine **234** completely de-energizes the IR LED **56** by turning off the sensitivity current source **210**, and energizes the red LED **54** by turning on its current source **209** with 0.5 mA. After a two hundred and fifty millisecond delay decremented by the timer, the controlling routine **230** samples the photodiode **58** output to yield the quantity "[red response @ 0.5 mA]." Secondly, the sample controlling routine **230**, together with the source controlling routine **234**, while maintaining the red LED de-energized, energizes the red LED with 1.0 mA, and after another two hundred and fifty millisecond delay, samples the photodiode output to yield the quantity "[red response @ 1.0 mA]."

Thirdly, the sample controlling routine **230** completely de-energizes the red LED **54** (FIG. **11**) by turning off its sensitivity current source **209** through the source controlling routine **234** and energizes the IR LED **56** with 0.5 mA by turning on its current source **210** with the source controlling routine. After the timer decrements another two hundred and fifty millisecond delay (FIG. **12**), the controlling routine **230** samples the photodiode output to yield the quantity "[IR response @ 0.5 mA]." Fourth, while keeping the red LED de-energized, the controlling routines **230**/**234** energize the IR LED with 1.0 mA by turning on its current source, and after another two hundred and fifty millisecond delay, the controlling routine **230** samples the photodiode output to yield the quantity "[IR response @ 1.0 mA]." The timer **189** causes this four-phase cycle to repeat once a second.

The photodiode waveform (FIG. **10**A) produced by the sample controlling routine **230** in accordance with the methodology described above is thus available for the sensitivity calculating routine **240** (FIG. **10**) to develop the red sensitivity, the IR sensitivity and the red/IR sensitivity ratio signals. The bargraph and readout generating routine **246** activates the x-axis of the display screen **132** with the red sensitivity, the IR sensitivity and the red/IR sensitivity ratio signals and creates red, IR, and red/IR bargraphs, as **300** (FIG. **15**), respectively in the bargraph channels **165**, **166**, and **168**. The generating routine also creates red, IR, and red/IR numerical readouts at the ends of the bargraphs, as also shown in FIG. **15**.

The probe sensitivity test as described above measures the sensitivity at two different current levels and takes the difference which eliminates the effect of ambient light under normal lighting conditions. By contrast, a very primitive test of sensitivity would be to measure the output of the photodiode **58** when the LEDs **54** and **56** were driven with X amount of current and this output analyzed and assumed to represent the sensitivity of the components. However, this analysis would overlook the effect of ambient light. Even with no electrical drive on the LEDs, ambient light is always producing an output from the photodiode, so a simple pulsing of the LEDs would always represent the effect of both ambient light and the current source. By driving the LEDs with current at two different levels, and subtracting the outputs, the effect of ambient light is eliminated.

From the foregoing, it will be understood that the present method and apparatus **20** for testing pulse oximeters **24** provides many advantages. The fundamental concept of the subject invention is that the testing philosophy is based on

an electrical interface between the oximeter and the testing apparatus, as contrasted with the optical interface heretofore utilized. Many advantages flow from this approach. Testing is more efficient and effective, safer and thus more reliable, because the biomedical technician can more readily determine whether a defect is in the main unit **26** of the oximeter or the probe **28**. Bypassing the optical interface also has the advantage of not introducing error because of the need for perfect placement of an artificial finger in the probe clamp **50** of a pulse oximeter **24**.

With the subject testing apparatus **20** electrically connected to a pulse oximeter, as **24**, the oximeter delivers signals to the testing apparatus which would normally be delivered to the probe **28**, and the testing apparatus modulates these signals in a manner which simulates the modulation resulting from a human finger placed in the probe when the oximeter is in regular use. The modulated signals are then fed back into the oximeter for processing by the oximeter and shown on its displays so that comparisons can be made with the known testing values. The subject method and apparatus allows for testing with single values of the testing parameters or with sequencing of profiles of the various parameters. Moreover, the test results can be manually or automatically logged and printed.

Experience of biomedical technicians in the patient care facilities shows that defects are usually in the probe **28**, especially the probe cable **30**. With the subject invention, it is possible to test the probe, that is, the probe probe cable and optics **54**, **56** and **58**, independently of the main unit **26** of the oximeter **24**, whereas such testing has not been possible with the prior oximeter testing equipment. Also, since the probes are not unique to particular oximeters, they are often stored independently of the oximeter instruments, and sometimes in a manner which subjects them to undue stress, causing defects. In the past, technicians who have wanted to test only a probe which is separated from an oximeter instrument have had to search around the hospital for an instrument, connect the probe to the instrument, and then test them together just to determine whether the probe is functioning properly. The subject invention obviates this exercise since the subject testing apparatus can readily test the probe alone.

It is also to be noted that the apparatus of the present invention allows a technician to test the probe without the assistance of any other person since the multiple terminals **66**, **70** of the probe connector are plugged into the interface connector **114** or **116** of the testing apparatus **20**, and the testing is performed. If a technician, acting alone, were to attempt to test the continuity of the probe with a multimeter, it would be virtually impossible, or at least very impractical, to connect or contact the terminals of the probe connector with the prongs of the multimeter while simultaneously wiggling the cable and looking at the meter reading.

Still further, the subject method and apparatus **20** improves the integrity of testing of the oximeter because it improves the testing of the probe **28**, and especially the probe cable **30**, where a majority of the defects occur. This invention allows detection of intermittent opens and shorts in the probe cable, whereas previous testers might allow the oximeter to filter out spikes caused by such intermittent defects and thereby mask a developing problem. Still further, the subject method and apparatus displays the results of the testing with waveforms which can be carefully examined for a better analysis of the problems.

Although a preferred embodiment of the present invention has been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. An apparatus for testing a pulse oximeter having means for optically sensing SpO_2 values of living tissue, electrical drive means for electrically activating the optically sensing means, and electrical signal processing means responsive to the optically sensing means for producing an oximeter signal corresponding to the SpO_2 value being sensed, said testing apparatus comprising:

first testing means bypassing the optically sensing means and responsive to the electrical drive means for generating selected first electrical test signals respectively representative of selected SpO_2 values in living tissue and for transmitting said first signals to the electrical signal processing means to test the ability of the signal processing means to process said representative SpO_2 values and produce oximeter signals corresponding to the selected SpO_2 values represented by the test signals generated, and

second testing means for generating second electrical test signals, for transmitting the same to the optically sensing means, for receiving response signals from the optically sensing means in response to transmission of the second test signals, and for providing an indication of said response signals thereby to test the optically sensing means separately from said testing by the first testing means.

2. The apparatus of claim **1**, wherein:

the optically sensing means includes an LED, a photodiode for producing an electrical output signal in response to activation of the LED, a first electrical circuit including the LED, and a second electrical circuit including the photodiode, said drive means being connected to the first electrical circuit for electrically activating the optically sensing means, said oximeter further including driven means interconnecting the second electrical circuit and the signal processing means for transmitting the electrical output signal from the photodiode to the signal processing means:

wherein said first testing means is capable of transmitting said first test signals instead of said photodiode output signal, to the driven means for testing the drive means, the driven means and the signal processing means,

said second test signals including electrical continuity test signals and electrical sensitivity test signals,

wherein said second testing means is capable of conducting the electrical continuity test signals through both of said first and second circuits to provide electrical continuity outputs,

wherein said second testing means is capable of conducting the electrical sensitivity test signals through said first circuit to provide an electrical sensitivity output in the second circuit, and further including

means for sensing said electrical continuity and sensitivity outputs from said circuits in response to said continuity and sensitivity test signals to test both the continuity and the optical sensitivity of the optical sensing means.

3. An apparatus for testing a pulse oximeter capable of sensing the SpO_2 in living tissue and including a probe including LEDs and a photodiode; and an electronic unit including an LED driver providing output signals for activating the LEDs, an electronic signal processor for receiving and processing input signals from the photodiode in response to activation of the LEDs, and a display for

showing the SpO_2 values represented by the input signals, said probe releasably interconnecting the LED driver and the LEDs and the photodiode and the signal processor, comprising:

means operable with the probe disconnected from the LED driver and the signal processor for providing electrical test signals in response to output signals from the LED driver;

means for modulating said electrical test signals so as to provide modulated electrical test signals representative of selected SpO_2 values corresponding to those in living tissue; and

means for transmitting said modulated electrical test signals to the signal processor in place of said input signals to cause the signal processor to process the test signals as if they were said input signals whereby SpO_2 values shown on the display can be compared with a range of selected SpO_2 values corresponding to the modulated electrical test signals thereby to test said electronic unit over its normal operating range.

4. The apparatus of claim **3**, further including:

electronic memory means adapted to store an SpO_2 profile including a plurality of SpO_2 values which vary over a predetermined time base; and

wherein said modulating means is adapted to modulate said electrical test signals with selected SpO_2 profiles so as to provide modulated electrical test signals representative of selected SpO_2 profiles.

5. The apparatus of claim **4** further including:

display means;

wherein said electronic memory means is also adapted to store a cursor for said profiles,

wherein said modulating means is further adapted to feed a selected SpO_2 profile and said cursor to said display means so that a selected profile and cursor can be displayed,

wherein said memory means, said modulating means and said display means cooperate to cause the cursor to move in steps over the displayed profile at a predetermined rate stored in said memory, with the position of the cursor at each step indicating on the display means the value of SpO_2 then modulating the test signal whereby the oximeter can be tested with said profile of SpO_2 values sequentially delivered to the signal processor.

6. An apparatus for testing the probe of a pulse oximeter having an electronic unit including an LED driver and an electronic signal processor; said probe including red and IR LEDs, a photodiode, and a probe cable, said probe cable being releasably connected to the driver and the signal processor when the probe is being used to sense the SpO_2 of living tissue and to feed a signal representative of the same to the signal processor, comprising:

means for supplying current to the LEDs and the photodiode while the probe is disconnected from the driver and the signal processor to provide electrical continuity outputs from the LEDs and the photodiode;

means for driving the LEDs while the probe is disconnected from the driver and the signal processor so as to activate the photodiode and provide electrical sensitivity outputs from the photodiode; and

means for sensing said outputs thereby to indicate the sensitivity and the continuity of the probe.

7. An apparatus for testing a pulse oximeter probe which includes optical sensing means providing an LED circuit including red and IR LEDs and a photodiode circuit including a photodiode, there being an interactive red LED-photodiode combination and an interactive IR LED-photodiode combination, said LED circuit, said photodiode circuit, said interactive red LED-photodiode combination, and said interactive IR LED-photodiode combination constituting first, second, third, and fourth parts, respectively, of the optical sensing means capable of being tested for continuity and sensitivity, comprising:

current supply means simultaneously connectable to the LED and photodiode circuits for causing testing current to flow in at least one of said circuits and for producing test output signals representative of the test results on at least one of said parts of the optical sensing means; and

means for receiving the test output signals and being responsive to the magnitude thereof to produce an indication of the results of said test to a user of the apparatus.

8. The apparatus of claim **7**, further including: indicator means,

wherein said current supply means and said receiving means interact to produce test output signals each of which individually represents the test results for one of said parts of the optical sensing means, and

wherein said indicator means is capable of indicating each of said individual output signals, whereby selected parts of the optical sensing means can be separately analyzed.

9. The apparatus of claim **7**, further including:

indicator means;

wherein for said continuity test, the current supply means is adapted to supply current simultaneously to each of said circuits thereby to produce LED circuit continuity output test signals and photodiode circuit continuity output test signals;

wherein said receiving means includes means for multiplexing said continuity output test signals and means for feeding said multiplexed output test signals to said indicator means; and

wherein said indicator means is adapted separately to indicate the LED and photodiode continuity output signals thereby to enable individual analysis of the continuity of the LED and photodiode circuits.

10. The apparatus of claim **7**, further including:

indicator means;

wherein said receiving means includes microprocessor means;

wherein, for said sensitivity test, the microprocessor means is adapted to cause the current supply means to alternately supply current to the red LED and the IR LED whereby said test output signals are alternately red sensitivity signals and IR sensitivity signals,

said microprocessor means being adapted to develop red sensitivity/IR sensitivity ratio signals from said red and IR sensitivity signals, and

said indicator means being adapted to indicate said red sensitivity signals, said IR sensitivity signals, and said red sensitivity/IR sensitivity ratio signals to a user of the apparatus, thereby to enable the user to analyze the sensitivity of said third and fourth parts of the optical sensing means.

11. An apparatus for testing the continuity of a pulse oximeter probe which provides an LED circuit and a photodiode circuit, said apparatus comprising:

means for activating each of said circuits so as to produce an electrical test output in each circuit representative of whether the circuit is open, continuous or shorted;

means for separating the test outputs representing the LED circuit from the test outputs representing the photodiode circuit; and

means for analyzing each of said outputs to determine whether or not the LED circuit or the photodiode circuit is open, continuous or shorted.

12. The apparatus of claim **11**, wherein:

said activating means is adapted to activate said photodiode circuit by causing current to flow in a direction in said photodiode circuit opposite to the direction current flows when light activates the photodiode.

13. The apparatus of claim **11**,

wherein said analyzing means includes display means providing separate channels respectively associated with the test outputs of the LED and photodiode circuits, and

wherein said analyzing means is capable of displaying representations of said test outputs in the respective channels for the LED and photodiode circuits so that a predetermined representation indicates whether the respective circuit is open, continuous, or shorted.

14. The apparatus of claim **11**,

wherein said analyzing means includes display means,

wherein said analyzing means is capable of displaying representations of said test outputs on the display means so that a predetermined representation represents a circuit that is open, continuous, or shorted, and

wherein said analyzing means is capable of freezing the representation on the display means when a circuit is open or shorted.

15. An apparatus for testing the sensitivity of a pulse oximeter probe which provides red and infrared LEDs an a photodiode adapted to be alternately activated by said LEDs, said apparatus comprising:

means for electrically alternately activating the LEDs so as to produce electrical red and IR sensitivity test output signals from the photodiode;

means for producing red sensitivity/IR sensitivity ratio signals from said red and IR test output signals; and

means for indicating each of said red sensitivity, IR sensitivity and red sensitivity/IR sensitivity ratio signals to determine the sensitivity of the optical sensing means.

16. The apparatus of claim **15**,

wherein said activating means is adapted alternately to supply relatively low and relatively high current to the red and IR LEDs to produce alternately low and high red signals and low and high IR signals, said apparatus further including

means for subtracting the low red from the high red signal and the low IR from the high IR signal, and

wherein said producing means is adapted to produce said red sensitivity signal from the difference between the high and low red signals and to produce said IR sensitivity signal from the difference between the high and low IR signals.

17. The apparatus of claim **15**,

wherein said indicating means includes display means for respectively separately displaying said red and IR sensitivities and said red sensitivity/IR sensitivity and said red sensitivity/IR sensitivity ratio.

18. A method for testing a pulse oximeter having means for optically sensing SpO_2 values in living tissue, means for electrically activating the optically sensing means, and electrical means responsive to the optically sensing means for indicating the SpO_2 value in tissue being sensed, said method comprising the steps of:

generating first test signals representative of SpO_2 values in living tissue in response to the electrically activating means and independently of the optically sensing means,

transmitting the first test signals to the electrical responsive means independently of the optically sensing means to test the ability of the oximeter to indicate said representative SpO_2 values,

generating a second test signal independently of the electrically activating means for testing the optically sensing means,

transmitting the second test signal to the optically sensing means independently of the electrically activating means, and

receiving an output from the optically sensing means indicative of the responses of the optically sensing means to the second test signal, thereby to test the operability of the optically sensing means.

19. The method of claim **18**,

wherein said generating step for testing the optically sensing means is capable of testing the electrical continuity of the optically sensing means.

20. The method of claim **18**, including the further step of:

disconnecting the optically sensing means from the electrically activating means and the electrical responsive means,

wherein said generating step includes receiving an output signal from the electrically activating means and modulating said output signal so as to provide a modulated test signal representative of a selected value of SpO_2 corresponding to that in living tissue; and

wherein said transmitting step involves transmitting said modulated test signal to the electrical responsive means so as to provide a modulated test signal representative of a selected value of SpO_2 corresponding to that in living tissue.

21. A method for testing a pulse oximeter over a range of values of SpO_2 expected to exist in living tissue said oximeter having a probe including LEDs and a photodiode; and an electronic unit including an LED driver providing an output signal for activating the LEDs, an electronic signal processor for receiving and processing input signals from the photodiode representative of SpO_2 values in living tissue in response to activation of the LEDs, and a display for showing the SpO_2 values represented by the input signals, said probe releasably interconnecting the LED driver and the LEDs and the photodiode and the signal processor, comprising the steps of:

disconnecting the probe from the driver and signal processor;

generating an electrical test signal in response to the output signal from the LED driver;

modulating said electrical test signal so as to provide a modulated electrical test signals representative of selected SpO_2 values in living tissue;

transmitting said modulated electrical test signals to the signal processor in place of said input signals to cause the signal processor to process the test signals as if they were said input signals thereby to test said electronic unit and,

displaying the selected SpO_2 values so that a comparison can be made with the SpO_2 values displayed by the oximeter display to determine the accuracy of the oximeter over a range of SpO_2 values.

22. The method of claim **21**, including the further steps of:

electronically storing an SpO_2 profile including a plurality of SpO_2 values which vary over a predetermined time base; and

wherein said modulating step is adapted to modulate said electrical test signals with selected SpO_2 profiles so as to provide modulated electrical test signals representative of selected SpO_2 profiles.

23. The method of claim **22** including the further steps of:

electronically storing a cursor for said profiles and a stepping rate for the cursor,

displaying a selected profile and said cursor; and

moving the cursor in steps over the displayed profile at said stepping rate so that the position of the cursor at each step indicates the value of SpO_2 then modulating the test signal whereby the oximeter can be tested with said profile of SpO_2 values sequentially delivered to the signal processor.

24. A method for testing a pulse oximeter probe which includes optical sensing means providing an LED circuit including red and IR LEDs and a photodiode circuit including a photodiode, there being an interactive red LED-photodiode combination and an interactive IR LED-photodiode combination, said LED circuit, said photodiode circuit, said interactive red LED-photodiode combination, and said interactive IR LED-photodiode combination constituting first, second, third, and fourth parts, respectively, of the optical sensing means one or more of which is capable of being tested for the parameters of continuity and sensitivity, comprising the steps of:

electrically activating said circuits so as to produce electrical test output signals which are representative of at least one of the parameters to-be-tested; and

sensing the test output signals and displaying an indication of whether one or more of said parts meet the standards established for said at least one of the parameters to-be-tested.

25. The method of claim **24**, wherein:

said activating step activates the circuits so as to produce output test signals which are not affected by ambient light on the photodiode.

26. The method of claim **24**, wherein:

said activating step involves causing current to flow in the photodiode circuit in the opposite direction from that occurring when the photodiode is activated by light.

27. The method of claim **24**, wherein:

said activating step involves alternatively supplying high and low current pulses in the red and IR LED circuits, respectively, to produce alternate red high and red low test output signals and IR high and IR low test output signals, said activating step further involving subtracting red low signals from the corresponding red high signals and IR low signals from the corresponding IR high signals, thereby to produce said red sensitivity and said IR sensitivity signals, respectively, and including the further step of

generating red sensitivity/IR sensitivity ratio signals from said red sensitivity and said IR sensitivity signals, and

wherein said sensing step involves analyzing said red and IR sensitivity signals and said red sensitivity/IR sensitivity ratio signals thereby to determine the sensitivity of the optically sensing means.

28. The method of claim **24**, further including the step of:

displaying graphical representations of the test output signals sensed from said circuits thereby to indicate the condition of the continuity of said circuits, and

displaying graphical representations of the test output signals sensed from the photodiode thereby to indicate the sensitivity of the optically sensing means.

29. A method for testing the continuity of a pulse oximeter probe which provides an LED circuit and a photodiode circuit, comprising the steps of:

activating each of said circuits so as to produce an electrical test output in each circuit representative of whether the circuit is open, continuous or shorted;

separating the test outputs representing the LED circuit from the test outputs representing the photodiode circuit; and

analyzing each of said outputs to determine whether or not the LED circuit or the photodiode circuit is open, continuous or shorted.

30. The method of claim **29**, wherein said analyzing step further includes:

displaying representations of said test outputs so that a predetermined representation represents a circuit that is open, continuous, or shorted, and

freezing the representation when a circuit is open or shorted.

31. The apparatus of claim **1**,

wherein said first and second testing means are capable of independently but simultaneously testing the signal processing means and the optically sensing means.

32. The apparatus of claim **1**,

wherein there is a housing enclosing both the first and second testing means, and

wherein there are spaced first and second connector means on the housing respectively connected to the first and second testing means and respectively adapted to be connected to the signal processing means and the optically sensing means.

33. The apparatus of claim **1**,

wherein there are microprocessor means for controlling the first and second testing means to enable the first and second testing means to test either the signal processing means or the optically sensing means separately or to test both the signal processing means and the sensing means simultaneously.

34. The apparatus of claim **1** wherein the optically sensing means includes an LED, a photodiode for producing an electrical output signal in response to activation of the LED, a first electrical circuit including the LED, and a second electrical circuit including the photodiode, said drive means being connected to the first electrical circuit for electrically activating the optically sensing means, said oximeter further including driven means interconnecting the second electrical circuit and the signal processing means for transmitting the electrical output signal from the photodiode to the signal processing means:

wherein said first testing means is capable of transmitting said first test signals, instead of said photodiode output signal, to the driven means for testing the drive means, the driven means and the signal processing means,

wherein said second test signals are electrical continuity test signals,

wherein said second testing means is capable of conducting the electrical continuity test signals respectively through said first and second circuits to provide electrical continuity outputs, and

wherein there are means for sensing said electrical continuity outputs and displaying an indication of the continuity of the optical sensing means.

35. The apparatus of claim **1** wherein the optically sensing means includes an LED, a photodiode for producing an electrical output signal in response to activation of the LED, a first electrical circuit including the LED, and a second electrical circuit including the photodiode, said drive means being connected to the first electrical circuit for electrically activating the optically sensing means, said oximeter further including driven means interconnecting the second electrical circuit and the signal processing means for transmitting the electrical output signal from the photodiode to the signal processing means:

wherein said first testing means is capable of transmitting said first test signals, instead of said photodiode output signal, to the driven means for testing the drive means, the driven means and the signal processing means,

wherein said second test signals are electrical sensitivity test signals,

wherein said second testing means is capable of conducting the electrical sensitivity test signals through said first circuit to provide electrical sensitivity outputs in the second circuit, and

wherein there are means for sensing said electrical sensitivity outputs and displaying an indication of the optical sensitivity of the optical sensing means.

36. The apparatus of claim **3**,

wherein the apparatus includes means for displaying the values of SpO_2 represented by the modulated electrical test signals whereby SpO_2 values showing on the oximeter display can be compared with selected SpO_2 values showing on the displaying means thereby to determine the accuracy of the oximeter throughout a range of SpO_2 values.

37. An apparatus for testing the continuity of a pulse oximeter probe which provides LED and photodiode circuits connected to LED and photodiode terminals of a probe connector, said apparatus comprising:

means simultaneously connectable to the LED and photodiode terminals of the probe connector for activating each of said circuits so as to produce an electrical test output in each circuit representative of whether the circuit is open, continuous or shorted; and

means responsive to said test outputs for displaying indicia representing whether said LED and photodiode circuits are open, continuous or shorted.

38. The apparatus of claim **37**,

wherein the activating means is a current source for each of said circuits.

39. The apparatus of claim **38**,

wherein the current sources are simultaneously connectable to their respective LED and photodiode circuits, and

wherein the activating means causes current from the current sources to supply current simultaneously to said circuits.

40. The apparatus of claim **37**, wherein the responsive means is capable of sensing and displaying intermittent test outputs of a predetermined threshold indicative of a glitch in either of said circuits.

41. The apparatus of claim **37**,

wherein there are means for combining the test outputs into a combined signal with alternating LED and photodiode pulses, and

wherein there are means for using the LED and photodiode pulses to display an indication of whether the LED and photodiode circuits are open, continuous or shorted.

42. The apparatus of claim **41**,

wherein the combining means combines the test outputs into a combined analog signal with said alternating LED and photodiode pulses,

wherein there are means for converting the combined analog signal into discrete digital signals representative of said LED and photodiode pulses; and

wherein there are means for sampling the digital signals and displaying the same to indicate whether or not the LED circuit or the photodiode circuit is open, continuous or shorted.

43. An apparatus for testing the continuity of a pulse oximeter probe that has an LED circuit and a photodiode circuit, comprising

means for supplying testing current to each of the LED and photodiode circuits to produce responses including separate analog LED and photodiode continuity voltages,

means for combining said voltages into a single voltage signal with alternating LED and photodiode pulses,

means for converting the single voltage signal into a series of discrete digital voltage pulses representative of the alternating LED and photodiode pulses,

means for sampling the digital voltage pulses,

display means, and

means for activating the display means with the signal samples to indicate whether the LED and photodiode circuits are open, continuous, or shorted.

44. The apparatus of claim **15**,

wherein said indicating means includes display means for respectively displaying bargraphs in separate channels of said red and IR sensitivities and said red sensitivity/IR sensitivity ratio.

45. The method of claim **18**,

wherein said generating step for testing the optically sensing means is capable of testing the optical sensitivity of the optically sensing means.

46. The method of claim **19**,

wherein said generating step for testing the optically sensing means is capable of testing the optical sensitivity of the optically sensing means.

47. A method for testing a pulse oximeter probe which includes optical sensing means providing an LED circuit including red and IR LEDs and a photodiode circuit including a photodiode, there being an interactive red LED-photodiode combination and an interactive IR LED-photodiode combination said LED circuit, said photodiode circuit, said interactive red LED-photodiode combination, and said interactive IR LED-photodiode combination constituting first, second, third, and fourth parts, respectively, of the optical sensing means to be subjected to such testing including the parameters of continuity and sensitivity, comprising the steps of:

electrically activating said circuits so as to produce electrical test output signals which are representative of the parameters to-be-tested of said parts;

electrically separating the test output signals so that there is a test output signal representative of continuity for each of said first and second parts and a test output signal representative of the sensitivity for each of said third and fourth parts;

and analyzing each of said output signals to determine whether or not said parts meet the standards established for said parameters.

48. The method of claim **24** which involves the use of a testing device capable of performing said activating, sensing and displaying steps, further including the step of:

electrically connecting the testing device simultaneously to both the LED and photodiode circuits prior to said electrically activating step thereby to enable testing of selected ones of said parts.

49. A method for testing the continuity of a pulse oximeter probe that includes an LED circuit and a photodiode circuit, comprising the steps of:

simultaneously connecting electrical activating means to both of the LED and photodiode circuits,

electrically activating each of said circuits with test signals thereby to produce an electrical test output in each circuit representative of whether the circuit is open, continuous or shorted; and

processing the test outputs to provide a visual indication of whether or not each circuit is open, continuous or shorted.

50. The method of claim **49**,

wherein the activating step involves simultaneously supplying said test signals in the form of current fed to each of said circuits from separate current sources respectively associated with said circuits.

51. The method of claim **49** wherein the probe includes a probe cable including conductors that are part of said circuits, including the further step of:

moving the cable around during the electrical activation so that if one or more of the conductors has an open or short condition that occurs only intermittently, such movement will cause the open or short to occur.

52. The method of claim **51**,

wherein the moving step causes a voltage spike in said test output of the circuit in which an intermittent short or open condition exists;

and wherein the processing step is responsive to the voltage spike to provide a visual indication of the same, whereby such intermittent short or open conditions are not overlooked by the user performing the test.

53. A method for testing the continuity of a pulse oximeter probe that has an LED circuit and a photodiode circuit, comprising the steps of:

supplying current to both the LED and photodiode circuits to produce responses including separate LED and photodiode continuity voltages; sensing said responses and combining them into a single voltage signal with alternating LED and photodiode pulses;

converting the single voltage signal into a series of discrete voltage pulses representative of the alternating LED and photodiode pulses; and

using the discrete voltage pulses to display indications of whether the LED and photodiode circuits are open, continuous or shorted.

54. An apparatus for testing the sensitivity of a pulse oximeter probe which provides red and infrared LEDs and a photodiode, said apparatus comprising:

a red current source that generates red LED activating signals, applies them to the red LED, and generates red high and red low outputs on the photodiode;

an IR current source that generates IR LED activating signals, applies them to the IR LED, and generates IR high and IR low outputs on the photodiode;

sensor circuitry that is responsive to the red high and the red low outputs on the photodiode and to the IR high and the IR low outputs on the photodiode and that generates red testing signals and IR testing signals from said outputs; and

a display that is responsive to the red and IR testing signals and produces an indication thereof, said indication being an indication of the sensitivity of the probe.

55. The apparatus of claim 54,

wherein the red current source generates high and low red activating signals and applies them to the red LED thereby to produce said high and low red outputs in the photodiode; and

wherein the IR current source generates high and low IR activating signals and applies them to the IR LED thereby to produce said high and low IR outputs in the photodiode.

56. An apparatus for testing the sensitivity of a pulse oximeter probe which provides red and infrared LEDs and a photodiode, said apparatus comprising:

means for applying red high and red low LED activating signals to the red LED so that red high and red low outputs are on the photodiode;

means for applying IR high and IR low LED activating signals to the IR LED so that IR high and IR low outputs are on the photodiode;

means for sensing the outputs on the photodiode and producing a red testing signal from the red high and red low outputs on the photodiode and an IR testing signal from the IR high and IR low outputs on the photodiode, said red and IR testing signals being the differences between their respective high and low outputs; and

means for displaying an indication of said testing signals whereby said indication is an indication of the sensitivity of the probe.

57. A method for testing the sensitivity of a pulse oximeter probe which provides red and infrared LEDs and a photodiode, comprising the steps of:

activating one of the LEDs with signals of high and low amplitude thereby producing first high and low outputs on the photodiode;

sensing the first high and low outputs on the photodiode;

producing a first testing signal from said first high and low outputs;

activating the other of the LEDs with signals of high and low amplitude thereby producing second high and low outputs on the photodiode;

sensing the second high and low outputs on the photodiode;

producing a second testing signal from said second high and low outputs; and

displaying an indication of said first and second testing signals thereby to indicate the sensitivity of the probe.

58. The method of claim 57,

wherein producing the first and second testing signals involves obtaining the difference between the first high and low outputs and the difference between the second high and low outputs resulting respectively in first and second difference signals.

59. An oximeter tester for an oximeter that includes a signal processor, an LED driver and a probe including LED and photodiode circuits respectively including light emitting diodes and a photodiode, the probe being releasably connected to the signal processor and the LED driver, the tester comprising:

a first sensor having an input adapted to be connected to the LED driver in the oximeter in place of the probe, the first sensor, when so connected, receiving electrical red and IR drive signals from the LED driver of the oximeter and producing red and IR pulses,

a de-multiplexer coupled to the sensor and separating the red and IR pulses,

a source of SpO_2 waveforms corresponding to those normally received by the oximeter when its probe is attached to a human being,

a modulator coupled to the de-multiplexer and modulating the separate red and IR pulses with said SpO_2 waveforms from the source and thereby generating first electrical test signals representative of SpO_2 waveforms of living tissue corresponding to those normally received by the oximeter when its probe is attached to a human being,

a tester driver having an input coupled to the modulator and an output adapted to be connected to the signal processor in the oximeter and, when so connected, delivering said first electrical test signals to the signal processor thereby to test the ability of the signal processor to process said SpO_2 waveforms and produce oximeter read-outs corresponding to SpO_2 values represented by the test signals generated;

a current source adapted to be connected to one or more diodes in the probe and, when so connected, coupling second electrical test signals to said one or more of the diodes thereby to activate the diodes;

a second sensor adapted to be connected to one or more diodes in the probe and, when so connected, receiving response signals from said one or more of the diodes in response to the second electrical test signals;

a display;

circuitry interconnecting the second sensor and the display and applying signals to the display indicative of the response signals from the sensor; and

a microprocessor coupled to the modulator, the display and the source and controlling the application of the SpO_2 waveforms to the modulator and the application of actuating current to said one or more diodes, and the application of the signals to the display.

60. An apparatus for testing a pulse oximeter having an optical sensor that senses SpO_2 values of living tissue, an electrical driver that produces an electrical signal that activates the optical sensor, and a signal processor responsive to the optical sensor that produces an oximeter signal corresponding to the SpO_2 value being sensed, said testing apparatus comprising:

for testing circuitry that is responsive to the signal from the electrical driver in the oximeter, that generates first electrical test signals that are SpO_2 waveforms simulating those generated by the probe of the oximeter when the oximeter is used to check the blood oxygen level of a patient, and that transmits said first signals to the signal processor of the oximeter independently of the optical sensor,

second testing circuitry that generates second electrical test signals, that transmits the second electrical test signals to the optical sensor in the oximeter independently of the electrical driver of the oximeter, and that receives response signals from said optical sensor in response to transmission of the second test signals, and

a display that provides an indication of said response signals from the second testing circuitry.

61. The testing apparatus of claim 60,

wherein the first testing circuitry includes an electrical sensor that receives the electrical signal from the electrical driver and produces an output, a modulator that is connected to the electrical sensor and generate the selected first electrical test signals respectively representative of selected SpO_2 waveforms in response to the output from the electrical sensor, and a tester driver that is connected to the modulator and transmits said first signals to the signal processor in the oximeter.

62. The apparatus of claim 61,

wherein the first testing circuitry includes an electronic memory that stores an SpO_2 profile including a plurality of said SpO_2 waveforms; and

wherein the modulator modulates said electrical test signals with selected SpO_2 profiles and provides modulated electrical test signals representative of selected SpO_2 profiles.

63. The testing apparatus of claim 60,

wherein the second testing circuitry includes a source of current that generates the second electrical test signals, electrical connections that transmit the second electrical test signals to the optical sensor, and electrical sensors that receive the response signals from the optical sensor, and

wherein the display is connected to the electrical sensors of the second testing circuitry and produces said indication from the output of the electrical sensors.

64. The apparatus of claim 60,

wherein there is a housing enclosing both the first and second testing circuitry, and

wherein there are spaced first and second connectors in the housing respectively connected to the first and second testing circuitry and respectively adapted to be connected to the signal processor and the optical sensor.

65. The apparatus of claim 60,

wherein there is a microprocessor that controls the first and second testing circuitry in testing the signal processor and the optical sensor.

66. The apparatus of claim 60 for testing a pulse oximeter the optical sensor of which has an LED circuit, a photodiode circuit, and an oximeter connector providing LED and photodiode terminals respectively connected to the LED circuit and photodiode circuits,

wherein the second testing circuitry includes LED testing circuitry, photodiode testing circuitry, and a tester connector having LED and photodiode terminals respectively connected to the LED testing circuitry and photodiode testing circuitry, the LED and photodiode terminals in the tester connector corresponding to the LED and photodiode terminals of the oximeter connector, so that when the tester connector is connected to the oximeter connector, the LED testing circuitry and photodiode testing circuitry are respectively connected to the LED circuit and the photodiode circuits.

67. An apparatus for testing the probe of a pulse oximeter, said probe including an LED, a photodiode, and a probe connector with LED and photodiode terminals respectively connected to the LED and photodiode, the testing apparatus comprising:

a tester connector having LED and photodiode terminals capable of connecting to LED and photodiode terminals of the probe connector;

a signal source that generates probe testing signals and that is connected to predetermined terminals of the tester connector for applying testing signals on the said predetermined terminals so that the testing signals will be applied to the probe when the tester connector is connected to the probe connector;

a signal sensor that is connected to certain terminals of the tester connector, that is responsive to outputs thereon resulting from application of the probe testing signals to the probe, and that generates output signals representative of the outputs from the probe; and

a display connected to the signal sensor for displaying an indication of said output signals, thereby to test the operability of the probe.

68. The apparatus of claim 67, the probe having LED and photodiode circuits respectively including the LED and the photodiode,

wherein the signal source generates probe continuity testing signals at the LED and photodiode terminals of the tester connector;

wherein the signal sensor is connected to the LED and photodiode terminals of the tester connector, is responsive to continuity outputs on said LED and photodiode terminals resulting from the continuity testing signals, and generates continuity output signals representative of the continuity of the LED and photodiode circuits; and

wherein the display shows an indication of the continuity of the LED and photodiode circuits.

69. The apparatus of claim 67,

wherein the signal source generates probe sensitivity testing signals at the LED terminals of the tester connector;

wherein the signal sensor is connected to the photodiode terminals of the tester connector, is responsive to sensitivity outputs on said photodiode terminals resulting from the sensitivity testing signals, and generates sensitivity output signals representative of the sensitivity of the probe; and

wherein the display shows an indication of the sensitivity of the probe.

70. The apparatus of claim 69, the probe having red and IR LEDs,

wherein the probe sensitivity signals generated by the signal source are high and low current signals for the red LED and high and low current signals for the IR LED, thereby to enable high and low red outputs and high and low IR outputs to be generated by the photodiode when the tester connector is connected to the probe connector;

wherein the signal sensor is responsive to the high and low red outputs and generates red difference signals representing the difference between said high and low red outputs;

wherein the signal sensor is responsive to the high and low IR outputs and generates IR difference signals representing the difference between said high and low IR outputs; and

wherein the display is responsive to the red and IR difference signals and displays an indication thereof to indicate the sensitivity of the red and IR LEDs.

71. A method for testing the continuity of a pulse oximeter probe that includes an LED circuit and a photodiode circuit, said method involving the use of a tester having a tester connector providing terminals connected to an electrically actuating source and a sensor in the tester, and a probe connector providing terminals connected to said circuits, comprising the steps of:

connecting the tester connector to the probe connector and thereby simultaneously connecting the electrically activating source and the sensor to the LED and photodiode circuits,

electrically activating each of said circuits with said source,

sensing each circuit with said sensor for outputs in response to said electrical activation,

producing indications of outputs that are sensed, and

determining the continuity of the circuits from said indications.

72. A method for testing the sensitivity of a pulse oximeter probe that has red and IR LED circuits and a photodiode circuit including a photodiode, said method involving the use of a tester having a tester connector providing terminals connected to an electrically actuating source and a sensor in the tester, and a probe connector providing terminals connected to said circuits, comprising the steps of:

connecting the tester connector to the probe connector and thereby simultaneously connecting the electrically activating source and the sensor to the LED and photodiode circuits,

electrically activating the LED circuits with said source,

sensing the photodiode circuit with the sensor for outputs in response to said electrical activation,

producing indications of outputs that are sensed, and

determining the sensitivity of the photodiode from said indications.

73. A pulse oximeter testing apparatus for testing a pulse oximeter having an optical sensor that senses SpO_2 values of living tissue, an electrical driver that produces an electrical signal that activates the optical sensor, and a signal processor responsive to the optical sensor that produces an oximeter signal corresponding to the SpO_2 value being sensed, said testing apparatus comprising:

a current sensor that is responsive to the electrical signal from the electrical driver in the oximeter and produces simulated red and IR signals;

an electronic memory storing SpO_2 waveforms that simulate SpO_2 waveforms in living tissue like those produced by the optical sensor in the normal operation of the oximeter;

a modulator responsive to the simulated red and IR signals from the current sensor, modulating the simulated red and IR signals with selected simulated SpO_2 waveforms from the memory, and generating modulated test signals respectively representative of the selected SpO_2 waveforms in living tissue; and

a tester driver responsive to the modulated test signals from the modulator, that produces electrical test signals representative of the selected SpO_2 waveforms, and that transmits the test signals to the signal generator in the oximeter to test the ability of the signal processor to process said representative SpO_2 waveforms and produce oximeter signals corresponding to the selected simulated SpO_2 waveforms.

74. The combination of a pulse oximeter and a testing apparatus, the oximeter having a signal processor, a display and a probe, the probe normally receiving signals from the oximeter and delivering modulated human signals to the signal processor resulting from a human finger or other body part placed in the probe,

wherein the testing apparatus is connected to the oximeter in place of the probe;

wherein the tester receives the signals from the oximeter that would normally be delivered to the probe;

wherein the testing apparatus includes an electronic memory containing a database of waveforms corresponding to those produced by human fingers or other body parts when placed in the probe of an oximeter;

wherein the testing apparatus also includes a modulator that modulates the signals received by the testing apparatus with selected waveforms from the electronic memory thereby generating modulated testing signals that simulate the modulated human signals resulting from a human finger or other body part placed in the probe when the oximeter is in its normal use;

wherein the testing apparatus delivers the modulated testing signals to the signal processor;

wherein the modulating testing signals are processed by the signal processor as if the modulating testing signals were the modulated human signals thereby producing processed signals; and

wherein the processed signals are displayed on the display whereby comparisons can be made with known values.

75. An apparatus for testing a pulse oximeter having an optical sensor that senses SpO_2 values of living tissue, an LED driver, a signal processor responsive to the optical sensor that produces an oximeter signal corresponding to the SpO_2 value being sensed and a display, said testing apparatus comprising:

first means for testing the LED driver and the signal processor of the oximeter separately from the optical sensor of the oximeter, the display in the oximeter displaying the results of the first testing means;

second means for testing the optical sensor of the oximeter separately from the LED driver and the signal processor of the oximeter; and

means for displaying the results of the second testing means.

76. An apparatus for testing a pulse oximeter having an optical sensor that senses SpO_2 values of living tissue, a signal processor responsive to the optical sensor that produces an oximeter signal corresponding to the SpO_2 value being sensed, and a display that displays the said SpO_2 values sensed, the testing apparatus comprising:

means for testing the signal processor of the oximeter with testing SpO_2 values independently of the optical sensor; and

means for enabling a comparison of the testing SpO_2 values with the SpO_2 values displayed on the oximeter display.

77. An oximeter probe tester for an oximeter probe having LED and photodiode circuits, comprising:

means for electrically activating the LED circuit and the photodiode circuit of the oximeter probe so as to produce electrical test output signals in the circuits that are representative of the continuity of the circuits,

means for sensing whether or not the test output signals are present in the circuits, and

means for displaying an indication of the test output signals sensed.

78. An oximeter probe tester for an oximeter probe having a LED circuit including LEDs and a photodiode circuit including a photodiode, comprising:

means for electrically activating the LEDs of the oximeter probe so as to produce electrical test output signals in the photodiode that are representative of the sensitivity of the photodiode,

means for sensing the test output signals, and

means for displaying an indication of the test output signals sensed.

79. An oximeter probe tester for an oximeter probe having an LED circuit including LEDs and a photodiode circuit including a photodiode, comprising:

means for electrically activating the LED circuit and the photodiode circuit of the oximeter probe so as to produce electrical test output signals in the circuits that are representative of the continuity of the circuits,

means for sensing whether or not the test output signals are present in the circuits,

means for electrically activating the LEDs of the oximeter probe so as to produce electrical test output signals on the photodiode that are representative of the sensitivity of the photodiode,

means for sensing the test output signals on the photodiode, and

means for selectively and separately displaying an indication of the test output signals that are representative of the continuity of the circuits and the test output signals that are representative of the sensitivity of the photodiode.

80. The apparatus of claim 54,

wherein the red testing signals are red difference signals that represent the difference between the red high and red low outputs from the photodiode; and

wherein the IR testing signals are IR difference signals that represent the difference between the IR high and IR low outputs of the photodiode.

81. The apparatus of claim 80.

wherein the red and IR testing signals also include ratio signals that represent the ratio of the red difference signals to the IR difference signals.

82. A method for testing a pulse oximeter with a testing instrument wherein the oximeter includes a probe, an LED driver, a signal processor, an oximeter interface connector connected to the signal processor and the LED driver, the probe including LEDs, a photodiode, and a probe connector connected to the oximeter interface connector in normal use of the oximeter, the LEDs being responsive to LED drive signals from the LED driver and the photodiode generating SpO_2 waveforms for delivery to the signal processor through the oximeter interface connector when the probe is attached to the human being, and wherein the testing instrument includes a housing, a probe testing connector mounted on the housing, and a simulator testing connector mounted on the housing, the method comprising the steps of:

connecting either the probe connector alone to the probe testing connector, the simulator testing connector alone to the oximeter interface connector, or both the probe connector and the simulator testing connector, respectively, to the probe testing connector and the oximeter interface connector;

with the simulator testing connector connected to the oximeter interface connector in place of the probe, generating first test signals representative of SpO_2 waveforms that simulate said human SpO_2 waveforms generated by the probe in response to said LED drive signals;

transmitting the first test signals to the signal processor through the interconnected simulator testing connector and oximeter interface connector;

with the probe connector connected to the probe testing connector instead of to the oximeter interface connector, generating a second test signal independently of the LED driver;

transmitting the second test signal to the probe through the interconnected probe connector and probe testing connector;

receiving an output from the probe in response to the second test signal; and

displaying said output.

83. A method for testing either the continuity or the sensitivity or both of a pulse oximeter probe that has an LED circuit including red and IR LEDs, a photodiode circuit including a photodiode, and a probe connector, the method involving the use of a housing enclosing electrically activating sources and signal sensing circuitry and mounting a probe testing connector providing LED and photodiode terminals connected to the electrically activating sources and the signal sensing circuitry, the method comprising the steps of:

interconnecting the probe connector and the probe testing connector and thereby interconnecting the LED and photodiode terminals and the LED and photodiode circuits respectively;

electrically activating both of the LED and photodiode circuits with an electrical activating source in the housing if continuity is being tested;

electrically activating only the LED circuits with an electrical activating source in the housing if sensitivity is being tested;

sensing both of the LED and photodiode circuits for outputs in response to said electrical activation if continuity is being tested;

sensing the photodiode circuit for outputs in response to said electrical activation if sensitivity is being tested;

displaying visual indications of the outputs that are sensed, and

determining the continuity and/or sensitivity of the probe from said visual indications.

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