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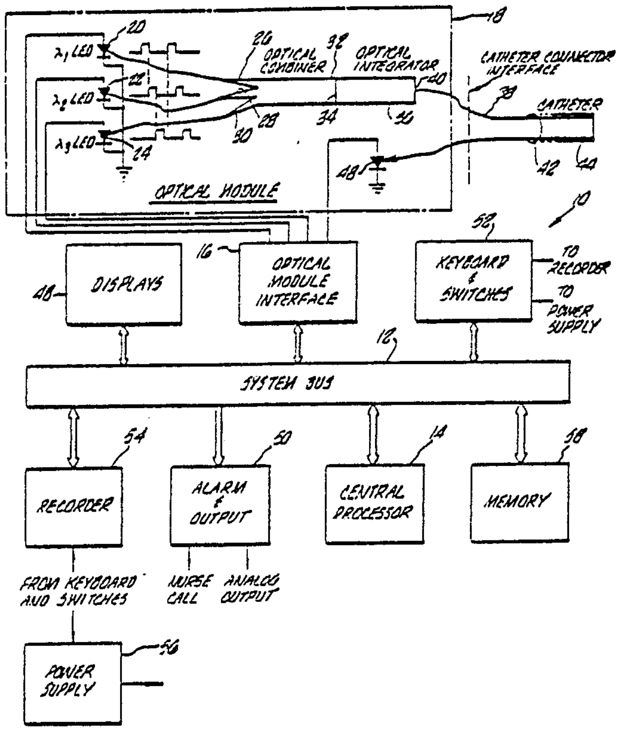
(57) Abstract

A signal filter method and apparatus for removing portions of a signal indicative of erroneous data, an exemplary apparatus including means (74, 76) for receiving the signal, means (122, 124, 126, 130, 138) for adjusting a threshold by increasing the threshold a first predetermined amount when the signal is in a predetermined relationship with the threshold and for decreasing the threshold a second predetermined amount when the signal is in a second predetermined relationship with the threshold, and means (90, 92, 94, 140) for comparing the signal with the adjusted threshold and for transmitting the signal if the signal bears a first predetermined relationship to the threshold. Disclosed herein are digital and analog implementations of the signal filter method and apparatus, particularly suited for use with catheter-type oximeter apparatus (10).



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Description

Signal Filter Method and Apparatus

Technical Field

The present invention relates generally to signal processing and more particularly to a signal filter method and apparatus suitable for use with in vivo catheter-type oximeters.

Background Art

Various catheter-type oximeter apparatus are known for determining blood oxygen saturation. One such apparatus is disclosed in U.S. Patent No. 4,114,604 to Shaw, et al., the disclosure of which is incorporated herein by reference. Typically with such apparatus, a catheter is introduced into a blood vessel and the blood within the vessel flows about the catheter tip. The catheter includes a first fiberoptic guide which conducts radiation from the oximeter apparatus to an aperture at the catheter tip. The blood flowing about the catheter tip scatters a portion of the incident radiation thereon back to a second aperture at the catheter tip where a second fiberoptic guide transmits this back-scattered radiation to the oximeter apparatus. The back-scattered radiation is then analyzed by the oximeter apparatus to provide a measurement of oxygen saturation.

As the blood under test flows about the catheter tip, the amount of radiation returning therefrom exhibits pulsatile fluctuations synchronized with the heartbeat. It is believed that these fluctuations result from the catheter tip impacting or very closely approaching the vessel wall. Since the vessel wall exhibits reflective characteristics not necessarily related to blood oxygen saturation, these substantial fluctuations resulting in greatest part from the reflectance of the vessel wall can introduce inaccuracies into the measurement of blood oxygen.

Various techniques have been utilized in reducing or eliminating these substantial fluctuations. In one system, the time constant or span of the oxygen saturation measurement is increased to thereby decrease the influence that the substantial radiation fluctuations may have on the oxygen saturation calculation. However, this technique does not remove from the oxygen saturation measurement process the erroneous data represented by the substantial radiation fluctuations. Thus, the oxygen saturation calculation is based at least in part upon erroneous data, thereby adversely affecting the accuracy of the oxygen saturation measurement.

In another oximeter apparatus, the catheter tip is enclosed within a cage-type structure in an attempt to prevent the oximeter tip from impacting the vessel wall. While the cage structure may effectively separate the catheter tip from the vessel wall, the structure also greatly increases the tendency for deposits to form on the catheter tip, an undesirable result.

Disclosure of the Invention

The method and apparatus of the present invention overcomes the limitations described above and provides a signal filter which removes therefrom portions of the signal indicative of erroneous data. An exemplary signal filter method in accordance herewith may include the steps of receiving the signal, adjusting a threshhold value by increasing the threshhold a first predetermined amount when the signal is in a first predetermined relationship with the threshhold value and decreasing the threshhold a second predetermined amount when the signal is in a second predetermined relationship with the threshhold. The signal is then compared with the adjusted threshhold and transmitted if the signal bears a first predetermined relationship to the threshhold. In one embodiment of the present invention, adjusting the threshhold may include the steps of comparing the signal to a base line, adjusting the base line toward the signal, and then establishing the threshhold as related to the base line. Signal transmission may be inhibited or a predetermined output transmitted in place of the signal.

A signal filter apparatus in accordance with the present invention may include means for receiving the signal, means for adjusting a threshhold by increasing the threshhold a first predetermined amount when the signal is in a first predetermined relationship with the threshhold and for decreasing the threshhold a second predetermined amount when the signal is in a second predetermined relationship with the threshhold, and means for comparing the signal with the adjusted threshhold value and for transmitting the signal if the signal bears a first predetermined relationship to the threshhold. The means for adjusting the threshhold may further include means for comparing the signal to a base line, means for adjusting the base line toward the signal, and means for determining the threshhold related to the base line. The apparatus can also include means for inhibiting the signal or transmitting a predetermined output if the signal bears a second predetermined relationship to the threshhold value.

It is thus seen that an exemplary method and apparatus in accordance herewith removes from the signal those portions of the signal indicative of erroneous data.

Further, in accordance herewith, the signal filter method and apparatus may be incorporated within an oximeter method or apparatus to thereby provide an improved oximeter method and apparatus less susceptible to erroneous reflected radiation received at the catheter tip.

Thus, it is an object of the present invention to provide a signal filter.

It is another object of the present invention to provide an improved oximeter method and apparatus.

It is yet a further object of the present invention to provide an improved oximeter method and apparatus employing a signal filter.

Brief Description of the Drawings

These and other objects and advantages of the present invention are apparent from a consideration of the entire specification and the following drawings in which:

Figure 1 is a block diagram of an oxygen saturation measurement apparatus suitable for use with the signal filter of the present invention;

Figure 2 is an exemplary wave form depicting intensity fluctuations in radiation returning from a catheter tip;

Figure 3 is an exemplary flow diagram for implementing a signal filter in accordance with the present invention;

Figure 4 is a portion of Figure 1 of the Shaw, et al., patent referenced above modified for use with an alternative embodiment of the present invention;

Figure 5 is an alternative embodiment of the signal filter of the present invention adapted for use with the modified circuitry of Figure 4.

Best Mode for Carrying Out the Invention

With reference now to Figure 1, an oxygen saturation measuring apparatus 10, sometimes herein referred to as an oximeter or oximeter apparatus, is preferably a microprocessor bus-oriented system, a configuration which is well known to those skilled in the art. More particularly, the apparatus 10 includes a system bus 12 comprising a plurality of conductors for transmitting address, data, program and control information to various portions of the apparatus 10. The apparatus 10 is controlled by a central processor 14, which is connected to and substantially controls the system bus 12. In an exemplary embodiment, the central processor 14 is a type 6800 manufactured by Motorola Semiconductor Products, Inc.

The system bus 12 communicates with an optical module interface 16 which in turn is connected to an optical module 18. The interface 16 drives a plurality of light-emitting diodes (LEDs) 20, 22, and 24, which emit radiation at preselected wavelengths λ_1, λ_2 and λ_3 respectively. This radiation is collected by fiberoptic guides 26, 28, and 30, which conduct the radiation emitted by the diodes 20-24 to an optical combiner 32. The optical combiner 32 in turn transmits radiation through an end cross-section 34 to an optical integrator 36. A transmitting fiberoptic guide 38 is coupled to the exit aperture 40 of the optical integrator 36 and the fiberoptic guide 38 consequently transmits radiation through a catheter 42 to an aperture within a distal tip 44 of the catheter 42. The catheter tip 44 is disposed within a blood vessel and the blood under test flows through the vessel and about the tip 44.

The radiation emitted from the fiberoptic guide 38 is back-scattered by the blood under test and is reflected by the vessel walls. This back-scattered and reflected radiation is then received through a second aperture within the catheter tip 44 by a second fiberoptic guide 46. The fiberoptic guide 46 transmits this radiation to a detector 48 which provides a signal proportional thereto to the optical module interface 16.

With continued reference to Figure 1, the apparatus 10 further includes various displays 48 responsive to the system bus 12. Furthermore, the system bus 12 is connected to an alarm and output circuit 50 which may provide an audio alert tone for the operator of the apparatus 10, nurse call signals and a suitable auxiliary analog output for driving ancillary equipment. A keyboard and control switches 52 is connected to the system bus 12 and also is directly connected to a recorder 54 and to a power supply 56. The recorder 54 is also responsive to the system bus 12 to produce a permanent strip chart record of the blood oxygen saturation as measured by the apparatus 10. The power supply 56 provides power throughout the apparatus 10.

The central processor 14, through the system bus 12, communicates with a memory 58 which may include program instructions for the central processor 14 in read-only memory (ROM) and which may further include temporary or scratch-pad random-access memory (RAM) for use by the central processor 14 during the operation of the apparatus 10.

In operation, the apparatus 10 is controlled by the keyboard and switches 52 to energize the power supply 56. The optical module interface 16 sequentially energizes the diodes 20-24 to sequentially provide radiation at the three preselected wavelengths λ_1, λ_2 and λ_3 via the catheter 42 to the catheter tip 44. Upon back-scattering by the blood under test and transmission via the catheter 42 to the detector 48, the optical module interface 16 converts the analog signal from the detector 48 indicative of radiation intensity into a digital signal which in the embodiment of Figure 1 may be 12 bits. This digital signal is then applied through the system bus 12 as controlled by the central processor 14 and is stored into the memory 58.

The central processor 14 subsequently uses this data stored in the memory 58 to calculate the blood oxygen saturation. For example, the central processor 14 may implement equation 8 from the referenced Shaw, et al., patent, which is as follows:

$$OS = \frac{A_0 + A_1 \left(\frac{I_1}{I_2}\right) + A_2 \left(\frac{I_1}{I_2}\right) + A_3 \left(\frac{I_3}{I_2}\right)}{B_0 + B_1 \left(\frac{I_1}{I_2}\right) + B_2 \left(\frac{I_1}{I_2}\right)^2 + B_3 \left(\frac{I_3}{I_2}\right)}$$

where A_0, A_1, A_2 and A_3 are weighting factors or coefficients, B_0, B_1, B_2 and B_3 are weighting factors or coefficients, and I_1, I_2, and I_3 are radiation intensities from the blood under test measured at wavelengths λ_1, λ_2, and λ_3, respectively, each normalized with respect to a reference light intensity measurement. Once the calculation is completed, the central processor 14 provides the resulting oxygen saturation (OS) value to the displays 48, and if enabled, to the recorder 54. If the central processor 14 detects that an alarm condition exists, the alarm and output circuit 50 generates an audio alarm tone or a nurse call signal.

It will be understood by those skilled in the art that the apparatus of Figure 1 is generally a digital implementation of the catheter oximeter apparatus and method which is disclosed in the referenced Shaw, et al., patent. Such a microprocessor-based bus-oriented system will be readily apparent to one skilled in the art. Moreover, other than three radiation intensities may be used which can provide an oxygen saturation measurement through other suitable mathematical relationships.

With reference now to Figure 2, an intensity curve 58 of the back-scattered and reflected radiation from, for example, LED 24 operating at wavelength λ_3, includes pulsatile fluctuations 60a-60d synchronized with the patient's heartbeat. Although the λ_3 intensity curve 58 is indicated by a continuous line, it is to be understood that the λ_3 intensity as detected by the detector 48 in the exemplary embodiment of Figure 1 is a series of individual intensity measurements which, when plotted together, form the λ_3 intensity curve 58 of Figure 2. The pulsatile fluctuations 60a-60d, if of sufficient magnitude, represent erroneous or unsuitable reflected radiation intensities which typically result from the catheter tip 44 impacting or very closely approaching the vessel walls as the catheter tip 44 is moved about within the vessel during a heartbeat. The λ_3 intensity shown in Figure 2 is converted by the optical module interface 16 of Figure 1 into a corresponding digital value which may then be utilized by the central processor 14 as is described below.

Turning now to Figure 3, a signal filter method flow diagram as shown therein implemented within the apparatus 10 of Figure 1 advantageously removes from the signals the portions thereof which are indicative of erroneous or unsuitable radiation readings. More particularly, and with continued reference to Figures 1 and 3, the central processor 14 reads from the system bus 12 the radiation intensities from the catheter tip at, for example, approximately four millisecond intervals and the control processor 14 sums each of the radiation intensities individually for a period of time which can be approximately 32 milliseconds. This initially averages the individual radiation intensities and thus slightly smoothes radiation intensities I_1, I_2 and I_3. The central processor 14 then compares the intensity I_3 with a base line intensity value which may be temporarily stored within the memory 58.

If the intensity I_3 is not greater than the base line intensity value, the central processor 14 decreases the base line value according to the following equation:

$$BL = BL - K_1 \cdot (BL - I_3)$$

where BL is the base line intensity value and K_1 is a predetermined constant which can equal approximately 0.25 in an exemplary embodiment.

Once the new base line intensity value is determined, a threshhold intensity value is determined wherein $TH = K_4 \cdot BL$, where TH is the threshhold intensity value and K_4 is a predetermined constant which can equal, for example, approximately 1.5. Once the threshhold intensity value TH is calculated, the λ_3 intensity I_3 is compared with the threshhold intensity value. If the intensity I_3 is not greater than the threshhold intensity value, then the intensities I_1, I_2, and I_3 are stored by the central processor 14 into the memory 58. In the embodiment of Figure 1, each intensity I_1, I_2, and I_3 is stored into the memory 58 and may further be separately accumulated to each form a weighted moving average for the respective wavelengths with a period of approximately five seconds.

However, if the intensity I_3 is greater than the threshhold intensity value, then the central processor 14 sets each intensity I_1, I_2 and I_3 to zero and stores these zero values into memory as part of the aforementioned weighted moving averages. It is to be noted that because equation 8 referred to above from the referenced Shaw, et al., patent is based on ratios of reflected radiation intensities, the accumulation of zero individual radiation intensity values I_1, I_2, and I_3 has no influence on the ultimately calculated blood oxygen saturation.

With continued reference to Figures 1 and 3, if the central processor 14 determines that the intensity I_3 is greater than the base line intensity value, the central processor 14 then determines whether the intensity I_3 has been greater than the base line intensity value for a predetermined time period which can be approximately five seconds, although other time lengths may be suitably selected. This may be accomplished, for example, by programming the central processor 14 to measure a time interval in a fashion which is well known to those skilled in the art. If the intensity I_3 has not been greater than the base line intensity value for the five second time period, then the central processor 14 determines a new base line intensity value according to $BL = (1 + K_2) \cdot BL$, where K_2 is a predetermined constant that can be, for example, approximately 0.004. The new base line intensity value is then used to calculate a new threshhold intensity value which is compared to the intensity I_3 as described above.

If, however, the intensity I_3 has been greater than the base line intensity value for the predetermined time period, then the base line intensity value is increased so that $BL = (1 + K_3) \cdot BL$, where K_3 is a predetermined constant that can have an exemplary value of approximately 0.120. Once the base line intensity value has been adjusted in this way, then the threshhold intensity value is again determined and the remaining steps are performed by the central processor 14 as described above.

Thus, it is apparent that the method of Figure 3 as implemented by the apparatus 10 of Figure 1 adjusts a base line intensity value which generally follows the low-level portions of the λ_3 intensity I_3. As seen in Figure 2, the λ_3 intensity I_3 plotted as the curve 58 thus may be thought to generally ride along or in relatively close proximity to a base line intensity value represented by a curve 62. The base line intensity value is continually updated in order to maintain this relationship. If the λ_3 intensity 58 is not greater than the base line intensity value 62, the base line is gradually decreased. On the other hand, if the λ_3 intensity 58 is greater than the base line intensity value 62, then the base line intensity value is increased by an amount related to the length of time that the λ_3 intensity has exceeded the base line intensity value. More particularly, if the λ_3 intensity 58 has been greater than the base line intensity value for not longer than the predetermined time period, then the base line intensity value is slightly increased for each λ_3 intensity comparison. However, if the λ_3 intensity I_3 has been greater than the base line intensity value for longer than the predetermined time period, then the base line intensity value is increased relatively quickly with respect to the previous base line intensity value to thereby quickly adjust the base line intensity value with respect to the λ_3 intensity.

Once the base line intensity value is adjusted in this way, then the threshhold intensity value represented by the dashed line 64 in Figure 2 is determined with respect to the base line intensity value. If the λ_3 intensity 58 is greater than the threshhold intensity value 64, the λ_1, λ_2 and λ_3 intensities I_1, I_2 and I_3 are set to zero and are then stored into the memory 58 as part of a moving average accumulation. Conversely, if the λ_3 intensity is not greater than the threshhold intensity value, then the λ_1, λ_2 and λ_3 intensities read by the central processor 14 from the optical module interface 16 are then stored into the memory 58 as part of the moving average accumulation. In this way, the threshhold intensity value determines the level above which the λ_3 intensity I_3 in particular and the associated λ_1 and λ_2 intensities I_1 and I_2 are presumed to be invalid. The moving average values for the intensities I_1, I_2 and I_3 are then used to determine oxygen saturation as described above.

It is to be understood that the predetermined constants K_1 - K_4 can be varied according to the particular system requirements. Moreover, the adjustments to the base line intensity value can be fixed rather than related to the constants K_1 - K_3 which will be readily apparent to those skilled in the art. It will be further apparent that the base line intensity value BL can be written in terms of the threshhold intensity value TH and the threshhold intensity value TH can therefore be considered to be adjusted directly with respect to the intensity I_3.

Thus, the signal filter method of Figure 3 and the apparatus 10 of Figure 1 provide an improved oximeter apparatus less susceptible to the pulsatile reflected radiation intensities indicative of erroneous or unuseable data. The steps set forth in Figure 3 can, of course, be implemented using well-known software techniques with the central processor 14.

With reference now to Figures 4 and 5, the apparatus disclosed in the referenced Shaw, et al., patent may be modified to incorporate the signal filter in accordance with the present invention.

As shown in Figure 4, such an apparatus includes a repetitive pulse generator 66 which sequentially energizes a plurality of light-emitting diodes (LED's) 68, 70 and 72. The LEDs 68, 70 and 72 are coupled through a suitable optical combiner, optical integrator, and catheter as, for example, shown in Figure 1, to provide to a detector 72 back-scattered and reflected radiation from the catheter tip. The LEDs 68, 70 and 72 emit radiation at three predetermined wavelengths λ_1, λ_2 and λ_3 as previously described above with reference to Figure 1.

The detector 74 provides a signal representative of the radiation from the catheter tip to an amplifier 76, the output of which is connected to a plurality of normally open switches 78, 80, 82, 84 and 86 (Figs. 4 and 5). The switches 78 and 80 are controlled by the generator 66 so as to be closed during the time that the LEDs 68 and 70, respectively, emit radiation. Similarly, the switches 82 and 84 are controlled by the generator 66 so as to be closed during the portion of time that the LED 72 emits radiation. Lastly, the switch 86, as controlled by the generator 66, is closed when none of the LEDs 68-72 is emitting, thus forming a closed loop servo system between the amplifier 76 and an amplifier 88 which establishes a bias voltage on the amplifier 76 that adjusts its output voltage to zero.

The switches 78-82 are in turn connected to normally closed switches 90-94 respectively. The switch 90 is connected through a resistor 96 to an amplifier 98 and a capacitor 100. Similarly, the switches 92 and 94 are connected through resistors 102 and 104 to amplifiers 106 and 108 and to capacitors 110 and 112. The amplifiers 98, 106 and 108 provide λ_1, λ_2 and λ_3 radiation intensity output signals I_1, I_2 and I_3, respectively.

As shown with reference to Figure 5, the switch 84 connects the signal from the amplifier 76 to signal filter circuitry designated generally 114. The switch 84 is connected through a resistor 116 to an amplifier 118 and a capacitor 120. The output of the amplifier 118 is connected to the anode of a diode 122, the cathode of which is connected through a resistor 124 via a line 142 to a first current source 126, a switch 128, a capacitor 130, an amplifier 132 and a comparator 134. The output of the amplifier 118 is also connected to a second input of the comparator 134. The output of the comparator 134 controls a timer 136 which in turn controls the switch 128. The switch 128 is also connected to a second current source 138. The output of the amplifier 132 is connected through a line 144 to the inverting input of a comparator 140, the non-inverting input of which is connected to the output of the amplifier 118. The output of the comparator controls the position of the switches 90, 92 and 94.

In operation, when the LED 72 emits radiation and the switches 82 and 84 are closed, the radiation from the catheter is detected by the detector 74. The detector 74 output is amplified by the amplifier 76 which applies a signal through the switch 84 to the amplifier 118. The current source 126 continuously provides current to the line 142 the signal on this line being proportional to a base line intensity value (BL), hereinafter referred to as a base line signal. The current source 126 increases the base line signal by a predetermined amount with respect to time, that is to say, at a predetermined rate. This base line signal is scaled or multiplied by the amplifier 132 to provide a threshhold signal (TH) on the line 144 to the comparator 140.

When the output of the amplifier 118 is less than the base line signal on the line 142, the capacitor 130 discharges through the resistor 124 and the diode 122 to thus decrease the base line signal on the line 142 and in turn proportionally decrease the threshhold signal on the line 144. If the output of the amplifier 118 is greater than the base line signal, however, then the current source 126 provides a first current to the line 142 to thereby increase the base line signal. Furthermore, if the output of the amplifier 118 is greater than the threshhold signal on the line 144, then the comparator 140 controls the switches 90-94 (Fig. 4) to connect the resistors 96, 102 and 104 to ground to thereby disable the further application of the signal from the amplifier 76 through the switches 78, 80 and 82. In this way, if the radiation intensity I_3 is greater than the threshhold signal on the line 144, indicating that erroneous radiation information is returning from the catheter, the signals proportional to the radiation intensities I_1, I_2 and I_3 are removed from the inputs to the amplifiers 98, 106 and 108.

If the output of the amplifier 118 remains less than the base line signal for more than five seconds, the comparator 134 and the timer 136 control the switch 128 to connect the second current source 138 to the line 142. The second current source 138 provides a fixed current to the line 142 which relatively quickly increases the base line signal thereon. As with the current source 126, the current source 126 increases the base line signal by a predetermined amount with respect to time, which is to say, at a predetermined rate.

Thus it is seen that the signal filter circuitry 114, in accordance with the present invention, provides a base line signal which generally follows the low-level portions of the radiation intensity I_3. A threshhold signal is provided which is related to the base line signal, and if the radiation intensity I_3 is greater than this threshhold signal, then the signals corresponding to the radiation intensities I_1, I_2 and I_3 are not applied to the respective amplifiers 98, 106 and 108. It is to be further noted that the circuitry 114 provides an analog implementation of the signal filter method of Figure 3.

Having thus described one embodiment of our invention in detail, it is to be understood that numerous equivalents and alterations which do not depart from the invention will be apparent to those skilled in the art, given the teachings herein. Thus, our invention is not to be limited to the above description but is to be of the full scope of the appended claims.

Claims

1. A method for filtering a signal to remove therefrom portions of the signal indicative of erroneous data, including the steps of

receiving the signal,

adjusting a threshhold by increasing the threshhold a first predetermined amount when the signal is in a first predetermined relationship with the threshhold and decreasing the threshhold a second predetermined amount when the signal is in a second predetermined relationship with the threshhold,

comparing the signal with the adjusted threshhold, and

transmitting the signal if the signal bears a first predetermined relationship to the threshhold.

2. A method as in Claim 1 wherein the adjusting step includes

varying a base line by a predetermined amount to adjust the base line toward the signal, and

determining the threshhold related to the base line.

3. A method as in Claim 2 wherein said varying step includes increasing the base line by a first predetermined amount when the signal is greater than the base line and decreasing the base line by a second predetermined amount when the signal is less than the base line.

4. A method as in Claim 3 wherein said first predetermined amount is varied in accordance with the length of time that said signal is greater than said base line.

5. A method for filtering a signal to remove therefrom portions of the signal indicative of erroneous data, including the steps of

receiving the signal,

varying a base line representation by a predetermined amount to adjust the base line representation toward the signal,

determining a threshhold representation related to the base line representation,

comparing the signal with the threshhold representation,

transmitting the signal if the signal bears a first predetermined relationship to the threshhold representation, and

transmitting a predetermined output if the signal bears a second predetermined relationship to the threshhold representation to thereby remove from the signal portions thereof indicative of erroneous data.

6. A method as in Claim 5 wherein the varying step is performed at a predetermined rate.

7. A method for filtering a signal to remove therefrom portions of the signal indicative of erroneous data, including the steps of

receiving the signal,

comparing the signal to a base line representation,

increasing the base line representation by a predetermined amount when the signal is greater than the base line representation,

decreasing the base line representation by a predetermined amount proportional to the difference between the base line representation and the signal when the signal is less than the base line representation,

determining a threshhold representation related to the base line representation by a predetermined ratio,

comparing the signal to the threshhold representation,

transmitting the signal if the signal bears a first predetermined relationship to the threshhold representation, and

transmitting a predetermined output if the signal bears a second predetermined relationship to the threshhold representation to thereby remove from the signal portions thereof indicative of erroneous data.

8. An apparatus for filtering a signal to remove therefrom portions of the signal indicative of erroneous data including

means for receiving the signal,

first means responsive to the received signal for adjusting a threshhold by increasing the threshhold a first predetermined amount when the signal is in a first predetermined relationship with the threshhold and decreasing the threshhold a second predetermined amount when the signal is in a second predetermined relationship with the threshhold,

second means responsive to the received signal and responsive to the adjusted threshhold for comparing the signal with the adjusted threshhold and for transmitting the signal if the signal bears a first predetermined relationship to the threshhold.

9. An apparatus for filtering a signal to remove therefrom portions of the signal indicative of erroneous data, including

means for receiving the signal,

first means responsive to the received signal for varying a base line representation by a predetermined amount to adjust the base line representation toward the signal,

second means responsive to the base line representation for determining a threshhold representation related to the base line representation,

third means responsive to the received signal and to the threshhold representation for comparing the signal to the threshhold representation and for transmitting the signal if the signal bears a first predetermined relationship to the threshhold representation.

10. An apparatus as in Claim 9 wherein the first means further includes means for increasing the base line representation by a first predetermined amount when the signal is greater than the base line representation and for decreasing the base line representation by a second predetermined amount when the signal is less than the base line representation.

11. An apparatus as in Claim 10 wherein said first predetermined amount is varied in accordance with the length of time that the signal is greater than the base line representation.

12. An apparatus for filtering a signal to remove therefrom portions of the signal indicative of erroneous data including

means for receiving the signal,

first means responsive to the received signal for comparing the signal to a base line representation,

second means responsive to the first means for increasing the base line representation by a first predetermined amount when the signal is greater than the base line representation and for increasing the base line representation by a second predetermined amount when the signal is greater than the base line representation for a predetermined time period,

third means responsive to the first means for decreasing the base line representation by a predetermined amount proportional to the difference between the base line representation and the signal when the signal is less than the base line representation,

fourth means responsive to the base line representation for determining a threshhold representation related to the base line representation,

fifth means responsive to the received signal and to the threshhold representation for comparing the signal to the threshhold,

output means responsive to the received signal for providing an output of the signal representation when the signal bears a first predetermined relationship to the threshhold representation and for providing an output of a second signal when the first mentioned signal bears a second predetermined relationship to the threshhold representation, said threshhold representation thereby determining the portions of the first mentioned signal which are indicative of erroneous data.

13. In a method of determining oxygen saturation of blood comprising the steps of

producing electro-magnetic radiation at a plurality of different wavebands,

coupling the radiation of the wavebands to blood under test,

detecting radiation at each of the wavebands received back from the blood under test for producing a corresponding electrical signal representative of the intensity of the radiation received back from the blood under test at the respective waveband, and

providing an output manifestation of oxygen saturation according to the relationship between the electrical signals;

a method for filtering the electrical signals for removing therefrom portions of the signal indicative of erroneous data, including the steps of

selecting one of the aforementioned electrical signals,

adjusting a threshhold representation by increasing the threshhold representation a first predetermined amount when the selected signal is in a first predetermined relationship with the threshhold representation and decreasing the threshhold representation a second predetermined amount when the selected signal is in a second predetermined relationship with the threshhold representation,

comparing the selected electrical signal with the adjusted threshhold representation, and

performing the aforementioned providing step when the selected electrical signal bears a first predetermined relationship to the threshhold representation.

14. A method as in Claim 13 wherein the adjusting step includes varying a base line representation by a predetermined amount to adjust the base line representation toward the selected signal, and determining the threshhold representation related to the base line representation.

15. A method as in Claim 14 wherein the varying step includes increasing the base line representation by a first predetermined amount when the selected signal is greater than the base line representation and decreasing the base line representation by second predetermined amount when the selected signal is less than the base line representation.

16. A method as in Claim 15 wherein the first predetermined amount is varied in accordance with the length of time that the selected signal is greater than the base line representation.

17. In a method for determining oxygen saturation of blood comprising the steps of

producing electro-magnetic radiation at a plurality of different wavebands,

coupling the radiation of the wavebands to blood under test,

detecting radiation at each of the wavebands received back from the blood under test for producing a corresponding electrical signal representative of the intensity of the radiation received from the blood under test at the respective waveband, and

providing an output manifestation of oxygen saturation according to the relationship between the electrical signals;

a method for filtering the electrical signals to remove therefrom portions of the signals indicative of erroneous data, including the steps of

selecting one of the aforementioned electrical signals,

varying a base line representation by a predetermined amount to adjust the base line representation toward the signal,

determining a threshhold representation related to the base line representation,

comparing the selected signal with the threshhold representation,

providing a first output comprising the aforementioned electrical signals if the selected electrical signal bears a first predetermined relationship with the threshhold representation,

providing a second output comprising predetermined electrical signals if the selected electrical signal bears a second predetermined relationship with the threshhold representation,

summing the first output and the second outputs to provide summed electrical signals for the respective wavebands, and

producing the aforementioned output manifestation of oxygen saturation according to the relationship between the summed electrical signals.

18. A method as in Claim 17 wherein the varying step is performed at a predetermined rate.

19. A method of determining oxygen saturation of blood comprising the steps of

producing electro-magnetic radiation at a plurality of different wavebands,

coupling the radiation of the wavebands to blood under test, detecting radiation at each of the wavebands received back from the blood under test for producing a corresponding electrical signal representative of the intensity of the radiation received back from the blood under test at the respective waveband,

selecting one of the aforementioned electrical signals,

comparing the selected electrical signal to a base line signal,

increasing the base line signal by a predetermined amount proportional to the base line signal when the selected electrical signal is greater than the base line signal,

decreasing the base line signal by a predetermined amount proportional to the difference between the base line signal and the selected electrical signal when the selected electrical signal is less than the base line signal,

determining a threshhold signal related to the base line signal by a predetermined ratio,

comparing the selected electrical signal with the adjusted threshhold signal,

providing a first output comprising the aforementioned electrical signals when the selected electrical signal bears a first predetermined relationship with the threshhold signal,

providing a second output comprising predetermined electrical signals when the selected electrical signal bears a second predetermined relationship with the threshhold signal,

summing the first output and the second output to provide a summed electrical signal for each respective waveband, and

providing an output manifestation of oxygen saturation according to a relationship between the summed electrical signals.

20. A method as in Claim 19 wherein the signals are digital.

21. A method as in Claim 19 wherein the signals are analog.

22. In an apparatus for determining oxygen saturation of blood comprising

source means for producing electro-magnetic radiation at a plurality of wavelengths,

means adapted to be coupled to the source means for supplying the radiation therefrom to blood under test with incident intensities at the respective wavelengths,

detector means adapted to receive radiation back from the blood under test for producing signals representative of the intensities of the radiation received thereby at the respective wavelengths, and

determining means responsive to the detector means for receiving the signals therefrom and for determining an output manifestation of oxygen saturation according to the relationship between the signals;

an apparatus for filtering the signals to remove therefrom portions of the signals indicative of erroneous data, including

first means responsive to a selected one of said signals for adjusting a threshhold representation by increasing the threshhold representation a first predetermined amount when the selected signal is in a first predetermined relationship with the threshhold representation and for decreasing the threshhold representation a second predetermined amount when the selected signal is in a second predetermined relationship with the threshhold representation,

second means responsive to the selected signal and responsive to the adjusted threshhold representation for comparing the selected signal with the adjusted threshhold, and

said detecting means being responsive to the second means for determining the aforementioned output manifestation when the selected signal bears a first predetermined relationship to the threshhold representation.

23. In an apparatus for determining oxygen saturation of blood comprising

source means for producing electro-magnetic radiation at a plurality of wavelengths,

means adapted to be coupled to the source means for supplying the radiation therefrom to blood under test with incident intensities at the respective wavelengths,

detector means adapted to receive radiation back from the blood under test for producing signals representative of the intensities of the radiation received thereby at the respective wavelengths, and

determining means responsive to the detector means for determining an output manifestation of oxygen saturation according to the relationship between the signals;

an apparatus for filtering the signals to remove therefrom portions of the signals indicative of erroneous data, including first means responsive to at least a selected one of said signals for varying a base line representation by a predetermined amount to adjust the base line representation toward the selected signal,

second means responsive to the base line representation for determining a threshhold representation related to the base line representation,

third means responsive to the selected signal and to the threshhold representation for comparing the selected signal to the threshhold representation, and

said determining means being responsive to the third means for determining the aforementioned output manifestation when the selected signal bears a first predetermined relationship to the threshhold representation.

24. An apparatus as in Claim 23 wherein the first means further includes means for increasing the base line representation by a first predetermined amount when the selected signal is greater than the base line representation and for decreasing the base line representation by a second predetermined amount when the selected signal is less than the base line representation.

25. An apparatus as in Claim 24 wherein the first predetermined amount is varied in accordance with the length of time that the selected signal is greater than the base line representation.

26. An apparatus for determining oxygen saturation of blood comprising

source means for producing electro-magnetic radiation at a plurality of wavelengths,

means adapted to be coupled to the source means for supplying the radiation therefrom to blood under test with incident intensities at the respective wavelengths,

detector means adapted to receive radiation back from the blood under test for producing signals representative of the intensities of the radiation received thereby at the respective wavelengths,

first means responsive to a selected one of said signals for comparing the selected signal to a base line representation,

second means responsive to the first means for increasing the base line representation by a first predetermined amount when the selected signal is greater than the base line representation and for increasing the base line representation by a second predetermined amount when the selected signal is greater than the base line representation for a predetermined time period,

third means responsive to the first means for decreasing the base line representation by a predetermined amount proportional to the difference between the base line representation and the signal when the signal is less than the base line representation,

fourth means responsive to the base line representation for determining a threshhold representation related to the base line representation by a predetermined ratio,

fifth means responsive to the selected signal and to threshhold representation for comparing the selected signal to the threshhold representation,

output means responsive to the selected signal for providing a first output comprising the aforementioned signals when the selected signal bears a first predetermined relationship with the threshhold representation and for providing a second output comprising second signals if the selected electrical signal bears a second predetermined relationship with the threshhold representation,

summing means responsive to the first output and the second output for summing the first output and the second output to provide a summed signal for each respective waveband, and

determining means responsive to the summed signals for determining an output manifestation of oxygen saturation according to the relationship between the signals.

27. An apparatus as in Claim 26 wherein the base line representation and the threshhold representation are digital signals.

28. An apparatus as in Claim 26 wherein the base line representation and the threshhold representation are analog signals.

29. An apparatus as in Claim 26 wherein the second means and the third means adjust the base line representation at predetermined rates.

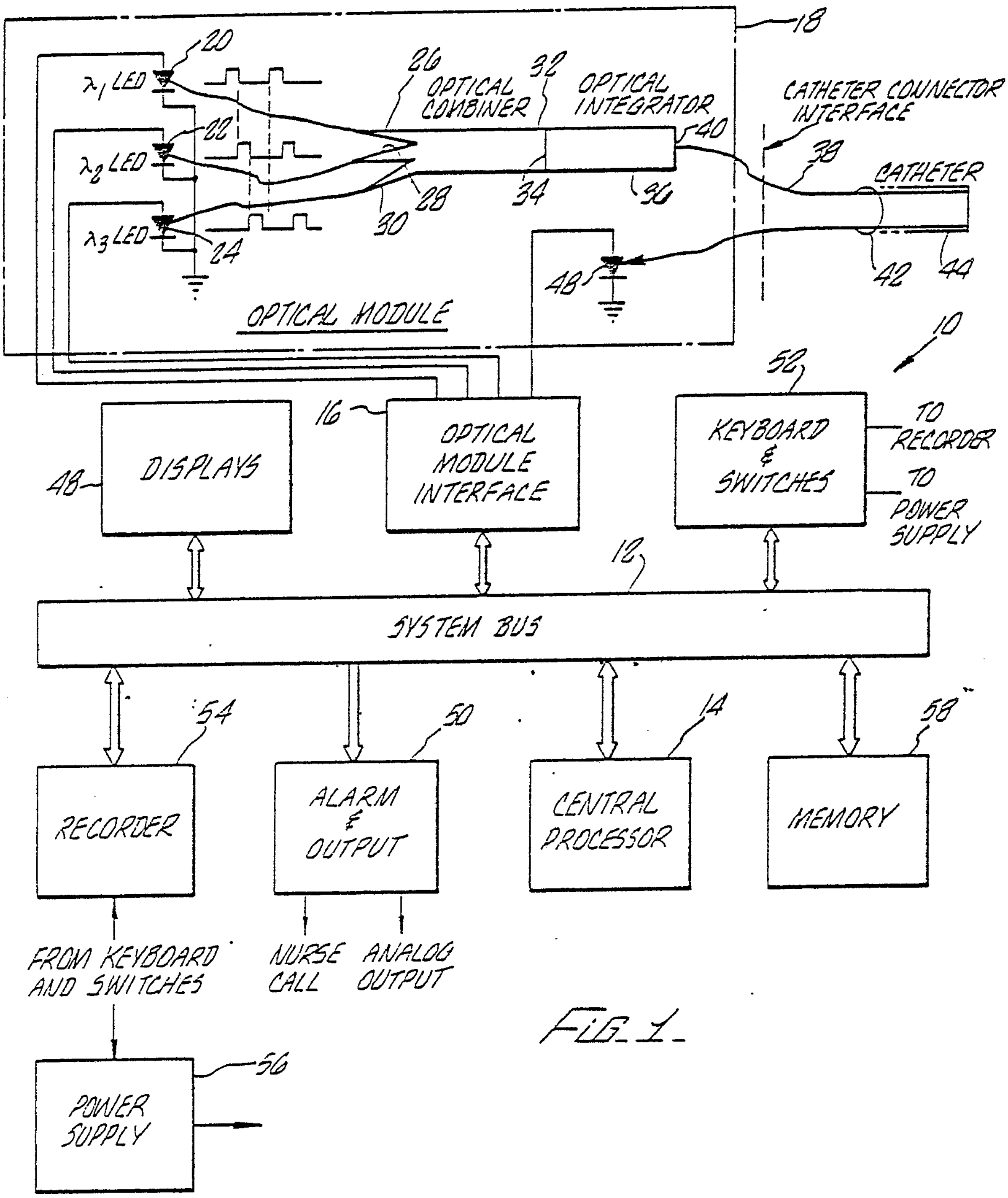

FIG. 1

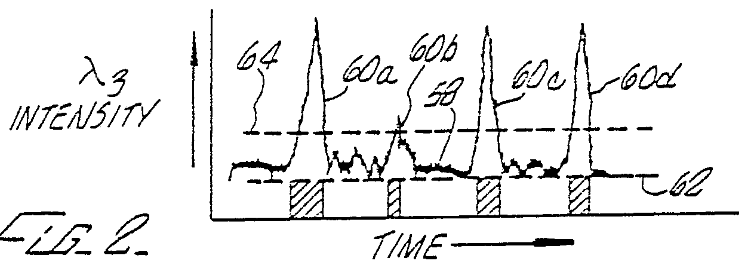

FIG. 2

SUBSTITUTE SHEET

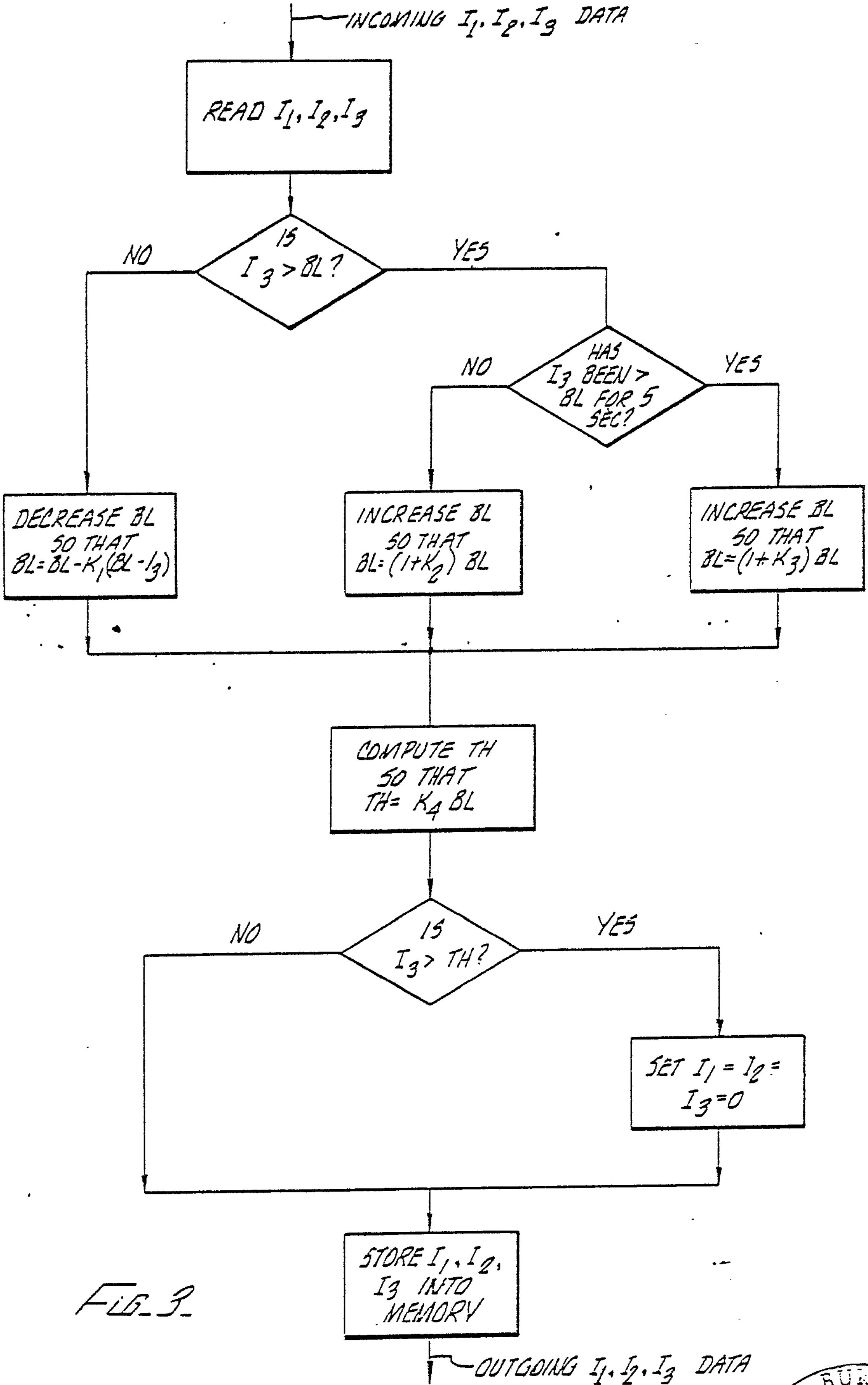
INCOMING I_1, I_2, I_3 DATA
READ I_1, I_2, I_3
IS I_3 > BL?
NO
YES
HAS I_3 BEEN > BL FOR 5 SEC?
NO
YES
DECREASE BL SO THAT $BL = BL - K_1(BL - I_3)$
INCREASE BL SO THAT $BL = (1+K_2)$ BL
INCREASE BL SO THAT $BL = (1+K_3)$ BL
COMPUTE TH SO THAT $TH = K_4$ BL
IS I_3 > TH?
NO
YES
SET $I_1 = I_2 = I_3 = 0$
STORE I_1, I_2, I_3 INTO MEMORY
OUTGOING I_1, I_2, I_3 DATA

FIG_3_

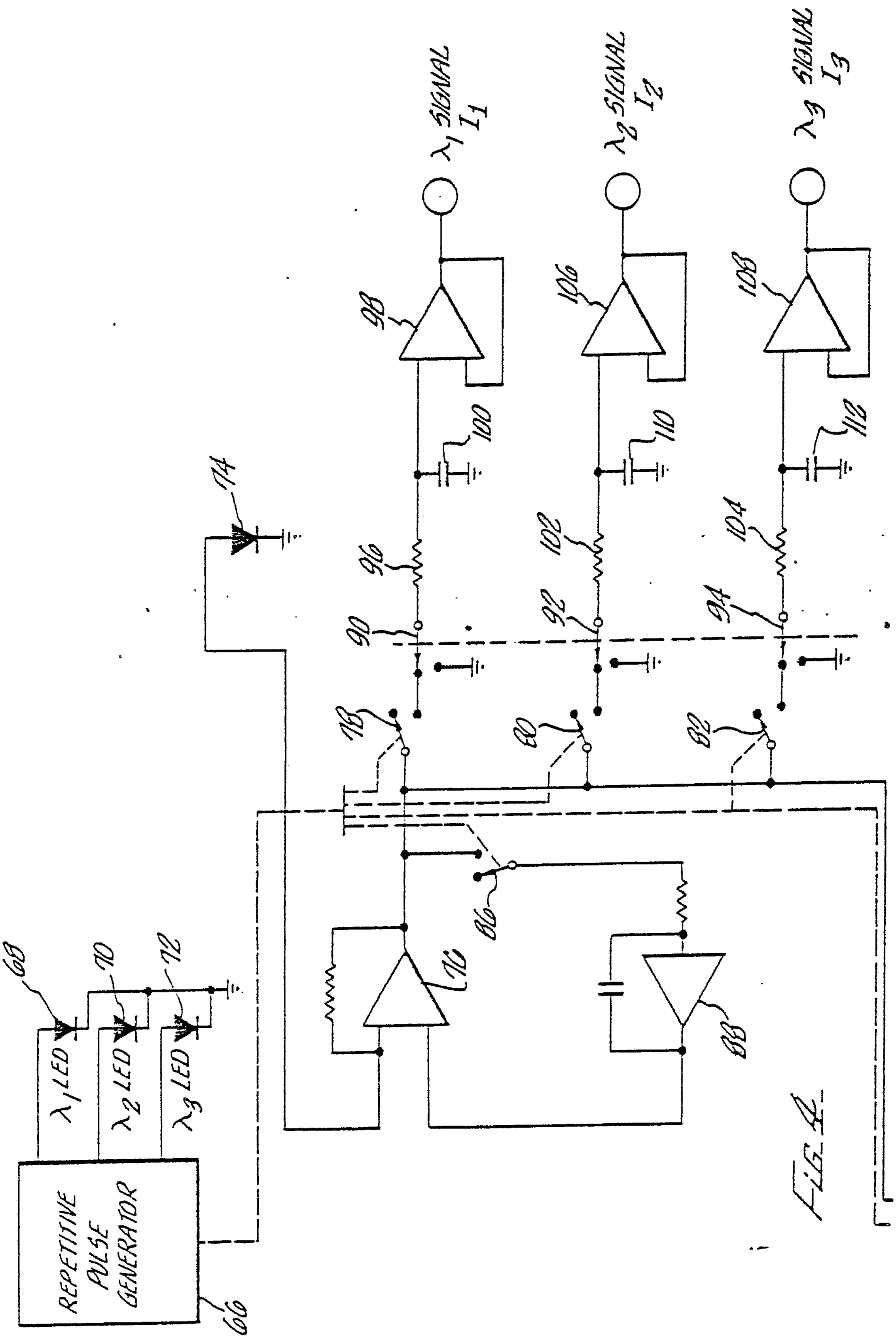
λ1 SIGNAL I1
λ2 SIGNAL I2
λ3 SIGNAL I3
98
106
108
100
110
112
96
102
104
90
92
94
74
78
80
82
86
76
88
68
70
72
λ1 LED
λ2 LED
λ3 LED
REPETITIVE PULSE GENERATOR
66

FIG. 4

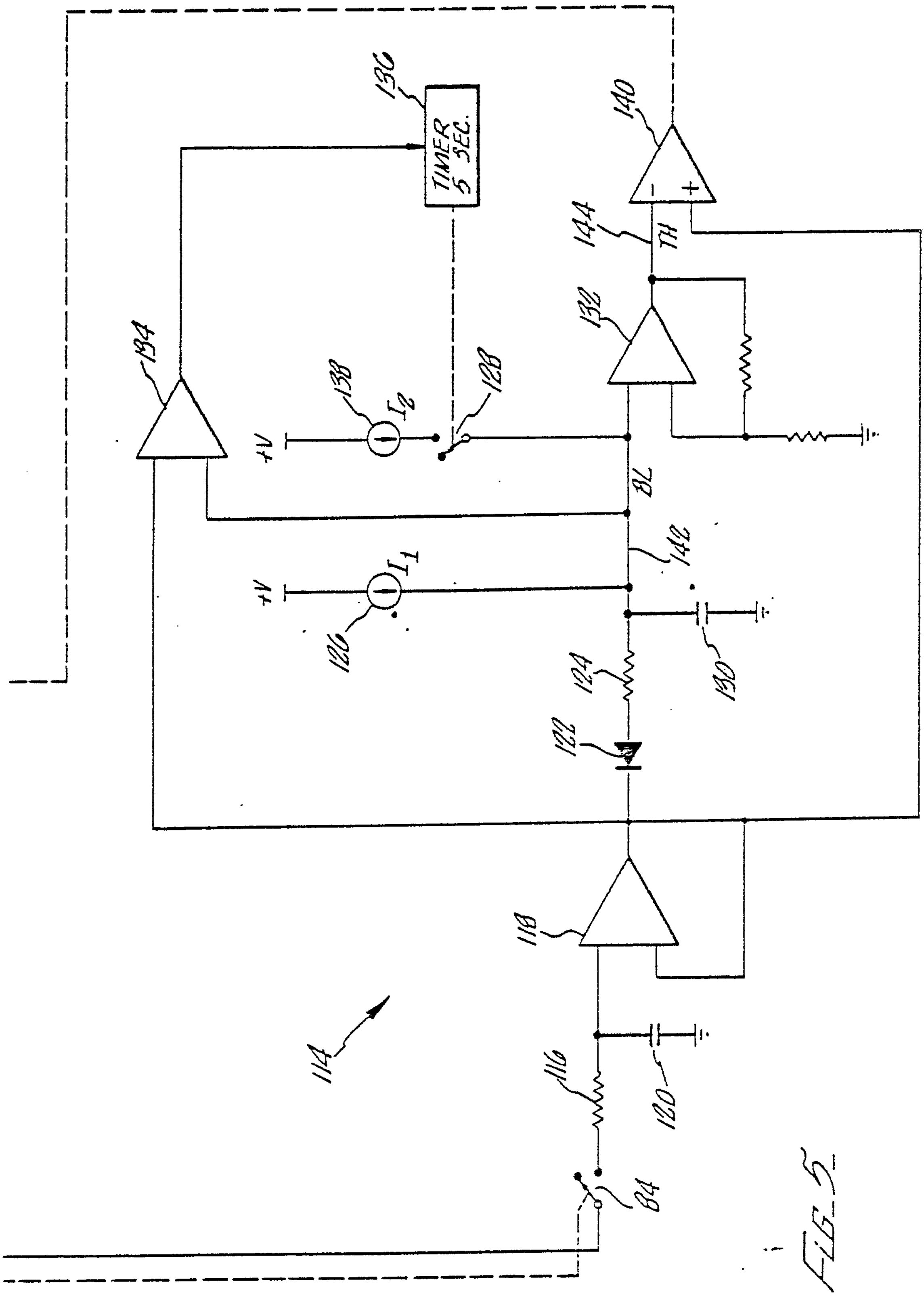
TIMER
5 SEC.
136
140
144
TH
134
138
I_2
128
132
+V
BL
142
I_1
126
124
122
130
118
116
120
114
84

FIG 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 81/01551

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT.CL[3] G06F 15/04,15/20; G01N 33/48
U.S. CL. 364/572

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	364/416,417,574,724 356/41 128/634,696 328/149,167 307/356,360,543,555

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 4,175,256, Published 20 Nov. 1979, Dolikian	1, 8
X	US, A, 3,848,586, Published 19 Nov. 1974, Suxuki, et al	1, 8
A,P	US, A, 4,266,554, Published 12 May 1981, Hamaguri	1-29
A	US, A, 4,167,331, Published 11 Sept. 1979, Nielsen	1-29
A	US, A, 4,161,945, Published 24 July 1979, Grossman	1-29
A	US, A, 4,109,643, Published 29 August 1978, Bond, et al	1-29
A	US, A, 4,035,734, Published 12 July 1977, Flormann, et al	1-29
A	US, A, 4,021,653, Published 3 May 1977, Sharp, et al	1-29
A	US, A, 3,999,084, Published 21 Dec. 1976,	1-29

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
18 January 1982	21 JAN 1982
International Searching Authority [1]	**Signature of Authorized Officer [10]**
ISA/US	Edward J. Wise

Form PCT/ISA/210 (second sheet) (October 1977)

BAD ORIGINAL

International Application No. PCT/US 81 / 01551

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

	Beaudette	
A	US,A, 3,955,101, Published 4 May 1976, Amelio, et al	1-29
A	US, A, 3,894,222, Published 8 July 1975, Siems	1-29

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers ______, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.