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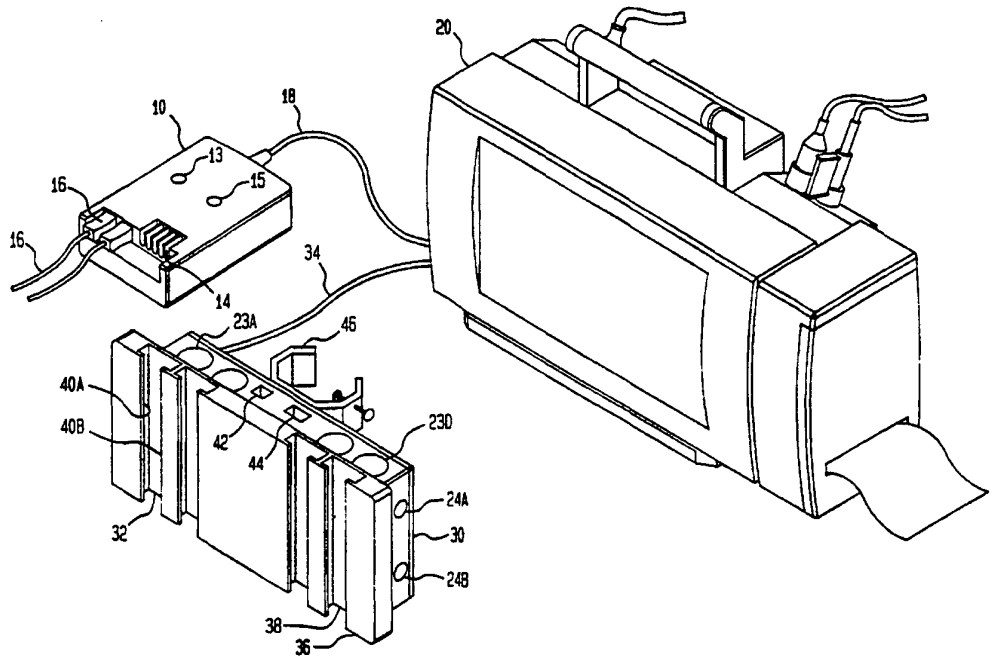


(57) **Abstract**

A self contained, independently positionable data acquisition pod (10) collects a plurality of analog data representing electrocardiogram (ECG) signals, blood oxygen saturation and either one of temperature or cardiac output. Data representing Electroencephalogram (EEG), blood pressure and blood carbon dioxide partial pressure may also be collected. The data acquisition pod (10) includes lines (16) for receiving the analog data signals from a plurality of sensors (410). The analog signals are filtered and amplified (418) and combined by a multiplexer (414). The combined analog signal is converted (412) to a digital signal. The data acquisition pod (10) may be selectively coupled to the display device (20) to provide the multiplexed output signal to the display device (20). The signal path (16) between the pod (10) and the patient is substantially shorter than the signal path (18) between the pod (10) and the display device (20) to reduce RF interference in the analog signals.

DATA ACQUISITION POD FOR A PATIENT MONITORING SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to medical systems and in particular to patient monitoring systems for collecting, storing and displaying medical data pertaining to the patient.

Description of the Related Art

In hospitals and other health care environments, it is often necessary to continually collect and analyze a variety of medical data from a patient. These data may include electrocardiogram signals, body temperature, blood pressure, respiration, pulse and other monitored vital signs.

Monitoring systems in the related art have typically fallen into one of two general categories: multi-function monitoring, recording and displaying systems which process and collect all of the data desired, but are bulky and difficult to transport; and small, portable systems which are easy to transport, but process and collect fewer types of data and have limited storage capability. Initially (e.g., in an ambulance or an emergency room) a patient is connected to a simple, portable monitor to observe a limited number of medical attributes, such as EKG or non-invasive blood pressure. As the patient moves to higher care facilities (e.g., an intensive care unit or operating room) it is desirable to augment these simple monitors to observe additional parameters. Generally, this is accomplished by disconnecting the patient from the simple monitor and

connecting the patient to a monitoring system having more robust capabilities.

The need for continuity of data collection and display is most pressing in emergency situations. Hospital personnel want to monitor additional parameters, change the selection of parameters viewed, or retrieve additional data from the patient's history. At the same time, the patient may have to move to a different care unit. During an emergency, the speed at which a patient is transferred from a bed to an operating room or intensive care unit may substantially impact the patient's chance of survival. Hospital personnel need to be able to quickly add functionality to the system and go to another care unit.

Two major considerations in the design of monitoring systems have been ease and speed of system reconfiguration. It is particularly undesirable to connect sensors to a patient or to disconnect them immediately prior to transportation or administration of critical procedures. U.S. Patent 4,715,385 and 4,895,385 to Cudahy et al. discuss a monitoring system which includes a fixed location display unit and a portable display unit. A digital acquisition and processing module (DAPM) receives data from sensors attached to the patient and provides the data to either or both of the fixed and portable display units. The DAPM remains attached to the patient during patient transport, eliminating the need to remove intrusive devices from the patient before transport and to reconnect the devices after transport. Normally, the DAPM is inserted into a bedside display unit located near the patient's bed. An electrical connection to the bedside display is formed when the DAPM is inserted into the bedside display.

When it is necessary to transport the patient, the following two reconfiguration steps are performed. The DAPM is first connected to the portable display by

attaching a cable, and is then disconnected from the bedside display by removing it from the bedside display unit. Once the DAPM is disconnected from the bedside display, a transportable monitoring system is formed, comprising the portable display and DAPM. In order to place the DAPM in the bedside monitor, sufficient cable length is provided between the sensors and the DAPM to reach the bedside display unit.

To enable insertion of the DAPM into the bedside monitor, the lines transmitting the analog data signals from the patient to the DAPM are long enough to reach from the patient to the bedside monitor. This cable length may produce undesirable interference between the analog signals, and may allow corruption of the analog signals with noise due to, for example, radio frequency interference (RFI) from external sources.

Furthermore, the digital acquisition and processing module of the Cudahy et al. system has a fixed parameter configuration, and if the parameter requirements change due to a change in condition of the patient, the digital acquisition and processing module must be disconnected and a different module including the new parameters which are required to be monitored must be connected. This process is not only time consuming, due to the reconnection of the sensors and cables between the patient and the module, but also destructive of data since patient data acquired in the first processing module is lost when the module is disconnected. Furthermore, the processing module of Cudahy et al. is bulky and difficult to position near a patient. In addition, the processing module of Cudahy et al. requires extensive cabling to the different patient sensors, which further adds to the complexity and set-up time of the system.

Besides the time delays which may be encountered when adding sensors to the monitor configuration, systems

in the prior art also leave much to be desired with respect to cable management. In typical patient monitoring systems, a large number of cables extend between the patient and the monitor. In the past, there has been at least one cable added for each parameter monitored. For example, there may be five cables for EKG, two for cardiac output, two for temperature, plus four hoses for measuring blood pressure using invasive sensors. This array of cables and hoses interferes with the movement of personnel around the patient's bed. The greater the number of cables and hoses, the greater the risk that someone will accidentally disrupt one of them. This has been a common problem in previous systems from several vendors.

Another aspect of prior art data acquisition devices is that they are not standalone devices. An example is the Sirecust™ cartridge system manufactured by Siemens Medical Equipment. Patient medical data are collected by one or more multiparameter cartridges. In order to display the data on a display, the cartridges are inserted into a SIREM™ module box. The large size of the module box makes it impractical to place the box on or above the bed; it typically must be placed beside the bed, and may get in the way of hospital personnel who are treating the patient. Not only is the box in the way, but as noted above, an array of cables between the cartridge and the patient further interferes with movement of hospital personnel. The Hewlett-Packard Merlin™ system and the Marquette TRAM™ systems are similar in that they also require insertion of a cartridge into a module box to display data on a bedside monitor. The Cudahy patent has a similar limitation: the DAPM must be inserted into the fixed (bedside) display to display data on that display. None of these is a standalone device.

Additional simplification is desired, in order to reduce the time to prepare the patient and monitoring system for transportation to an operating room or intensive

care unit. Reduction in the noise and RFI in collected analog signals is also desirable. Reduction in total size of the whole data acquisition apparatus (including the module box) is desired.

SUMMARY OF THE INVENTION

The present invention is embodied in a data acquisition pod suitable for use in a system that includes a display. The pod continually collects a plurality of analog data signals representing at least two parameters of a patient condition using a plurality of sensors coupled to a medical patient. The data may be collected using the data acquisition pod while the patient is stationary and while the patient is being transported.

The data acquisition pod receives patient data signals representing at least two different parameters from the plurality of sensors. According to one aspect of the invention, the patient data signals are conditioned for transmission to the display device by circuitry within the data acquisition pod. The circuitry is selectably locatable proximate to the sensors. According to another aspect of the invention, the data acquisition pod is a standalone apparatus, and is selectively coupled directly to the display device. The circuitry may be positioned independent of the display device.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a perspective drawing which shows two data acquisition pods in a accordance with the invention.

Figure 2 is a block diagram of a data acquisition pod as shown in figure 1.

Figure 3a is a block diagram of the EKG pod shown in figure 1.

Figure 3b is a block diagram of the EKG printed circuit board shown in figure 3a.

Figure 3c is a block diagram of the SPO2 and Opto-isolation printed circuit boards shown in figure 3a.

Figure 4 is a block diagram of the pressure pod shown in figure 1.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

Figure 1 shows a system which includes two exemplary data acquisition pods 10 and 30 in accordance with the invention. The pod 10 includes a plurality of terminals 14 for coupling to EKG electrodes and a plurality of multi-function terminals 12 for coupling to resistance sensors such as temperature, nasal respiration or cardiac output thermodilution. Leads from these sensors are connected to the terminals 12 by a plurality of receiving lines 16. The pressure pod 30 includes terminals 23a-23d for receiving signals from pressure transducers (not shown), and terminals 24a and 24b for receiving signals from temperature sensors. The electrodes and sensors (not shown) are attached to a patient, and remain attached to the patient and to the pod while the patient is stationary as well as while the patient is being transported. The pod may be placed on a bedside table or may be attached to the bed or an intravenous pole.

Unlike the data acquisition cartridges known in the prior art, data acquisition pods 10 and 30 are preconfigured, standalone (self contained), multiparameter units. As preconfigured devices, pods 10 and 30 include all of the electronics required to receive the analog pressure signals from the sensors, filter the signals, combine them into a single multiplexed analog signal, and convert the single signal from analog form to digital form. This digital output signal may be transferred directly to

a display device 20 (which may include data processing functions) by wire 34 or a wireless (e.g., infrared) link (not shown). As a standalone device (unlike the prior art cartridges), pods 10 and 30 are neither inserted into a bulky box or rack, nor into the display device itself, to form electrical paths to the display device. The data acquisition pods are independently positionable because they are standalone devices. Using the data acquisition electronics described below with reference to Figures 3a, 3b, 3c and 4, pods 10 and 30 may be formed in small enough packages to be conveniently placed in a variety of locations in close proximity to the patient. Reduction is size is all the more important where, as in pods 10 and 30, multiple medical parameters are monitored by a single pod.

The data acquisition pod is selectively and detachably coupled by a single coupling line 18 to a display 20, which may be a portable display. If for any reason, it is desirable to replace display 20 with a further selected display (not shown), this is accomplished by detaching a single coupling line 18 from the old display, and attaching the line 18 to the new display. Another data acquisition pod 30 is also shown. Pod 30 is adapted to receive data representing blood pressure or both pressure and temperature. Although the EKG Pod 10 and the pressure pod 30 each include aspects of the invention, they may be used in combination with one another in a data acquisition system, as shown in figure 1. Pods 10 and 30 may be independently with respect to from each other and to the display 20. Pods 10 and 30 are small enough in size to be conveniently located close to the patient.

The electrical path between the patient and the pod, as determined by the length of the receiving lines 16 to which the sensors attach, is substantially less than the length of coupling line 18 or 34 which couples the pod to the display 20. A data acquisition pod 10 or 30

constructed in accordance with the circuit descriptions which follow is compact enough to be collocated with the sensors. EKG pod 10 may be placed on the bed adjacent the patient, and the pressure transducers (not shown) may be mounted on pod 30 by inserting them in the channels 38 of the housing of pod 30.

The detachable coupling between the data acquisition pod 10 and display 20 is intended to include any manner of communicating the acquired data signals to display 20, such as a wireless communication link (not shown), which may be an infrared link.

Figure 2 shows a block diagram of an exemplary data acquisition pod 11. Pod 11 performs functions which are common to both the EKG pod 10 and the pressure pod 30 shown in figure 1. The pod 11 receives patient data from a plurality of sensors 410a-410n. Sensors 410a-410n may be a subset of the sensors attached to the patient. These sensors may measure EKG, blood pressure, pulse, temperature, EEG or other physiological parameters. Each input data stream is filtered to remove noise and any undesirable signals (e.g., radio frequency (RF) distortion) which the sensors may acquire. The filtered signal is amplified. The filtered output signals 420a-420d are combined to form a single signal. This combining may be performed by a time division multiplexer 414. Alternatively, other methods of combining the data to form a single signal (e.g., frequency division multiplexing) may be used, as is understood by those skilled in the art. The combined signal is then converted from analog form to digital form by A/D converter 412. In the discussion that follows, the combining device is referred to as a multiplexer. A/D converter 412 includes a single data communications coupling 19 to display 20. This coupling is through a communications application specific integrated circuit (ASIC) 416. Pods 10 and 30 may include all of the functions of the pod 11 shown in figure 2.

The data provided by each sensor that is coupled to the pod 11 may be sampled at a respectively different rate. The multiplexer 414 is controlled by a control means 430, to provide a clock signal and to sample the analog signals associated with each respective sensor during at least one time division in accordance with its respective assigned sampling rate. Data representing each of the sensors' output signals is included in a single time division multiplexed output signal 415 during a fraction of the time divisions. In this manner, all signals may be conveyed on a single line, each at its desired sample rate.

As noted above in the discussion of figure 1, the lines 16 between the patient and the pod 10 are short, while the coupling line 18 between the pod 10 and the display 20 is long. This configuration shortens the electrical path traveled by the analog signals between the patient and the analog filter/amplifiers 418a-418n. The noise added to each signal prior to amplification is reduced by shortening the electrical path over which the signal travels before amplification. Noise and signal transport artifacts are avoided, which would otherwise occur if the amplification were performed further from the patient and the impedances of the couplings to the patient were imbalanced. Interference is further reduced by the electrical isolation provided in the pod 10 for the EKG circuitry by way of reducing the capacitance between the signal conditioning circuitry and noise sources remote from the patient.

This is particularly important in monitoring EKG signals. The room may have an electrical field gradient (e.g., due to lighting or to electro-surgery units). If line 16 were very long and pod 10 were placed near monitor 20, far from the patient, this field gradient could cause a significant difference in the potential between the patient and the pod. Current would flow between the pod

and the patient. If the electrodes have identical impedances, this would be a common mode current which could be eliminated by differential amplification. If, however, the electrode resistances are different from one another (as is typically the case), there is a differential voltage component between the electrodes. This differential voltage would be amplified and become noise in the EKG waveform.

Instead, in the exemplary embodiment, pod 10 is close to the patient and a low capacitance isolation is provided within the pod, isolating the circuits coupled to the patient from the circuits coupled to monitor 20. The shorter the distance between the patient and pod 10, the smaller the potential difference due to electric field gradients, and, therefore, the smaller the differential voltage noise component due to non-uniform electrode impedances.

In pod 10, the signals are converted to digital form in A/D converters 412a-412n before being transmitted across the comparatively long coupling line between the pod 11 and the display 20. Once converted to digital form, the data are less vulnerable to corruption due to crosstalk between signals and RFI.

A non-volatile memory device 432 is included in pod 11. Memory 432 may be a conventional electrically erasable programmable read only memory (EEPROM). Memory 432 may store patient demographic data, alarm limits for the sensors, and patient trend data. By storing these data in pod 11, exchanging equipment (e.g., substituting another display for display 20) is simplified. Pod 11 may be disconnected from display 20 and reconnected to another display without the need for time consuming data downloads from display 20 to the other display.

It is understood by those skilled in the art that the memory may be a distinct memory device 434 located outside of the housing (as shown in phantom) of pod 11, and may be connected to pod 11. Memory 434 is selectively detachable from pod 11. A single memory 434 is shown coupled to sensor 410n and filter 418n. Similar memories may be coupled to each sensor. If each sensor has a respective memory 434, it is convenient to allow the memories 434 to accompany the sensors when the patient moves. Thus, if a department does not wish to allow its pod 11 to accompany the patient to another part of the hospital (e.g., out of a concern that the pod will not be returned), memory 434 may be detached from pod 11 and may be connected to another pod for transportation to a different part of the hospital. This provides an additional element of flexibility in selectively coupling pods 11 to display 20.

Figure 3a is a block diagram showing the circuitry which forms the EKG data acquisition pod 10. The basic pod configuration includes three printed circuit boards (PCB's): the EKG PCB 100, the SPO2 PCB 200 and the opto-isolation power board 134. The EKG PCB 100 includes circuitry for receiving and processing EKG and temperature signals, where the temperature signals may represent respiration or cardiac output data. The opto-isolation power board 134 ensures patient safety by providing a power source and a return circuit for the EKG PCB 100 which are separate from return circuit used by the rest of the sensor systems. The SPO2 PCB 200 receives data from blood oxygen saturation pressure sensors, and handles communications between the pod 10 and the display 20. Additional PCBs 280 and 290 may be provided for collecting, respectively, electroencephalogram (EEG) data on one hand and transcutaneous oxygen and carbon dioxide pressure (TCP O2/CO2) data on the other.

Figure 3b is a functional block diagram of the EKG printed circuit board PCB 100 of the pod 10. The EKG PCB 100 includes circuitry for receiving and processing data from five EKG electrodes (102, 104, 106, 108 and 110), two cardiac output thermistors or nasal thermistors, and two body temperature thermistors. The EKG PCB 100 includes filters and amplifiers (112, 114, 116, 118, and 120) for processing the EKG signals received from each respective electrode. Conventional signal processing algorithms are applied to the signals from these electrodes, which are well known in the art.

It is also well known in the art that an EKG lead is formed by comparing the voltage difference between two electrodes. The output signals from the five filter/amplifier circuits (112, 114, 116, 118 and 120) are multiplexed in multiplexers 122 and 124, and are provided to differential amplifier 128. Using this configuration, seven EKG signals are derived from a selected seven pairings of the five electrodes (102, 104, 106, 108 and 110).

The output signal 123 from multiplexer 122 is stored in buffer 126, and a delayed signal 127 is provided by the buffer. The output signal 123 from multiplexer 122 is also provided to differential amplifier 128. The buffer 126 provides a delay which compensates for the signal delay caused by the differential amplifier 128, so that signals 127 and 129 represent data collected during the same period of time. The differential amplifier receives input signals 123 and 125 from multiplexers 122 and 124, respectively. The differential amplifier 128 subtracts signal 125 from signal 123, forming an EKG lead signal 129 from the two electrode output data signals 123, 125. The output signal 129 from differential amplifier 128 and the output signal 127 from buffer 126 are provided to multiplexer/analog-to-digital (A/D) converter 130.

Multiplexer 122 also receives input signals from temperature sensors 150, 152, 154 and 156. Sensors 150 and 152 may collect two sets of body temperature data, or one set of body temperature data and one set of nasal respiration data. If respiration data are desired, sensor 152 may be a rapidly responding temperature sensor placed at the nose or mouth, which responds to temperature changes in the air entering and leaving the airway. The changes in nasal passage temperature due to the difference in temperature between inhaled and exhaled air are thus measured. The data collected from sensors 150 and 152 are filtered by conventional filter means 160 and 162, respectively.

As noted in the description of Figure 1, the terminals 12 may receive data representative of temperature, nasal respiration, or cardiac output. Figure 3b shows a variation of the embodiment in figure 1, in which separate terminals 12a-12d receive data from two sets of sensors: temperature 150, 152 and either of cardiac output or nasal respiration 154, 156. It is understood that a further variation may be practiced in which additional terminals are provided for simultaneous collection of temperature, respiration and cardiac output data.

Sensors 154 and 156 are located in an Edwards-type catheter and provide cardiac output data using the thermodilution method. An Edwards type catheter (not shown) is used to inject either cooled or room temperature water into the coronary artery. An Edwards calibration resistor 158 is also located within the catheter probe (not shown) for calibrating the sensors 154 and 156. Downstream blood temperature and injectate temperatures are measured. Comparison of these temperatures yields a measurand of cardiac output, as is well known to one skilled in the art.

The output signals 161 and 163 from respective filters 160 and 162 are provided to a multiplexer 168, which time division multiplexes the signals together. The output signal 169 from multiplexer 168 is then provided to an amplifier 172. Similarly, the cardiac output signals from filters 164 and 166 are multiplexed, along with the calibration signal 159. The output signal 171 of the multiplexer 170 is provided to amplifier 174. The amplified signals 173 and 175 are time division multiplexed together and are provided to multiplexer 122.

In order to take measurements from the EKG, cardiac output, temperature and nasal respiration sensors, the multiplexers 122, 128 and 176 are controlled to sample signals from each sensor in accordance with its respective sample rate. For example, EKG channels may be sampled at one hundred times the rate used for cardiac output.

The control and clock signals 133 used to control the multiplexers are provided through an EKG communications Application Specific Integrated Circuit (ASIC) 132. The EKG communications ASIC 132 transfers data between the EKG PCB 100 and the opto-isolation power PCB 134. The opto-isolation power PCB 134 protects the patient by maintaining a 5000 volt electrical isolation between the EKG / respiration circuitry and the SPO2 PCB 200 as shown in figure 3c. At the same time, hardware efficiency is attained by routing the power and data transfers between the portable display 20 and the EKG PCB through the SPO2 PCB. The line receiver 144, line driver 146 and DC power 148 connections to the display 20 share a separate return which is isolated from both the EKG return 136 and the main enclosure of the display 20.

Figure 3c is a block diagram showing the SPO2 PCB 200. The SPO2 PCB includes circuitry to receive and process data from an SPO2 sensor 250, which may be, for example, a commercially available sensor such as that

manufactured by the Nelcor company. The SPO2 sensor 250 includes two light emitting diodes (LEDs) 252 and 254, which emit red and infra-red light respectively for passing light through a portion of the patient's body (e.g., an ear lobe, fingertip or toe). A photodiode 260 measures the amount of light, in particular bands of frequencies, which is passed through the patient's tissue and, thus, provides a signal representative of the relative saturation of oxygen in the patient's blood.

The input signal driving LEDs 252 and 254 is provided by analog mux 210 on the SPO2 PCB 200. A 2.5 volt reference input signal is converted to an analog signal by DAC 216 and is converted to a known current level by voltage-to-current converter 212. The converter 212 provides an input signal to the analog mux 210. The polarity of the 2.5 volt input signal is switched between positive and negative to alternately activate respective LEDs 252 and 254.

The current signal generated in the photodiode 260 in response to illumination provided by the photodiodes 252 and 254 is converted to a voltage signal 219 by a current-to-voltage converter 218. This voltage signal 219 is passed through a filter 220 to cancel out components of the signal which are attributable to ambient light. The remaining signal 221 is then fed through a demultiplexer which is synchronized to the mux 214, to separate the red and infra-red components of the signal, which are processed by respective filters 224 and 226.

Multiplexing the sensor input signals and demultiplexing the sensor output signals provides a degree of flexibility in the design of the SPO2 PCB 200. A controller 215 synchronizes the operations of multiplexer 214 and demultiplexer 222, so that demultiplexer 222 samples signal 221 at the same rate that multiplexer 214 transmits signals 213. But this sample rate may differ

from the rest of the components within the PCB 200. By this method, the sample rate of the returned signals 223 and 225 may differ from the sample rate of the input signals red, R, and infrared, IR.

The demultiplexed red 223 and infrared 225 data signals are processed by respective filters 224 and 226, and amplifiers 228 and 230. The output signal 229 from amplifier 228 is multiplexed with a red reference calibration signal 257 from a reference resistor 256. The multiplexed red signal 233 and the amplified infrared signal 231 are converted to digital form by respective A/D converters 234 and 236. The red 235 and infrared 237 digital output signals are provided to the pod communications ASIC 238 for transmission to the display 20.

The opto-power board 134 provides the optional isolation between the EKG circuitry and the remaining sensors and circuits. Commands are sent from the display 20 to the EKG PCB 100 by way of line receiver 144 and opto-isolation 136. Data are returned from the EKG PCB 100 to the display 20 by way of opto-isolation 138 and line driver 146, so that the EKG return is isolated from the display ground path. Power is transferred from the display 20 to the EKG PCB 100 by way of isolation power supply 140. An EKG synchronization signal ESYNC is provided through the isolation power supply 140. The components of the SPO2 PCB 200 receive commands from the display 20 (shown in figure 2) directly through the line receiver 144. The SPO2 PCB 200 transmits data to the display 20 directly through the line driver 146. DC power is furnished directly from the display 20. A synchronization signal SSYNC (distinct from the EKG synchronization signal ESYNC) is provided to the SPO2 PCB 200, as well.

As shown in Figure 3a, additional sensors may be added to the data acquisition pod 10 to receive data from additional electrodes for an EEG PCB 280, or from

transcutaneous oxygen and carbon dioxide PCB 290. Each of these PCB's 280 and 290 includes filters, amplifiers, A/D converters and multiplexers to provide a single time division multiplexed (TDM) digital data output signal to the pod communications ASIC 238. The EEG PCB circuits 280 use the same opto-isolation circuits and isolation power supply as does the EKG PCB 100. The TCP O2/CO2 PCB 290 circuits share the return, power and synchronization signals with the SPO2 PCB 200.

The configuration of the EEG PCB 280 is as shown for pod 11 in Figure 2, except that in PCB 280, the single multiplexed output signal 19 is provided to the opto-isolation power PCB 134. The output signals of the EEG PCB 280 share the same return circuit as the output signals of the EKG PCB 100. This return path is isolated from the rest of the sensor systems. PCB 134 then passes the EEG signal on to the display 20. In an embodiment which includes PCB 280, the additional terminals for receiving EEG signals may be also be used to receive data from further EKG electrodes, instead of EEG. In this embodiment, the EKG communications ASIC 132 would be modified to receive the additional EEG/EKG signals provided by PCB 280 and to provide output signals 282 and 284 to respective multiplexers 122 and 124 (as shown in phantom in figure 3b), so that data collected from the additional electrodes is combined with data from electrodes 102-110.

Similarly, the TCP O2/CO2 PCB 290 is as shown in figure 2, except that in PCB 290, the single multiplexed output signal 19 is provided to the pod communications ASIC 238, which provides the data signals to the display 20.

As shown in Figure 1, pod 10 includes two proximately located switches 13 and 15. Switch 13 is coupled to a circuit which transmits a signal to display 20 causing display 20 to start the cardiac output procedure (e.g., perform range and alarm limit adjustments). The

operator actuates switch 13 at the same time that he or she injects the injectate into the patient for cardiac output measurement. The display 20 calculates the waveform of the temperature gradient between thermistors for the cardiac output procedure. Similarly, switch 15 is coupled to a circuit which transmits a signal to display 20 causing display 20 to configure itself to start the wedge procedure and/or switch the display to wedge mode. The operator actuates switch 15 at the same time that he or she inflates a balloon inside the patient's pulmonary artery for pulmonary artery wedge pressure measurement. Switches 13 and 15 are conveniently co-located on pod 10 (near the sensors on the patient). This facilitates concurrent actuation of switch 13 while starting the cardiac output measurement, and facilitates concurrent actuation of switch 15 while starting the wedge procedure.

Systems in the prior art typically featured the cardiac output switch 13 and wedge switch 15 on the display 20 or on a foot operated pedal on the floor. It is more convenient to locate switches 13 and 15 close to the patient (as in the present invention) than on display 20 (as done in the prior art), because the operator is close to the patient while injecting liquid or inflating a balloon in the patient's artery. Since pod 10 is relatively small and is easily located close to the patient, pod 10 is an advantageous device on which to locate switches 13 and 15. In some hospital room configurations, it may be desirable to place display 20 too far away to be conveniently accessed while starting the procedures. In these instances, locating the switch on pod 150 may be advantageous. Furthermore, safety is enhanced by locating the switches on the pod, because the operator does not have to walk around the lines (e.g., lines 18 and 34) connected to display 20.

Referring again to Figure 1, there is shown a pressure pod 30. Pod 30 has a housing 36. All of the

circuitry for conditioning and combining the pressure data from transducers 302a-302d is contained inside housing 36. Each transducer is connected to a hose (not shown) at the end of which is a catheter which is inserted into a blood vessel. On the outside of housing 36 are channels 38 for receiving pressure transducers 302a-302d. The pressure transducers 302a-302d slide into channels 38 and engage electrical contacts 40a and 40b to transmit blood pressure signals to the conditioning and combining circuitry within pod 30. Because the transducers 302a-302d are located on the pressure pod 30, for accurate pressure measurement it's desirable that the height of the pressure pod be adjustable so that pod 30 may be placed at the height of the patient's heart. Mechanical design features of pod 30, including small size and a clamping device 46 allow easy mounting on a dedicated stand (not shown) an intravenous pole (not shown) or the railing of the patient's bed (not shown).

The zero switch 42 is conveniently located on pod 30, where it may easily be actuated while zeroing sensors 302a-302d (by exposing them to atmospheric pressure). Actuating the zero switch causes pod 30 to transmit a zero signal to the display 20, causing display 20 to reset the value of its waveform to zero in response to the voltage currently detected across sensor 302. A second switch 44 located on pod 30 sends a further signal to the display 20, causing display 20 to begin a wedge procedure, as described above with reference to switch 15 of pod 10. The location of the zero switch 42 and wedge switch 44 on pod 30 provide the same advantages discussed above with respect to switches 13 and 15. The wedge switch 15 may be actuated easily while inflating the balloon in the pulmonary artery to begin the pulmonary artery wedge pressure measurement.

Figure 4 is a block diagram of the pressure/temperature data acquisition pod 30 shown in figure 1. The pod 30 receives data from up to four pressure transducers 302a-302d and two temperature

transducers 350a, 350b. Power is provided by a single step-down power supply 310. The output signals from the transducers 302a-302d are provided to respective clamping and filtering networks 304a-304d, to limit the range of the signals and remove noise.

The output signals 303a, 303b from each of the networks 304a-304d are provided to a differential-to-single-ended converter and 4-to-1 multiplexer 308. The differential-to-single-ended converter 308 generates a single signal 314 representative of pressure difference from each pair of the signals 303a, 303b.

Instead of activating all four sensors with continuous DC voltage (i.e., applying power to the resistive bridge element inside all four sensors), power is applied to one sensor at a time in a pulse fashion. A switch 370a closes and applies power to one of the sensors 302a. A capacitor (not shown) within pressure sensor 302a charges up to a differential voltage which is proportional to the pressure in sensor 302a. (Sensor 302a has a bridge output signal which is differential in nature). Subsequently, switch 370a is opened again and power to sensor 302a is turned off. The voltage is trapped in the internal capacitor of sensor 302a, representing the output signal of the sensor. Subsequently, successive switches 370b-370d are individually closed to apply power to respective pressure sensors 302b-302d in succession. This technique is known as the flying capacitor technique.

An advantageous aspect of this configuration is that power is conserved, relative to a system in which all four sensors are simultaneously activated. There is no continuous excitation voltage. In the exemplary embodiment of the invention, four sensors are used, consuming no more power than is required to operate one transducer continuously. It is particularly valuable to reduce power

consumption if the data acquisition pod is intended for use in conjunction with a portable display such as display 20, with limited battery capacity.

The capacitor in sensor 302a is accessed by differential multiplexer 308. The input signal to multiplexer 308 is differential. The output signal 314 of multiplexer 308 is differential, except that one of the differential output lines of multiplexer 308 is tied to ground. One electrode of the capacitor is tied to ground through multiplexer 308. As soon as multiplexer 308 accesses the capacitor, the capacitor output signal changes from a differential voltage to a single ended voltage. The output signal 314 is thus a single ended voltage referenced to ground. This signal may be sensed by a single ended amplifier.

The output signals from networks 304b-304d are similarly converted to pressure difference signals. The converter 308 is controlled by signals 309a-309f sent over a timing bus 368. The timing bus 368 also controls the transducers, so that the converter acts as a time division multiplexer, transmitting signals representative of the respective transducers in round robin fashion.

The output signal 314 is multiplexed together with reference pressure signals 316a, 316b in multiplexer 312. Multiplexer 312 is controlled by signals 313a-313c which are received from the timing bus 368. The signal 317 is boosted by amplifier 318 so that it occupies a range of values coextensive with the input range of the A/D converter 320, which converts it to digital form. The digital output data signal 322 is Manchester encoded in a logic gate array 324 and is sent out to the display 20 by data transmitter 332.

An EEPROM 326 is provided for local storage of calibration coefficients and/or alarm limits which may be used by gate array 324. A data receiver 334 receives commands from the display 20. A second EEPROM 372 stores permanent data, such as the serial number or revision level of a printed circuit board.

The output signals 351a and 351b from respective temperature sensors, 350a and 350b, are filtered and clamped by circuits 352a and 352b, to remove noise and to limit the signal range. The filtered signals are provided to multiplexer 356, which produces a single TDM signal 357. An offset signal 360 is added to the TDM signal 357 in adder 358, and the resulting signal is boosted in amplitude by amplifier 362. The amplified signal 363 is multiplexed together with plus and minus five volt monitor signals provided by the step down power supply 310 in multiplexer 364. The power supply monitor signals are provided to allow deviations from the nominal five volt operational power signal provided by power supply 310 to be detected. The multiplexer output signal is then boosted by amplifier 366 and the resulting signal is provide to A/D converter 320. The temperature data is provided to the logic gate array 324 where it is Manchester encoded and transmitted to the display.

It is understood by one skilled in the art that many variations of the embodiments described herein are contemplated. While the invention has been described in terms of exemplary embodiments, it is contemplated that it may be practiced as outlined above with modifications within the spirit and scope of the appended claims.

What is Claimed:

1. In a patient monitoring system, a data acquisition pod that collects a plurality of patient data signals using a respective plurality of sensors which are coupled to the patient, said signal representing at least two parameters of a patient condition, to be displayed on a display device, the data acquisition pod comprising:

circuit means for receiving respective patient data signals representing at least two different parameters from at least two sensors selected from the plurality of sensors, and for processing the patient data signals for transmission to the display device, the circuit means being selectably locatable proximate to the sensors; and

means for selectively coupling the data acquisition pod directly to the display device to provide an output signal to the display device, wherein the circuit means are independently positionable from the display device and wherein the data acquisition pod forms a standalone apparatus.

2. A data acquisition pod in accordance with claim 1, in which the circuit means include combining means for combining signals representing at least two parameters to generating a combined signal.

3. A data acquisition pod in accordance with claim 2, wherein the combining means include a time division multiplexer.

4. A data acquisition pod in accordance with claim 3, in which the combining means include:

means for assigning a respective sample rate for sampling the data collected from each of the plurality of sensors;

a source of clock signal which establishes time divisions;

means for sampling the signals associated with each respective sensor during at least one of the time divisions in accordance with its respective assigned sample rate,

wherein each of the plurality of signals is included in the combined signal during a fraction of the time divisions which is proportional to its respective assigned sample rate.

5. A data acquisition pod in accordance with claim 2, wherein the combined signal is an analog signal, and wherein the circuit means include means for converting the combined signal to a digital signal.

6. A data acquisition pod in accordance with claim 1, in which the circuit means include means for receiving patient electrocardiogram (ECG) signals, blood oxygen saturation signals and one of temperature signals and cardiac output signals.

7. A data acquisition pod in accordance with claim 6, in which the circuit means include means for receiving data representative of patient electroencephalogram signals.

8. A data acquisition pod in accordance with claim 7, in which the circuit means include means for receiving at least one signal selected from the group consisting of a blood oxygen partial pressure signal and a blood carbon dioxide partial pressure signal.

9. A data acquisition pod in accordance with claim 8, in which the combining means include:

first multiplexing means coupled to the ECG and the temperature signal receiving means for generating first multiplexed data signals representative of the ECG and the temperature signals, the first multiplexing means including a first return circuit;

second multiplexing means coupled to the blood oxygen saturation signal receiving means for generating second multiplexed data signals representative of blood oxygen saturation, the second multiplexing means including a second return circuit distinct from the first return circuit; and

third multiplexing means coupled to the first and second multiplexing means for generating the combined signal from the first and second multiplexed data signals.

10. A data acquisition pod in accordance with claim 9, in which the display device has a ground path, and the first return circuit is isolated from the ground path and from the second return circuit.

11. A data acquisition pod in accordance with claim 1, further comprising:

a housing;

a first circuit which transmits a signal to the display device to cause the display device to start a cardiac output measurement;

a second circuit which transmits a signal to the display device to cause the display device to force to zero a value of a waveform, the waveform being derived from a blood oxygen saturation signal; and

first and second switches for controlling respective first and second circuits, wherein the first and second switches are located on the housing.

12. A data acquisition pod in accordance with claim 1, in which:

the selective coupling means include a coupling line which couples the data acquisition pod to the display device and transfers the output signal to the display device, wherein the coupling line has a coupling line length; and

the circuit means include a plurality of receiving lines which couple the data acquisition pod to the patient and transfer the analog data signals to the data acquisition pod, each respective receiving line having a receiving line length which is substantially less than the coupling line length, thereby to reduce signal transport artifacts.

13. A data acquisition pod in accordance with claim 1, including a power supply with a ground path, wherein each of the plurality of sensors is electrically isolated from the ground path, and each respective one of the plurality of sensors is electrically isolated from every other one of the plurality of sensors.

14. A data acquisition pod in accordance with claim 1, in which the circuit means include means for receiving patient blood pressure signals.

15. A data acquisition pod in accordance with claim 14, in which the circuit means include means for receiving patient temperature signals.

16. A data acquisition pod in accordance with claim 1, further comprising a memory which stores at least

one data value selected from the group consisting of patient demographic data, alarm limits and trend data.

17. A data acquisition pod in accordance with claim 16 further comprising a housing for the circuit means, wherein the memory is positioned outside of the housing, and the memory is detachable from the data acquisition pod.

18. In a patient monitoring system which includes a display device, a data acquisition system that collects a plurality of patient data signals representing at least two parameters of a patient condition using a plurality of sensors coupled to a medical patient, the data acquisition system comprising:

a first self-contained, independently positionable data acquisition pod comprising:

circuit means for receiving respective analog data signals representing at least two different parameters from at least two sensors selected from the plurality of sensors, for processing the patient data signal and for transmitting the processed signal to the display device, the circuit means being selectably locatable proximate to the sensors; and

means for selectively coupling the data acquisition pod directly to the display device to provide an output signal to the display device, wherein the circuit means are able to be positioned independently from the display device, and wherein the first data acquisition pod forms a standalone apparatus; and

a second self-contained data acquisition pod, which is positioned independently from the first data acquisition pod, the second data acquisition pod comprising:

means for receiving signals representing blood pressure from a blood pressure transducer and signals representing temperature from a temperature sensor, and

means for selectively coupling the second data acquisition pod to the display device to provide the signals representing blood pressure and temperature to the display device.

19. A data acquisition system in accordance with claim 18, wherein each data acquisition pod further comprises:

combining means for receiving the plurality of patient data signals and for combining the plurality of patient data signals to form a combined signal.

20. A data acquisition system in accordance with claim 19, wherein the combining means include a time division multiplexer.

21. A data acquisition system in accordance with claim 19, wherein each data acquisition pod further comprises:

means for converting the combined signal to a digital output signal for transmission to the display device.

22. A data acquisition pod in accordance with claim 18, in which the circuit means of the first data acquisition pod include means for receiving patient electrocardiogram (ECG) signals, blood oxygen saturation signals and one of temperature signals and cardiac output signals.

23. A data acquisition system in accordance with claim 22, wherein the circuit means of the first data

acquisition pod include means for receiving blood oxygen saturation signals and one of temperature signals and cardiac output signals.

24. A data acquisition system in accordance with claim 23, wherein the signal receiving means of the first data acquisition pod include means for receiving electroencephalogram signals.

25. A data acquisition pod in accordance with claim 24, in which the signal receiving means include means for receiving at least one signal selected from the group consisting of a blood oxygen partial pressure signal and blood carbon dioxide partial pressure signal.

26. A data acquisition system in accordance with claim 18, wherein the second data acquisition pod includes means for detachably mounting the second data acquisition pod to an intravenous pole.

27. A data acquisition system in accordance with claim 18, wherein the second data acquisition pod includes means for adjusting the second data acquisition pod in height relative to the patient.

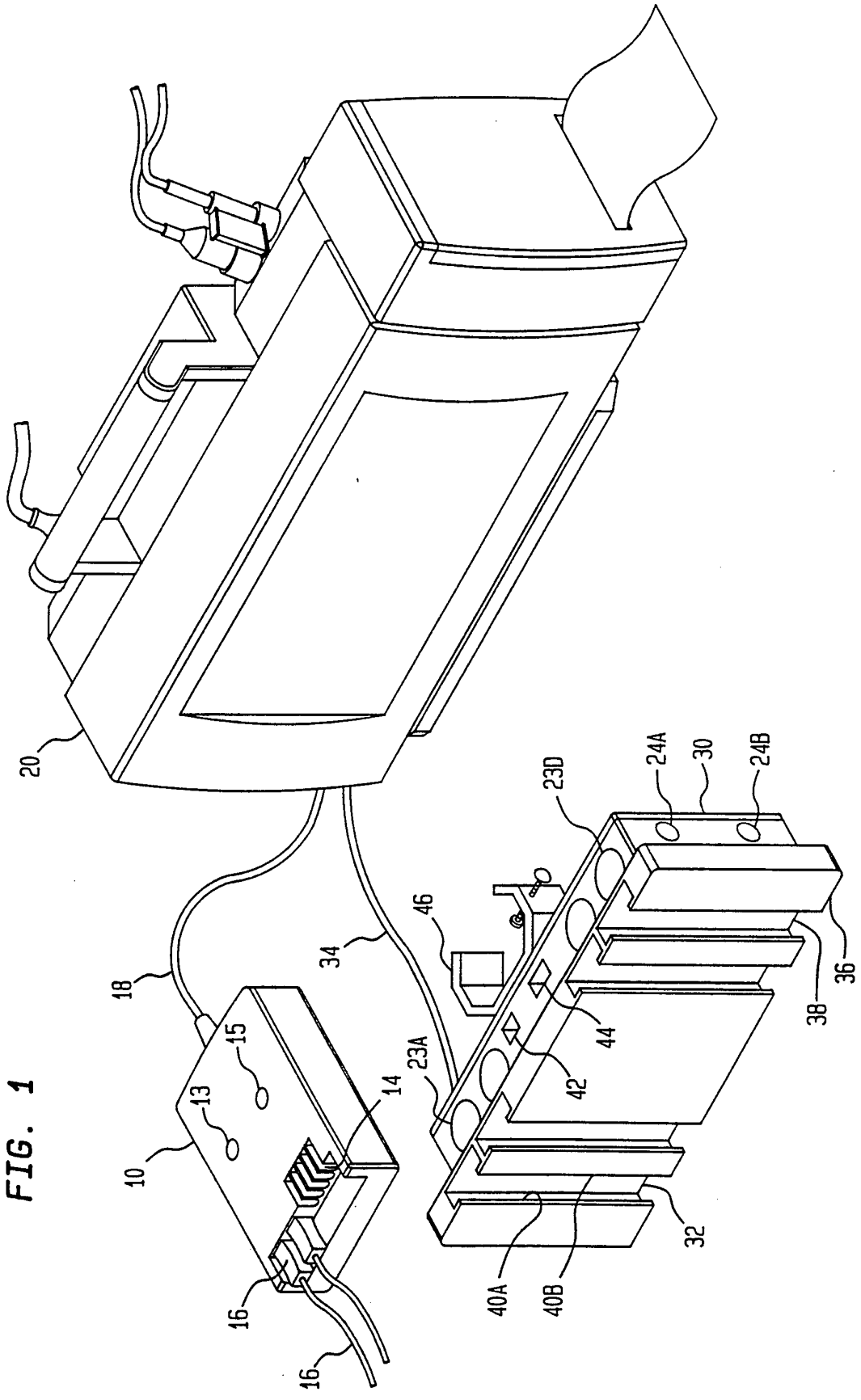
28. In a patient monitoring system which includes a display device, a data acquisition system that collects a plurality of analog patient data signals representing patient condition using a plurality of sensors coupled to a medical patient, the data acquisition system comprising:

first and second preconfigured, independently positionable, standalone data acquisition pods, each of the data acquisition pods comprising:

circuit means for receiving analog patient data signals representing at least two different parameters from

at least two sensors selected from the plurality of sensors, for processing the analog patient data signals, and for converting the processed signal to a digital signal for transmission to the display device, the circuit means being selectably locatable proximate to the sensors; and

means for selectively coupling the data acquisition pod directly to the display device to provide an output signal to the display device, wherein the circuit means are able to be positioned independently from the display device.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40B
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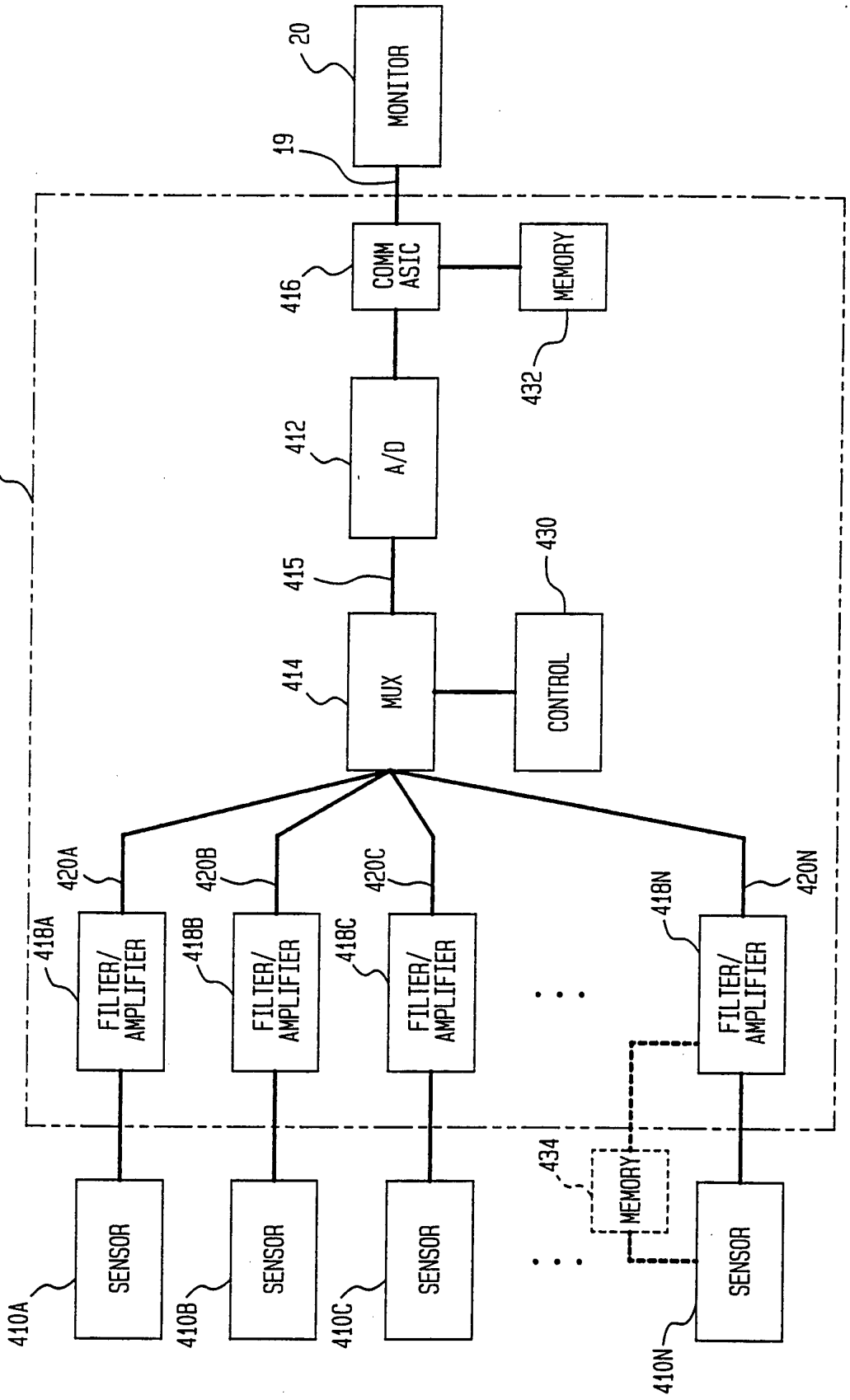
FIG. 1

FIG. 2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FILTER/ AMPLIFIER
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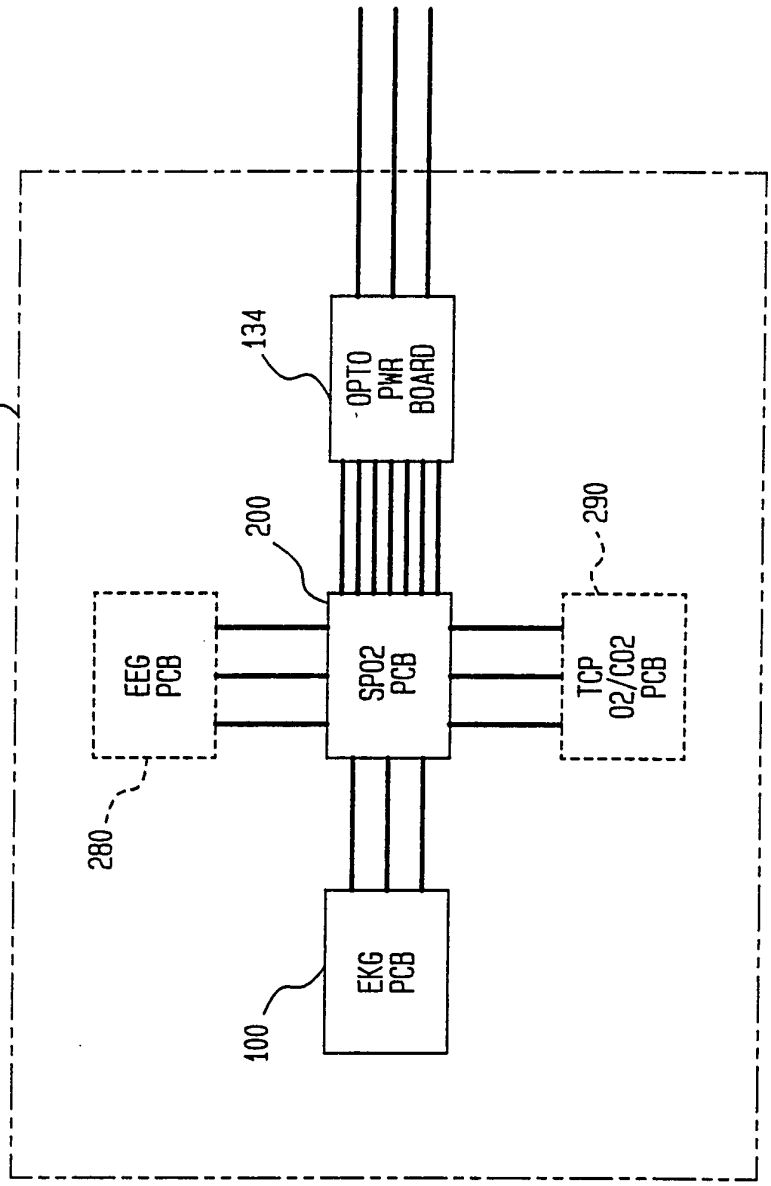
SENSOR

FIG. 3A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EKG PCB
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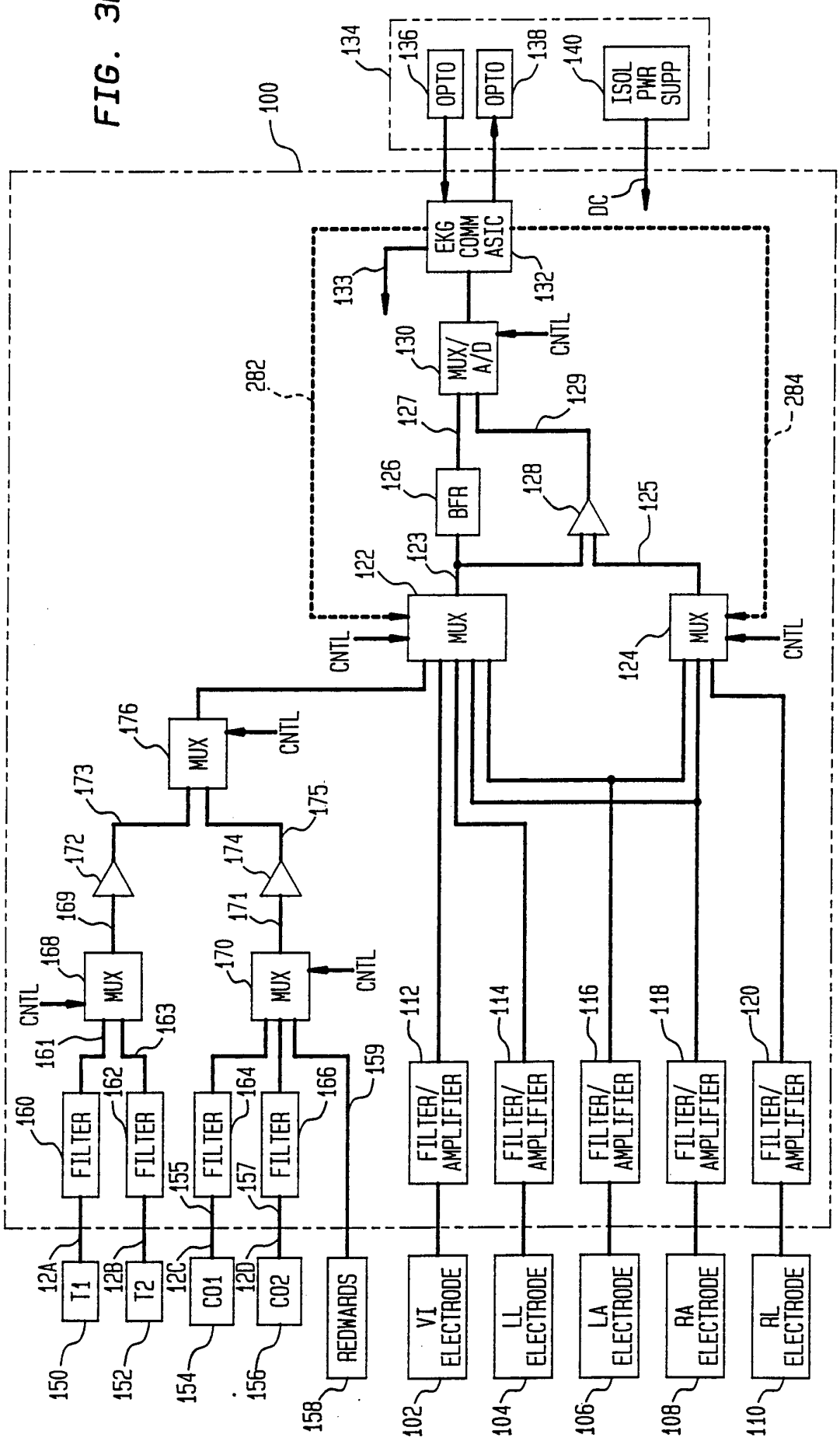
FIG. 3B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174
169
171
168
MUX
170
MUX
CNTL
CNTL
161
163
160
162
164
166
159
FILTER
FILTER
FILTER
FILTER
155
157
112
114
116
118
120
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FILTER/ AMPLIFIER
FILTER/ AMPLIFIER
12A
12B
12C
12D
T1
T2
C01
C02
REDWARDS
VI ELECTRODE
LL ELECTRODE
LA ELECTRODE
RA ELECTRODE
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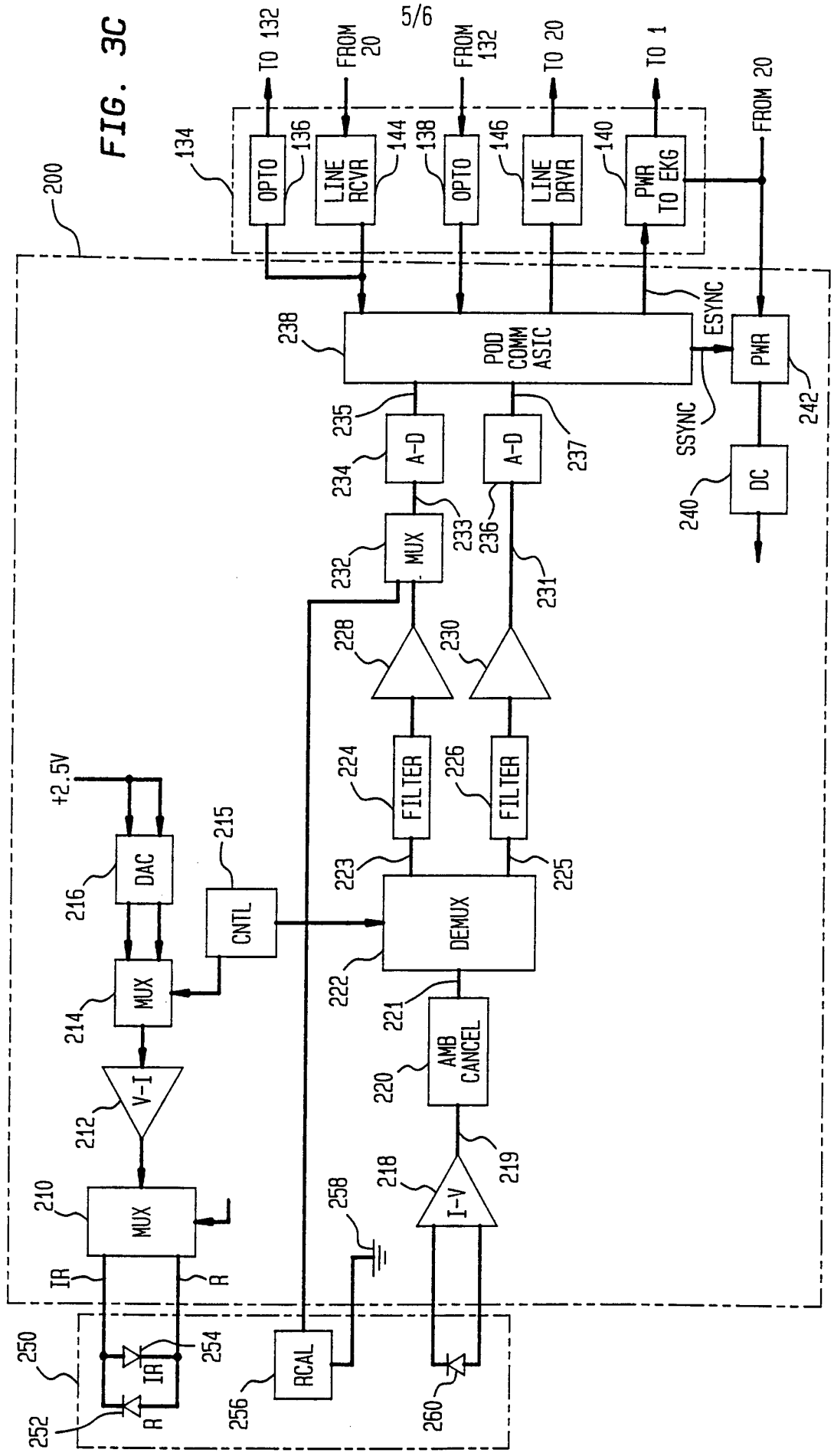
FIG. 3C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TO 132
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FROM 132
TO 20
TO 1
FROM 20
238
POD COMM ASIC
ESYNC
SSYNC
PWR
242
DC
240
235
A-D
234
A-D
237
233
MUX
232
236
231
228
230
FILTER
224
FILTER
226
223
225
DEMUX
222
221
AMB CANCEL
220
219
I-V
218
258
+2.5V
DAC
216
215
CNTL
MUX
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IR
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IR
254
R
RCAL
256
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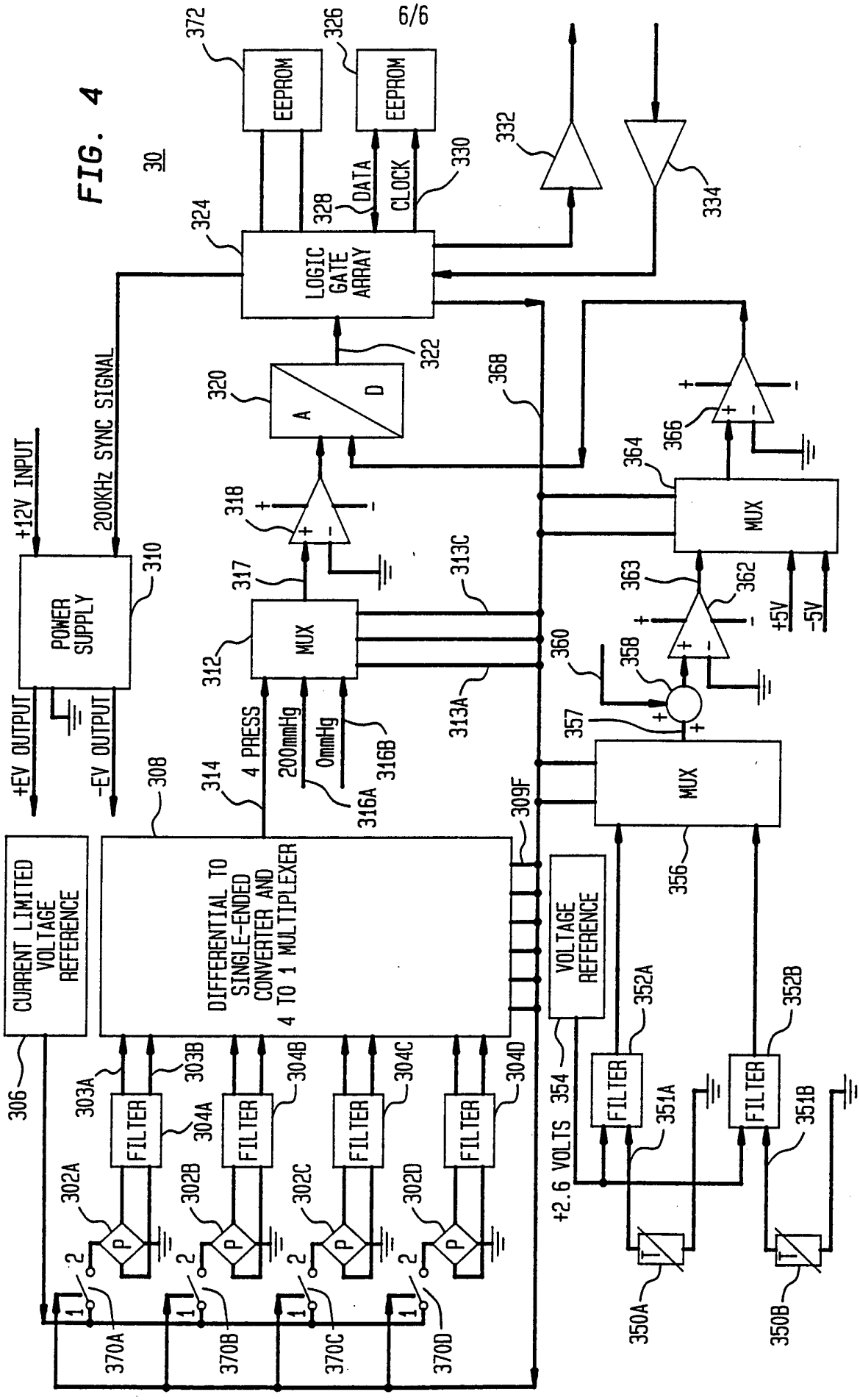
FIG. 4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EEPROM
332
334
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CLOCK
330
322
320
A
D
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+12V INPUT
200KHz SYNC SIGNAL
POWER SUPPLY
310
318
317
MUX
313C
312
313A
4 PRESS
200mmHg
0mmHg
316B
316A
314
308
+EV OUTPUT
-EV OUTPUT
309F
CURRENT LIMITED VOLTAGE REFERENCE
DIFFERENTIAL TO SINGLE-ENDED CONVERTER AND 4 TO 1 MULTIPLEXER
306
VOLTAGE REFERENCE
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356
MUX
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358
360
363
362
+5V
-5V
364
366
MUX
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303B
304A
304B
304C
304D
FILTER
302A
302B
302C
302D
P
T
352A
352B
351A
351B
350A
350B
370A
370B
370C
370D

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 93/11710

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 A61B5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,3 910 257 (J.C. FLETCHER) 7 October 1975	1-6,10
X	see column 2, line 37 - column 3, line 59	12,15
X	see column 5, line 68 - column 7, line 19	18-22,28

X	US,A,4 686 998 (A. ROBBINS) 18 August 1987	1-4,6,15
X	see column 3, line 16 - line 39	18-22,28
	see column 6, line 1 - column 8, line 9	
	see column 12, line 40 - line 62	
	see column 15, line 25 - line 65	

X	FR,A,2 145 020 (J.E.N. RICHALET) 16 February 1973	1,2,5-8, 14-16, 18, 22-25,28
A	see page 2, line 5 - page 6, line 31	3,11,12, 17,20,21

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published 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; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
25 April 1994	24. 05. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Rieb, K.D.

INTERNATIONAL SEARCH REPORT

Int ional Application No
PCT/US 93/11710

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,89 00024 (MICROMEDICAL INDUSTRIES PTY, LTD.) 12 January 1989	1,6,8, 12,14
X	see page 3, line 33 - page 6, line 21	21-23,28
A	see page 8, line 26 - page 9, line 38	11,16,18

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int ional Application No
PCT/US 93/11710

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-3910257	07-10-75	NONE		
US-A-4686998	18-08-87	NONE		
FR-A-2145020	16-02-73	DE-A-	2232875	18-01-73
		GB-A-	1391948	23-04-75
WO-A-8900024	12-01-89	AU-A-	1993288	30-01-89
		JP-T-	3502893	04-07-91