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[54] APPARATUS FOR THE DETECTION OF MOTION TRANSIENTS

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[51] **Int. Cl.**[5] **A61B 5/00**

[52] **U.S. Cl.** **128/633**; 356/41

[58] **Field of Search** 128/633, 664, 665, 670, 128/677, 682; 356/40, 41

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Assistant Examiner—Kevin Pontius
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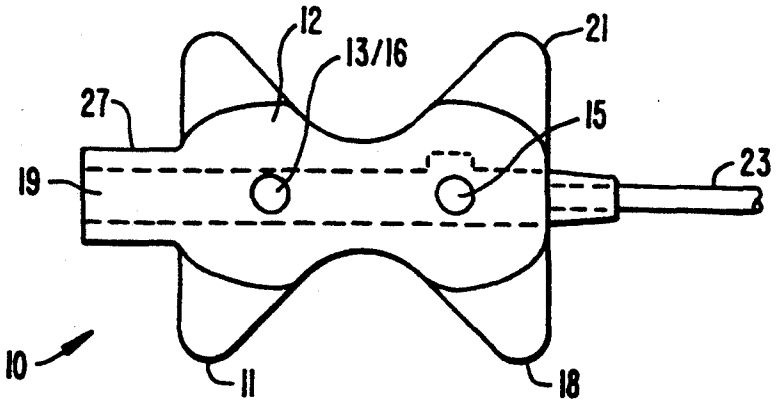
[57] **ABSTRACT**

An apparatus for detecting movement in patients coupled to pulse oximeters and a method for using the signal generated by the apparatus to filter out the effects of motion from the test results generated by the pulse oximeter are disclosed. In a preferred embodiment, a piezoelectric film located in close proximity to the pulse oximeter's sensor provides a voltage signal whenever movement occurs near the sensor. This voltage signal is processed and the resulting signal is used to correct the oximeter's measurements. In addition to piezoelectric film, accelerometers and strain gauges are also usable to provide a signal indicative of motion.

6 Claims, 3 Drawing Sheets



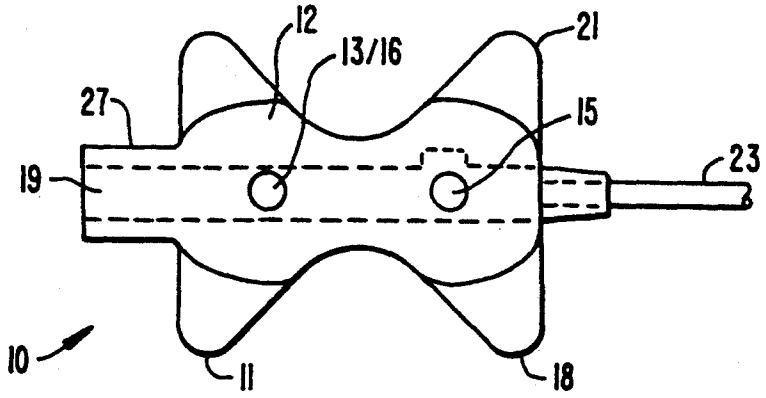


FIG. 1.

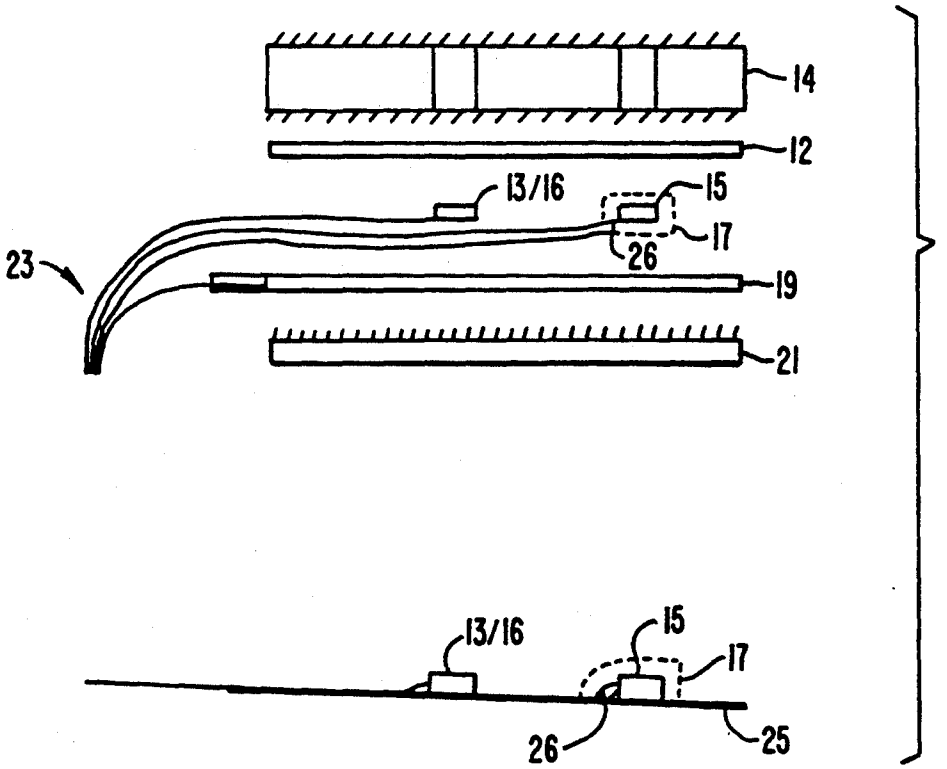


FIG. 2.

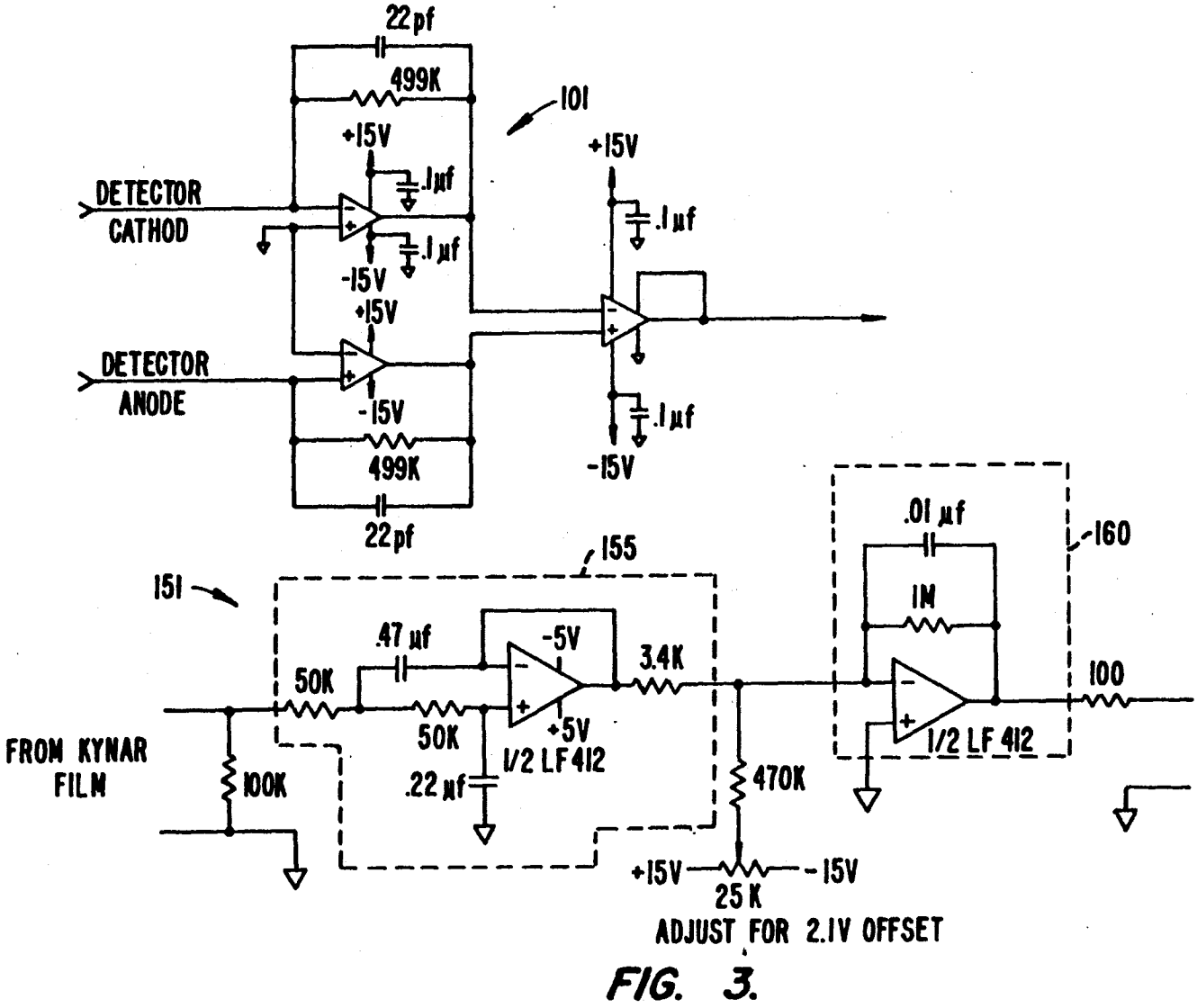


FIG. 3.

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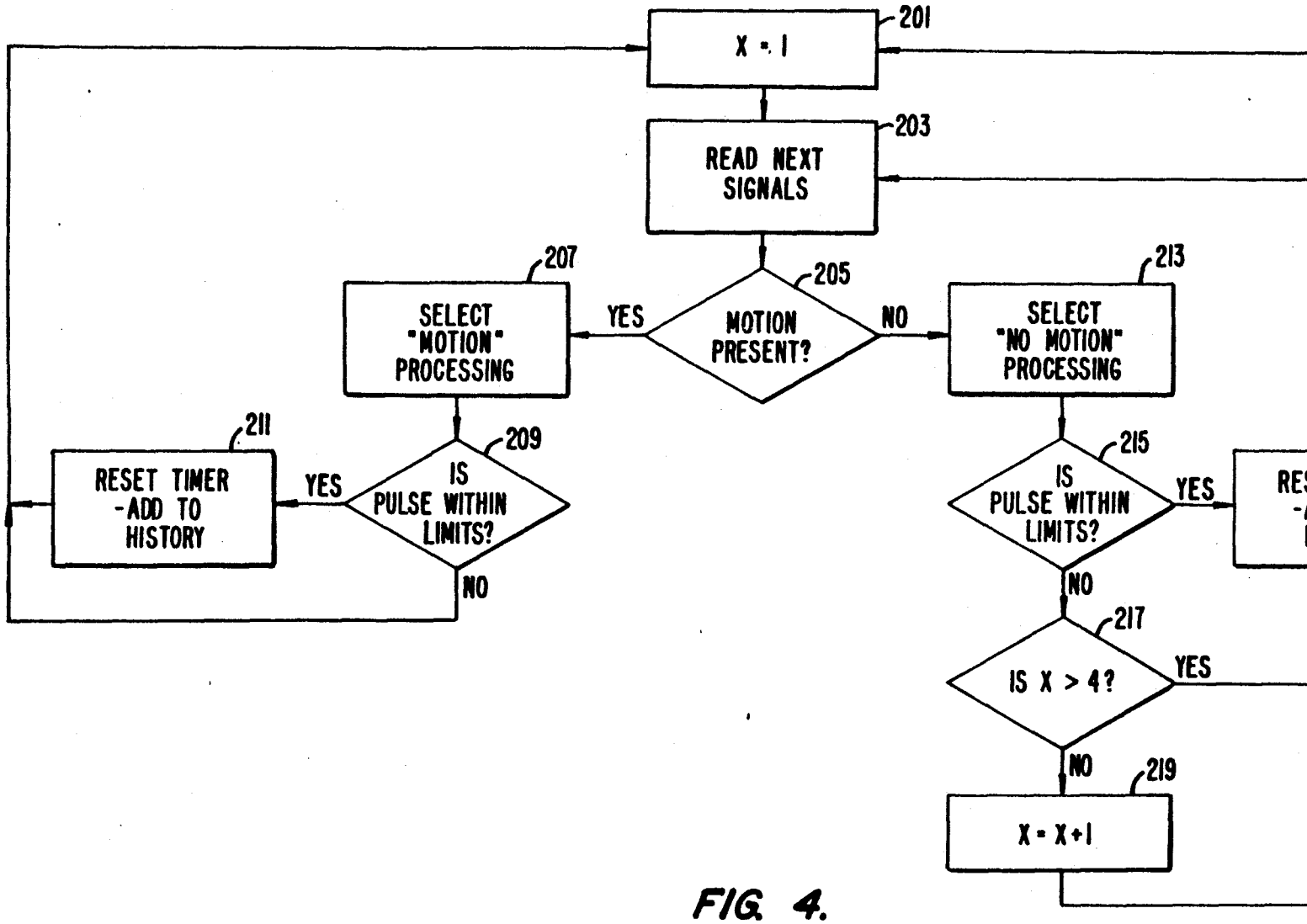

FIG. 4.

APPARATUS FOR THE DETECTION OF MOTION TRANSIENTS

BACKGROUND OF THE INVENTION

This invention relates generally to non-invasive pulse monitors such as pulse oximeters. In particular, it relates to the detection of motion transients and the filtering of these transients from the blood oxygen signals sent to the pulse oximeter.

Photoelectric pulse oximetry is known. Pulse oximeters typically measure and display various blood flow characteristics including the blood oxygen saturation of hemoglobin in arterial blood, the volume of individual blood pulsations supplying the flesh, and the rate of blood pulsations corresponding to each heartbeat of the patient. The oximeters pass light through body tissue in a location where blood perfuses the tissue (i.e. a finger or an ear) and photoelectrically sense the absorption of light in the tissue. The amount of light absorbed is then used to calculate the amount of the blood constituent being measured.

Several different wavelengths of light are simultaneously or nearly simultaneously transmitted through the body tissue. These wavelengths are selected based on their absorption by the blood components being measured. The amount of transmitted light passing through the tissue will vary in accordance with the changing amount of blood constituent in the tissue.

An example of a commercially available pulse oximeter is the Nellcor Incorporated Pulse Oximeter model N-200 (herein "N-200"). The N-200 is a microprocessor controlled device that measures oxygen saturation of hemoglobin using light from two light emitting diodes ("LEDs"), one having a discrete frequency of about 660 nanometers in the red light range and the other having a discrete frequency of about 925 nanometers in the infrared range. The N-200's microprocessor uses a four-state clock to provide a bipolar drive current for the two LEDs so that a positive current pulse drives the infrared LED and a negative current pulse drives the red LED. This illuminates the two LEDs alternately so that the transmitted light can be detected by a single photodetector. The clock uses a high strobing rate, roughly 1,500 Hz, and is consequently easy to distinguish from other light sources. The photodetector current changes in response to the red and infrared light transmitted and is converted to a voltage signal, amplified and separated by a two-channel synchronous detector—one channel for processing the red light wave form and the other channel for processing the infrared light waveform. The separated signals are filtered to remove the strobing frequency, electrical noise and ambient noise and then digitized by an analog to digital converter ("ADC"). As used herein, incident light and transmitted light refers to light generated by the LEDs or other light sources, as distinguished from ambient or environmental light.

The light source intensity can be adjusted to accommodate variations in patients' skin color, flesh thickness, hair, blood, and other variants. The light transmitted is thus modulated by the absorption of light in the blood pulse, particularly the arterial blood pulse or pulsatile component. The modulated light signal is referred to as the plethysmograph waveform, or the optical signal. The digital representation of the optical signal is referred to as the digital optical signal. The portion of the digital optical signal that refers to the pulsatile component is called the optical pulse.

The detected digital optical signal is processed by the microprocessor of the N-200 to analyze and identify arterial pulses and to develop saturation. The microprocessor decides whether or not to accept a detected pulse as corresponding to an arterial pulse by comparing the detected pulse against the pulse history. To be accepted, a detected pule must meet certain predetermined criteria, including the expected size of the pulse, when the pulse is expected to occur, and the expected ratio of the red light to infrared light in the detected optical pulse. Identified individual optical pulses accepted for processing are used to compute the oxygen saturation from the ratio of maximum and minimum pulse levels as seen by the infrared wavelength.

A problem with pulse oximeters is that the plethysmograph signal and the optically derived pulse rate may be subject to irregular variants in the blood flow that interfere with the detection of the blood flow characteristics. For example, when a patient moves, inertia may cause a slight change in the venous blood volume at the sensor site. This, in turn, alters the amount of light transmitted through the blood and the resetting optical pulse signal. These spurious pulses, called motion artifacts, may cause the oximeter to process the artifact waveform and provide erroneous data.

It is well known that electrical heart activity occurs simultaneously with the heartbeat and can be monitored externally and characterized by an electrocardiogram ('ECG') waveform. The ECG waveform comprises a complex waveform having several components that correspond to electrical heart activity. A QRS component relates to ventricular heart contraction. The R wave portion of the QRS component is typically the steepest wave therein, having the largest amplitude and slope, and may be used for indicating the onset of cardiovascular activity. The arterial blood pulse flows mechanically and its appearance in any part of the body typically follows the R wave of the electrical heart activity by a determinable period of time that remains essentially constant for a given patient.

One method to reduce or eliminate the effects of motion artifacts is to synchronize the ECG signal and the optical pulse signal and process the two signals to form a composite signal. This composite signal is then used to measure the level of oxygen saturation. This method is called ECG synchronization.

In the first stage of synchronization, the optical pulse signal is filtered to minimize the effects of electronic high frequency noise, using a low pass filter. Next, the oximeter positions the newly acquired optical pulse in memory, using the QRS complex as a reference point for aligning sequential signals. In other words, when the QRS complex occurs, the oximeter begins processing the optical pulse data.

In the third stage, the new optical pulse signal is combined with the composite of the signals that were previously stored in the memory. Signals are combined using an adjustable weighted algorithm wherein, when the new composite signal is calculated, the existing memory contents are weighted more heavily than the new optical signal pulse.

Finally, the oxygen saturation level is measured from the composite signal. This determinaton is on the ratios of the maximum and minimum transmission of red and infrared light. As each sequential QRS complex and optical pulse signal are acquired, the process of filtering,

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