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(54) METHOD AND SYSTEM FOR MEASURING MULTIPLE SIGNALS IN A BODY

VERFAHREN UND SYSTEM ZUR MESSUNG MEHRERER SIGNALE IN EINEM KÖRPER

PROCÉDÉ ET SYSTÈME POUR MESURER DE MULTIPLES SIGNAUX DANS UN CORPS

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to signal analysis, in particular, signal analysis of active sensors, e.g., pulse oximetry biometric measurements.

BACKGROUND

[0002] Certain biometric measurements are subject to noise which makes it very difficult to provide a proper analysis of the sensor signals. In particular, pulse oximetry measurements are noise sensitive. Pulse oximetry uses a pulse oximeter which is a non-invasive medical device that monitors the oxygen saturation of a patient's blood and heart rate.

[0003] Referring to Figures 5 and 6, depicted are schematics of a general overview block diagram and a more detailed block diagram of a prior technology pulse oximetry measurement system. A pulse oximeter monitors the oxygen saturation (SpO_2) of a human's blood based on the red light (600-750 nm wavelength) and infrared light (850-1000 nm wavelength) absorption characteristics of oxygenated hemoglobin (HbO_2) and deoxygenated hemoglobin (Hb). The pulse oximeter flashes red and infrared lights, e.g., light emitting diodes (LEDs), alternately through a finger to a photodiode. HbO_2 absorbs more infrared light and allows more red light to pass through. On the other hand, Hb absorbs more red light and allows more infrared light to pass through. The photodiode receives the non-absorbed light from each LED. The light intensity measurements for each red and infrared light source must be taken at different times and ambient light (background light noise) will affect these measurements. Flickering lights (e.g., fluorescent lights) as a noise source are difficult to eliminate.

[0004] Operation of the circuits shown in Figures 5, 6 and 7 are more fully explained in Application Note AN1525, "Pulse Oximeter Design Using Microchip's Analog Devices and dsPIC® Digital Signal Controllers (DSCs)" by Zhang Feng, published 2013 by Microchip Technology Inc., available at www.microchip.com. Figure 7 shows exemplary waveforms displaying the pulse signals from the pulse oximeter systems of Figures 5 and 6.

[0005] Document EP 0 502 717 A1 discloses a method of photoplethysmographics by phase-division multiplexing and demultiplexing. First and second carrier signals, distinguishable by phase, are respectively applied to infrared and red energy emitters. A detector receives the sum of the energy after modulation at the infrared and red wavelengths. The signal is then demultiplexed into its original first and second components, thereby allowing determining of both the infrared and red modulation components. EP 0 502 717 A1 suggests to use a sine wave as a first carrier.

[0006] Document US 2014/0214330 A1 discloses low power monitoring systems and a method. According to the document, various systems have been proposed which include a patient sensing device connected to a local monitor by way of a wireless link. Unfortunately, sensors that incorporate a wireless link may be limited to power provided on the sensor itself, which may be drained very quickly. US 2014/0214330 A1 accordingly suggests to decrease the amount of power used in an, e.g., photoplethysmograph, by configuring the sensor device to emit sporadic pulses of light rather than regular, frequent emission of light. Document EP 1 568 320 discloses simultaneous signal attenuation measurements utilizing frequency orthogonal random codes.

SUMMARY

[0007] Therefore a need exists for a noise immune sensor signal measurement method, system and apparatus, in particular for pulse oximetry measurements. This and other objects can be achieved by a system and method as defined in the independent claims. Further enhancements are characterized in the dependent claims.

[0008] According to an embodiment, a system for measuring multiple signals in a body according to claim 1 is provided.

[0009] According to a further embodiment, a digital filter may filter the correlated digital representations. According to a further embodiment, a heartbeat detection circuit may be coupled to an output of the digital filter. According to a further embodiment, a blood oxygen saturation (SpO_2) determination circuit may be coupled to an output of the digital filter. According to the embodiment of claim 1 the pseudo-random noise generator comprises a linear feedback shift register receiving a clock signal that generates a maximum length (ML) sequence, wherein the clock signal is also be coupled to the ADC. According to a further embodiment, the ADC may be triggered on a positive going edge of the clock signal and the pseudo-random noise generator may be triggered on a negative going edge of the clock signal. According to a further embodiment, the ML sequence may be phase shifted for each one of the light sources. According to the embodiment of claim 1, the ML sequence is be phase shifted for each one of a plurality of other sources. According to a further embodiment, the linear feedback shift register may comprise a plurality of shift registers that may be either added to or subtracted from based upon a corresponding output of the pseudo-random noise generator.

[0010] Further disclosed is a system comprising: at least one first digital-to-analog converter (DAC) having an analog output coupled to the at least one first light source; and at least one second digital-to-analog converter (DAC) having an analog output coupled to the at least one second light source; wherein the at least one first and second DACs control light intensities of the first and second light sources. According to a further embodiment, the first color light may be at substantially a red wavelength and the second color light may be at substantially an infrared wavelength. According to a further embodiment, the first color light may be at substantially a green wavelength and the second color light may be at substantially a yellow-green wavelength. According to a further embodiment, digital representations of ambient light samples may be subtracted from the digital representations of the sampled light amplitudes from the at least one first and second light sources. According to a further embodiment, interfaces for the at least one first and second light sources and the at least one light sensor, the pseudo-random noise generator, ADC, and correlation circuit may be provided by a microcontroller. According to a further embodiment, a communications interface may be coupled to the microcontroller and may provide oxygen saturation and heartbeat information. According to a further embodiment, the at least one first and second light sources may comprise light emitting diodes (LEDs) and the at least one light sensor may comprise at least one photo-diode or photo-transistor.

[0011] According to an embodiment, a method for measuring multiple signals in a body according to claim 11 is provided.

[0012] According to a further embodiment of the method, may comprise the step of filtering the correlated digital representations with a digital filter. According to a further embodiment, the step of determining oxygen saturation (SpO_2) of blood from the digital may be representations of the sampled light amplitudes. The method further comprises the step of phase shifting the pseudo-random times from the pseudo-random noise generator.

[0013] Further disclosed is a microcontroller configured for measuring multiple signals in a body may comprise: at least one first driver for turning on and off at least one first light source generating a first color light; at least one second driver for turning on and off at least one second light source generating a second color light; at least one analog input for receiving an output from at least one light sensor adapted for detecting light amplitudes, wherein the at least one first and second light sources and the at least one light sensor may be adapted for a portion of a body to be located therebetween; a pseudo-random noise generator coupled to the at least one first and second drivers for turning on and off the at least one first and second light sources at pseudo-random times; an analog-to-digital converter (ADC) for converting sampled light amplitudes received from the at least one light sensor into digital representations thereof; and a correlation circuit coupled to a digital output of the ADC and the pseudo-random noise generator, wherein the correlation circuit associates the digital representations with corresponding ones of the at least one first and second light sources.

[0014] Said disclosed microcontroller may comprise: at least one first digital-to-analog converter (DAC) coupled to at least one first analog output adapted for coupling to the at least one first light source; and at least one second digital-to-analog converter (DAC) coupled to at least one second analog output adapted for coupling to the at least second first light source; wherein the at least one first and second DACs control intensities of the first and second color lights.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] A more complete understanding of the present disclosure may be acquired by referring to the following description taken in conjunction with the accompanying drawings wherein:

Figure 1 illustrates a schematic block diagram of a pulse oximetry measurement system using PDM, according to a specific example embodiment of this disclosure;

Figure 2 illustrates a schematic block diagram of a pulse oximetry measurement system using PDM, according to another specific example embodiment of this disclosure;

Figure 3 illustrates a schematic timing diagram for the pulse oximetry measurement system shown in Figure 2;

Figure 4 illustrates exemplary waveforms of the pulse oximetry measurement systems shown in Figures 1 and 2, according to the teachings of this disclosure;

Figure 5 illustrates a schematic block diagram of a general overview of a prior technology pulse oximetry measurement system;

Figure 6 illustrates a more detailed schematic block diagram of a prior technology pulse oximetry measurement system;

Figure 7 illustrates exemplary waveforms of the prior technology pulse oximetry measurement systems shown in Figures 5 and 6; and

Figure 8 illustrates a schematic graphical plot of a ML sequence used to generate the red and IR signals, according to the teachings of this disclosure.

[0016] While the present disclosure is susceptible to various modifications and alternative forms, specific example embodiments thereof have been shown in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific example embodiments is not intended to limit the disclosure to the particular forms disclosed herein.

DETAILED DESCRIPTION

[0017] According to various embodiments of this disclosure, a pulse oximetry measurement system uses a pseudo-random noise (PN) generator to stimulate one or more light emitting diodes (LEDs). The light amplitudes from these LEDs, after passing through a part of a body, are detected by a phototransistor or photodiode and digitized with an analog-to-digital converter (ADC). The digitized light amplitude values are then re-correlated with the outgoing pseudo-random noise stimulus using phase division multiplexing. Spread spectrum techniques are known for their noise mitigation properties, and ability to pass multiple signals through the same medium without interference. Thus, these measurements can be performed on two or more LEDs with minimal interference from each other.

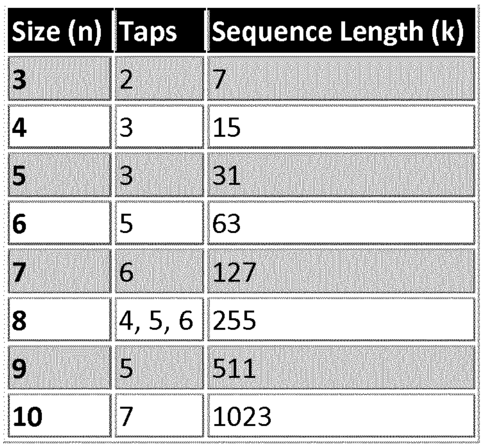
[0018] One problem faced by sensors utilizing a plurality of signal sources (LEDs in the case of the pulse oximeter) is like that faced by communications systems that have many users. Each LED must share the same sensor (photodiode). This is typically done by turning on each light source in sequence, and then taking each measurement in turn. So, each source gets its own slice of time in which the sensor can get its measurement. This is called time-division multiplexing (TDM). The chief drawback to using TDM is that adding more sensors, while keeping all else the same, requires more time to get measurements from every source, reducing the overall sample rate for each source. Also, since the signal you’re trying to measure (arterial pulsation) is a changing signal, the measurements are biased by the order in which they were taken. A high sample rate can help reduce both concerns, but the last concern is that current techniques require a background measurement to be subtracted from the source measurements.

[0019] The method that many wireless applications have arrived at is to use code division multiple access (CDMA). In this technique, systems use coded sequences (e.g., gold codes) that have a very low cross-correlation between each other. This allows multiple users of the spectrum to coexist simultaneously with very little cross-talk between codes. In digital systems, that minimal amount of cross-talk can be discarded easily, but it is enough to cause issues when trying to take precise analog measurements. According to the teachings of this disclosure, a pulse oximeter may use a maximal length (ML) sequence, (maximal length sequences can also be used to generate gold codes) but instead of using multiple sequences like in CDMA, only one sequence is required and may be phase shifted for each LED source. This will be referred to hereinafter as "phase division multiplexing (PDM)", and works because of certain properties of ML sequences.

[0020] A ML sequence gets its name because it represents the maximum number of (non-zero) states that can be represented by a given number of bits. For example, given 4-bits, the sequence will repeat after every 15 (2n-1) states or "chips". Thus, there’s almost an equal number of Is, and 0s in every ML sequence (exactly one fewer 0s than Is). By convention, the 0’s may be treated as -1’s. This causes the circular auto-correlation of the sequence to peak at 15 (again, 2n-1) when lined up. That should be trivial to see, since every multiplication is either 1x1 or -1x-1 and so you just sum up the 15 results to get 15. What is significant is that the off-peak response is a flat-1 for the entire correlation function. This means that if the same sequence is repeated and shifted, the constituent signals may be separated by using correlation.

[0021] This property is illustrated in Figure 8. The plot at the top shows the ML sequence. The ML sequence is shifted to generate the "red", and "IR" signals. The ADC 106 sees the combined signal, and the final plot shows the circular cross-correlation between the reference, and the signal. The two peaks line up with the phase shifts for the red, and IR signals. The correlation for all other phase offsets is zero. This means another 13 sensor sources could be slotted in without impacting the measurement period or the results of the other two sources. That represents a significant advantage over traditional TDM methods.

[0022] ML sequences may be generated using Linear Feedback Shift Registers (LFSRs). These can be implemented in either hardware or software. LFSRs can be made using any length of shift register of three or more flip-flops, and XORing the outputs of a set of flip-flops back to the input of the shift register. Table 1 below provides a selection of valid LFSR parameters. An LFSR may have multiple taps, and there will always be at least two tap options for any given size. The LFSR configuration used in Figure 2 may be constructed using configurable logic cells (CLCs) 238.



Size (n)	Taps	Sequence Length (k)
3	2	7
4	3	15
5	3	31
6	5	63
7	6	127
8	4, 5, 6	255
9	5	511
10	7	1023

[0023] Typically, conventional reflectance pulse oximetry uses two light wavelengths, Red and Infrared (IR). Alternatively, Green and Yellow-Green may be used. The heart rate of the person wearing the light sensor may also be determined from the signals received therefrom. According to the teachings of this disclosure, a pulse oximetry measurement system correlates the measured light intensities with a pseudo-random noise (PN) generator, and may then compute the measured and correlated peak-to-peak detected light amplitudes to obtain a ratio between these light amplitudes for determining oxygen saturation in the blood.

[0024] In comparison to the proposed solution disclosed herein, prior technology pulse oximetry measurement systems lack of randomization of measurement sequences leads to measurement bias. Flickering lights (*e.g.*, fluorescent lights) as a noise source are difficult to eliminate. Movement presents difficulty in measuring heartbeat or SP/O_2. No consumer wrist or touch oximeters are available yet.

[0025] Referring now to the drawings, the details of example embodiments are schematically illustrated. Like elements in the drawings will be represented by like numbers, and similar elements will be represented by like numbers with a different lower case letter suffix.

[0026] Referring now to Figure 1, depicted is a schematic block diagram of a pulse oximetry measurement system using phase division multiplexing (PDM), according to a specific example embodiment of this disclosure. The pulse oximetry measurement system using PDM, generally represented by the numeral 100, may comprise analog brightness control 102, digital LED control 104, an analog-to-digital converter (ADC) 106, a correlation circuit (match filtering) 108, digital filtering 110, *e.g.*, finite impulse response (FIR) and/or infinite impulse response (IIR) filters; heartbeat detection 112, and oxygen saturation determination (SpO_2) 114. The aforementioned elements may be provided with an analog/digital mixed signal integrated circuit, *e.g.*, a microcontroller. The pulse oximetry measurement system 100 may further comprise at least one red light source (*e.g.*, Red LED) 116, at least one infrared light source (*e.g.,* IR LED) 118, at least one light sensor (*e.g.,* photodiode, phototransistor) 120, a current sensing resistor 122, and switches 124 and 126, *e.g.*, metal oxide semiconductor field effect transistor (MOSFET), bipolar transistor, junction field effect transistor (JFET), and the like. The resistor 122 may be used to provide a voltage signal to the ADC 106 that is representative of the light intensity received by the at least one light sensor 120. Resistors 142 and 144 limit the currents through the LEDs 116 and 118, respectively. It is contemplated and within the scope of this disclosure that Green and Yellow-Green light sources may be used in combination with and/or in place of the Red and Infrared light sources. A plurality of light sources may be used and are contemplated herein. A communications interface 150 may be provided in the microcontroller for communicating with external displays and controls.

[0027] The analog brightness control 102 may comprise a first digital-to-analog converter (DAC) 130, a first buffer amplifier 132, a second DAC 134 and a second buffer amplifier 136. The digital LED control 104 may comprise a pseudo-random noise generator 138 and a clock or timing source 140. The outputs of the DACs 130 and 134 may be coupled to buffer amplifiers 132 and 136, respectively, *e.g.*, unity gain operational amplifiers, and used to control the voltage on the collectors (or drains if using FETs) of the switches (transistors) 124 and 126, which in turn control how bright the LEDs 116 and 118 are when the DC voltages from the buffer amplifiers 132 and 136, respectively, are applied when each respective switch 124 or 126 is turned on.

[0028] The clock or timing source 140 may be used to drive the hardware or software based pseudo-random noise (PN) generator 138. The pseudo-random noise generator 138 may have one or more outputs that may be coupled to the bases (or gates) of the switches (transistors) 124 and 126. The property of a maximum length (ML) sequence generates (*e.g.*, by a linear feedback shift register) code that sums up to $(2^n)-1$ when correlated in phase, where n is the number of flip-flops or bits in a shift register 238 as shown in Figure 2. When out of phase, the correlation = -1. Coherent noise is exponentially reduced. White noise may be reduced by averaging. Multiple sensors may use the same code at different phases (*e.g.*, PDM) to measure multiple signals simultaneously. A phase that isn't tied to a sensor may be used to measure background noise and then may be subtracted from the other sensor measurements.

[0029] Referring now to Figure 2, depicted is a schematic block diagram of a pulse oximetry measurement system using PDM, according to another specific example embodiment of this disclosure. The pulse oximetry measurement system using PDM, generally represented by the numeral 200, may comprise analog brightness control 202, digital LED control 204, an analog-to-digital converter (ADC) 106, a correlation circuit (match filtering) 108a, digital filtering 110, e.g., finite impulse response (FIR) and/or infinite impulse response (IIR) filters; heartbeat detection 112, and oxygen saturation determination (SpO_2) 114. The aforementioned elements may be provided with an analog/digital mixed signal integrated circuit, e.g., a microcontroller. The pulse oximetry measurement system 200 may further comprise at least one red light source (*e.g.,* Red LED) 116, at least one infrared light source (*e.g.,* IR LED) 118, 118a, at least one light sensor (*e.g.*, photodiode, phototransistor) 120, a current sensing resistor 122, and switches 124 and 126, *e.g.*, metal oxide semiconductor field effect transistor (MOSFET), bipolar transistor, junction field effect transistor (JFET), and the like. The resistor 122 may be used for providing a voltage signal to the ADC 106 that is representative of the light intensity received by the at least one light sensor 120. Resistors 142, 144 and 144a limit the currents through the LEDs 116, 118 and 118a, respectively. It is contemplated and within the scope of this disclosure that Green and Yellow-Green light sources may be used in combination with and/or in place of the Red and Infrared light sources. A plurality of light sources may be used and are contemplated herein. A communications interface 150 may be provided in the microcontroller for communicating with external displays and controls.

[0030] The analog brightness control 102 may comprise a first digital-to-analog converter (DAC) 130, a first buffer amplifier 132, a second DAC 134, a second buffer amplifier 136, a third DAC 134a, and a third buffer amplifier 136a. The digital LED control 204 may comprise a pseudo-random noise generator comprising shift registers 238 and a clock source 140. The outputs of the DACs 130,134 and 134a may be coupled to buffer amplifiers 132, 136 and 136a, respectively, *e.g.*, unity gain operational amplifiers, and used to control the voltage on the collectors (or drains if using FETs) of the switches 124, 126 and 126a, which in turn control how bright the LEDs 116, 118 and 118a are when the DC voltages from the buffer amplifiers 132, 136 and 136a, respectively, are applied when each respective switch 124, 126 or 126a is turned on. A capture compare pulse width modulation (CCP) module 240 (*e.g.*, PDM) may provide phase control for triggering the ADC 106.

[0031] The digital LED control 204 may comprise a clock or timing source 140 that may be used to drive a pseudo-random noise (PN) generator implemented as a linear feedback shift register (LFSR) and comprising shift registers 238a, 238b, 238c and 238d that produce a maximum length sequence (ML) sequence code. The same signals that control the switching of the LEDs may also be used to correlate the ADC 106 conversion results. This allows the measurements to be effectively taken simultaneously. This method may use a pair of pseudo-random noise codes (PN codes) to stimulate one to many LEDs or other sensors. Measurements of the LEDs are effectively "simultaneous," as well as ambient light measurements. Pseudo-random measurements of IR and Red LEDs eliminate sequence biasing and the problem of flickering background lights. Motion is not removed with short PN codes, but may be eliminated by using longer PN codes.

[0032] There is also one position of the LFSR that may be correlated but is not used to switch on a light source (LED). This may be used to get a measurement of the ambient light or background noise that may then be subtracted from the other two light source (red and IR) measurements. The PN sequence must repeat deterministically. Figure 3 shows an exemplary timing diagram of control signals for the Red and IR LEDs. The PN sequence is shown for the Red and IR LEDs. The pattern may take just under 4 milliseconds to repeat, and measurements are effectively taken for red, IR and ambient light over the course of the same approximately 3.75 millisecond period. Subtraction of this background noise is optional as the correlation already diminishes the background/ambient noise significantly.

[0033] The pseudo-random noise generator (shift registers 238) may have one or more outputs that may be coupled to the bases (or gates) of the transistors 124 and 126. A maximum length (ML) sequence is a type of pseudorandom binary sequence. The properties of the ML sequence, *e.g.*, generated by a linear feedback shift register 238, are when correlated in phase, sum up to $(2^n)-1$, where n is the number of flip-flops or bits in the shift register 238. When out of phase, the correlation = -1. Coherent noise is exponentially reduced. White noise is reduced by averaging. Multiple sensors may use the same code at different phases (PDM) to measure multiple signals simultaneously. A phase that isn't tied to a sensor may be used to measure background noise and then be subtracted from the other sensor measurements. The generated ML sequence is provided by the ML sequence. For example, using a three (3) bit LFSR the ML sequence may be 1, 1, 1, -1, 1, 1, -1.

[0034] In phase:

Reference	*	Signal	=	Product
1	*	1	=	1
1	*	1	=	1

(continued)

Reference	*	Signal	=	Product
1	*	1	=	1
-1	*	-1	=	1
-1	*	-1	=	1
1	*	1	=	1
-1	*	-1	=	1
		Sum:		7

Where $n = 3$ and $2^n-1 = 7$. If one of the above columns is shifted up or down (with wrap-around), the products become out of Phase:

[0035] Out of phase:

Reference	*	Signal	=	Product
1	*	-1	=	-1
1	*	1	=	1
1	*	1	=	1
-1	*	1	=	-1
-1	*	-1	=	1
1	*	-1	=	-1
-1	*	1	=	-1
		Sum:		-1

Regardless of LFSR length, the result when the two columns are out of phase with each other will always be -1. Since there cannot be a negative light, the results may be represented as:

[0036] In Phase:

Reference	*	Signal	=	Product
1	*	1	=	1
1	*	1	=	1
1	*	1	=	1
-1	*	0	=	0
-1	*	0	=	0
1	*	1	=	1
-1	*	0	=	0
		Sum:		4

Where $2^{(n-1)} = 4$

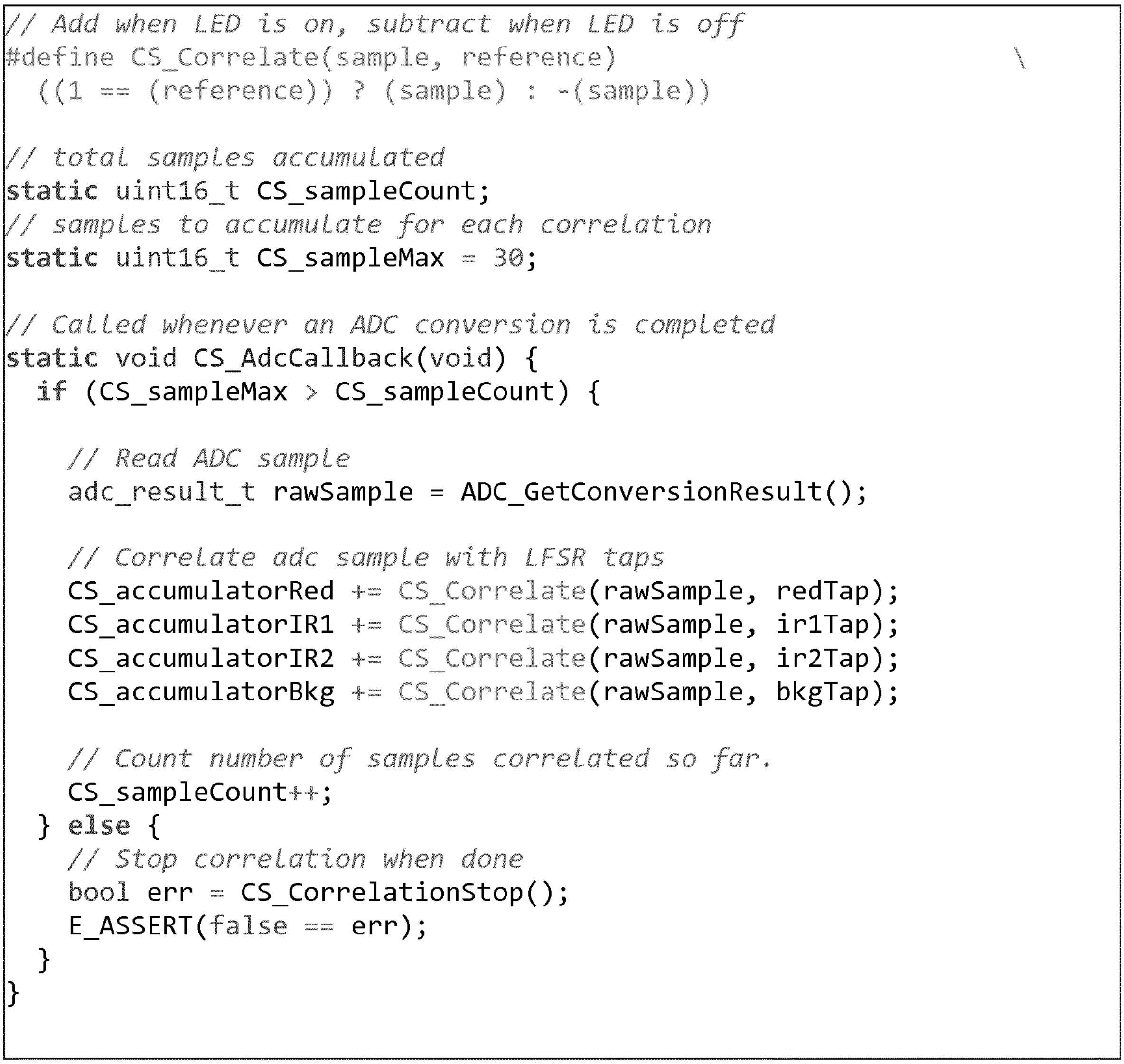
[0037] Out of phase:

Reference	*	Signal	=	Product
1	*	0	=	0
1	*	1	=	1
1	*	1	=	1
-1	*	1	=	-1
-1	*	0	=	0
1	*	0	=	0
-1	*	1	=	-1
		Sum:		0

In this case, the sum when out of phase will always be 0.

[0038] The ADC 106 as shown in Figures 1 and 2 may be triggered using hardware logic or software programming at any point in time except at the active edge for the PN generator (shift registers 238). The ADC 106 may be triggered one or more times per clock period. As shown in Figure 2, the same clock source 140 may be used for both the ADC 106 and the PN generator (shift registers 238). The ADC 106 may be triggered on the positive edge and the PN generator may be triggered on the negative edge of the clock signal. The CCP module 240 provides for phase control over when the ADC 106 is triggered relative to when the LFSR shift registers 238 are shifted.

[0039] For correlation, each ADC sample may be duplicated into n+ 1 shift registers (where n is the number of active sensors or LEDs). Each shift register is either added to or subtracted from, based upon the corresponding output of the PN generator. That is, if LED1 is on, and LED2 is off, the LED1Reg = previousLEDlReg + ADCSamp, and LED2Reg = previousLED2Reg - ADCSamp. After some number of full repetitions of the PN code, the shift registers may be read and then zeroed by the application software. This may also be done in hardware with the appropriate architecture. The correlation circuit (match filtering) 108 and 108a checks if the referenced (LED) is on, then adds if it is, and subtracts if the LED is off. Example coding is shown as follows. One having ordinary skill in the art of software coding and having the benefit of this disclosure could write different code that accomplishes the same purpose, and is contemplated herein.



```
// Add when LED is on, subtract when LED is off
#define CS_Correlate(sample, reference)                         \
  ((1 == (reference)) ? (sample) : -(sample))

// total samples accumulated
static uint16_t CS_sampleCount;
// samples to accumulate for each correlation
static uint16_t CS_sampleMax = 30;

// Called whenever an ADC conversion is completed
static void CS_AdcCallback(void) {
  if (CS_sampleMax > CS_sampleCount) {

    // Read ADC sample
    adc_result_t rawSample = ADC_GetConversionResult();

    // Correlate adc sample with LFSR taps
    CS_accumulatorRed += CS_Correlate(rawSample, redTap);
    CS_accumulatorIR1 += CS_Correlate(rawSample, ir1Tap);
    CS_accumulatorIR2 += CS_Correlate(rawSample, ir2Tap);
    CS_accumulatorBkg += CS_Correlate(rawSample, bkgTap);

    // Count number of samples correlated so far.
    CS_sampleCount++;
  } else {
    // Stop correlation when done
    bool err = CS_CorrelationStop();
    E_ASSERT(false == err);
  }
}
```

[0040] Digital filtering may be used for additional filtering to smooth out the signal response and remove DC components if necessary. These digital filters may be any combination of FIR and/or IIR DSP elements, as known by those having ordinary skill in the digital filter arts and having the benefit of this disclosure.

[0041] For heartbeat detection, any method may be used. A software phase-locked-loop (PLL) may be used for implementation of heartbeat detection, or a state machine representation may also be used. The peak-to-peak signal output from the LEDs may be measured over the period of each heartbeat. These values can be further filtered, and the ratio of IR/Red or Green/Yellow-Green light intensities may be used in determining oxygen saturation levels (SP/O_2).

[0042] Figure 4 shows exemplary waveforms displaying the pulse signals according to various embodiments. The waveforms shown in Figure 4 are taken at the output of the correlation (match filter) 108 before any digital filtering 110 is applied thereto. These waveforms provide for a superior signal range, even before subsequent filtering, compared to the prior technology signal range that has been filtered and is shown in Figure 7. In summary, signal generation may be provided in hardware, for example using the configurable logic circuits available in PIC microcontrollers such as the PIC16F1778. Filtering arithmetic requires only adding and subtracting. A communications interface (not shown) may be coupled to or part of the microcontroller and provide oxygen saturation and heartbeat information to a display and/or computer (not shown).

[0043] It is contemplated and within the scope of this disclosure that the signal analysis as discussed hereinabove using a pseudo-random noise generator is not restricted to pulse oximeter measurement but may also apply to other sensor signal evaluations that require a driving signal to produce a measurement signal. Hence, the method as proposed herein may apply to various other sensor signal evaluation systems and methods. The present invention is solely defined by the scope of the appended claims.

Claims

1. A system for measuring multiple signals in a body, said system comprising:

   at least one first light source (116) generating a first color light;
   at least one second light source (118) generating a second color light;
   at least one light sensor (120) adapted for detecting light amplitudes, wherein the at least one first and second light sources (116, 118) and the at least one light sensor (120) are adapted for a portion of a body to be located therebetween;
   a pseudo-random noise generator (138), comprising one or more outputs, adapted for turning on and off the at least one first and second light sources (116, 118) at pseudo-random times, wherein the pseudo-random noise generator (138) comprises a linear feedback shift register adapted to receive a clock signal and to generate a maximum length (ML) sequence used for driving said first and second light sources (116; 118), wherein the clock signal is also coupled to the ADC (106), wherein the ML sequence is phase shifted for each one of the light sources (116, 118);
   an analog-to-digital converter (ADC, 106) adapted to convert sampled light amplitudes from the at least one light sensor into digital representations thereof; and
   a correlation circuit (108) adapted to use phase division multiplexing coupled to a digital output of the ADC (106) and the pseudo-random noise generator (138), wherein the correlation circuit is adapted to associate the digital representations with the one or more outputs of the pseudo-random noise generator (138) for the at least one first and second light sources (116, 118).

2. The system according to claim 1, further comprising a digital filter (110) adapted to filter the correlated digital representations.

3. The system according to claim 1 or claim 2, further comprising a heartbeat detection circuit (112) and/or a blood oxygen saturation (SpO_2) determination circuit (114) coupled to an output of the digital filter.

4. The system according to one of the preceding claims, wherein the ADC (106) is adapted to be triggered on a positive going edge of the clock signal and the pseudo-random noise generator (138) is adapted to be triggered on a negative going edge of the clock signal.

5. The system according to claim 1, wherein the linear feedback shift register comprises a plurality of shift registers that are adapted to be either added to or subtracted from the ADC sample based upon a corresponding output of the pseudo-random noise generator (138).

6. The system according to one of the preceding claims, further comprising:

   at least one first digital-to-analog converter (DAC, 130) having an analog output coupled to the at least one first light source; and
   at least one second digital-to-analog converter (DAC, 134) having an analog output coupled to the at least one

second light source;
wherein the at least one first and second DACs (130, 134) are adapted to control light intensities of the first and second light sources (116, 118).

7. The system according to one of the preceding claims, wherein the system is adapted to subtract digital representations of ambient light samples from the digital representations of the sampled light amplitudes from the at least one first and second light sources (116, 118).

8. The system according to one of the preceding claims, wherein the at least one first and second light sources (116, 118) comprise light emitting diodes (LEDs) and the at least one light sensor (120) comprises at least one photo-diode or photo-transistor.

9. The system according to one of the preceding claims, wherein the pseudo-random noise generator (138), the ADC (106) and the correlation circuit (108) are formed within a microcontroller.

10. The system according to claim 9 in combination with claim 6, wherein the microcontroller comprises said first and second DACs (130, 134), the microcontroller further comprising:

at least one first driver (136) configured for providing a first drive signal for the at least one first light source (116);
at least one second driver configured for providing a second drive signal for the at least one second light source (118);
at least one analog input coupled with said ADC configured to receive an output from the at least one light sensor (120).

11. A method for measuring multiple signals in a body, said method comprising the steps of:

generating a first color light with at least one first light source (116);
generating a second color light with at least one second light source (118);
detecting light amplitudes with at least one light sensor (120), wherein the at least one first and second light sources (116, 118)and the at least one light sensor (120 are adapted for a portion of a body to be located therebetween;
turning on and off the at least one first and second light sources (116, 118) at pseudo-random times generated by a pseudo-random noise generator (138), wherein the pseudo-random noise generator (138) comprises a linear feedback shift register receiving a clock signal that generates a maximum length (ML) sequence used for driving said light sources (116; 118), wherein the clock signal is also coupled to the ADC (106), wherein the ML sequence is phase shifted for each one of the light sources (116, 118);
converting sampled light amplitudes from the at least one light sensor into digital representations thereof with an analog-to-digital converter (ADC, 106); and
correlating the digital representations of the sampled light amplitudes using phase division multiplexing with one or more outputs of the pseudo-random noise generator (138) for the at least one first and second light sources (116, 118) using the pseudo-random times from the pseudo-random noise generator (138).

12. The method according to claim 11, further comprising the step of filtering the correlated digital representations with a digital filter (110).

13. The method according to one of claims 11 - 12, further comprising the step of phase shifting the pseudo-random times from the pseudo-random noise generator (138).

14. The method according to one of the preceding claims 11-13, further comprising the step of
determining oxygen saturation (Sp02) of blood from the digital representations of the sampled light amplitudes.

15. The method according to one of the preceding claims 11-14, wherein for correlation:

each ADC sample is duplicated into n+ 1 shift registers, wherein n is the number of active light sources;
wherein, if a light source is on, then an associated shift register is set to a previous value of the associated shift register plus the ADC sample and if and a light source is off, an associated shift register is set to a previous value of the associated shift register minus the ADC sample.

Patentansprüche

1. System zur Messung mehrerer Signale in einem Körper, wobei das System aufweist:

   zumindest eine erste Lichtquelle (116), die ein erstes Farblicht erzeugt;
   zumindest eine zweite Lichtquelle (118), die ein zweites Farblicht erzeugt;
   zumindest einen Lichtsensor (120), der zum Erfassen von Lichtamplituden geeignet ist, wobei die zumindest eine erste und zumindest eine zweite Lichtquelle (116, 118) und der zumindest eine Lichtsensor (120) dazu geeignet sind, dass sich ein Teil eines Körpers dazwischen befindet;
   einen Pseudozufallsrauschgenerator (138), der einen oder mehrere Ausgänge aufweist, die zum Ein- und Ausschalten der zumindest einen ersten und zumindest einen zweiten Lichtquelle (116, 118) zu Pseudozufallszeiten geeignet sind, wobei der Pseudozufallsrauschgenerator (138) 138) ein lineares Rückkopplungsschieberegister aufweist, das geeignet ist, ein Taktsignal zu empfangen und eine Sequenz maximaler Länge (ML) zu erzeugen, die zum Ansteuern der ersten und zweiten Lichtquelle (116; 118) verwendet wird, wobei das Taktsignal auch mit dem ADC (106) gekoppelt ist, wobei die ML-Sequenz für jede der Lichtquellen (116, 118) phasenverschoben ist;
   einen Analog-Digital-Wandler (ADC, 106), der geeignet ist, abgetastete Lichtamplituden von dem zumindest einen Lichtsensor in digitale Repräsentationen davon umzuwandeln; und
   eine Korrelationsschaltung (108), die geeignet ist, mit einem digitalen Ausgang des ADC (106) und dem Pseudozufallsrauschgenerator (138) gekoppeltes Phasenteilungsmultiplexing zu verwenden, wobei die Korrelationsschaltung geeignet ist, die digitalen Repräsentationen dem einen oder den mehreren Ausgängen des Pseudozufallsrauschgenerators(138) für die zumindest eine erste und zumindest eine zweite Lichtquelle (116, 118) zuzuordnen.

2. System gemäß Anspruch 1, das weiterhin ein digitales Filter (110) aufweist, das zum Filtern der korrelierten digitalen Repräsentationen geeignet ist.

3. System gemäß Anspruch 1 oder Anspruch 2, das weiterhin eine Herzschlagdetektionsschaltung (112) und / oder eine Blutsauerstoffsättigungs-(SpO_2) Bestimmungsschaltung (114) aufweist, die mit einem Ausgang des digitalen Filters gekoppelt ist.

4. System gemäß einem der vorhergehenden Ansprüche, wobei der ADC (106) angepasst ist, an einer ins Positive gehenden Flanke des Taktsignals ausgelöst zu werden, und der Pseudozufallsrauschgenerator(138) angepasst ist, an einer ins Negative gehenden Flanke des Taktsignals ausgelöst zu werden.

5. System gemäß Anspruch 1, wobei das lineare Rückkopplungsschieberegister eine Vielzahl von Schieberegistern aufweist, die angepasst sind, um basierend auf einer zugehörigen Ausgabe des Pseudozufallsrauschgenerators (138) entweder zu dem ADC-Abtastwert addiert oder von diesem subtrahiert zu werden.

6. System gemäß einem der vorhergehenden Ansprüche, das weiterhin aufweist:

   zumindest einen ersten Digital-Analog-Wandler (DAC, 130), der einen analogen Ausgang aufweist, der mit der zumindest einen ersten Lichtquelle gekoppelt ist; und
   zumindest einen zweiten Digital-Analog-Wandler (DAC, 134), der einen analogen Ausgang aufweist, der mit der zumindest einen zweiten Lichtquelle gekoppelt ist;
   wobei der zumindest eine erste und der zumindest eine zweite DAC (130, 134) angepasst sind, um Lichtintensitäten der ersten und zweiten Lichtquellen (116, 118) zu steuern.

7. System gemäß einem der vorhergehenden Ansprüche, wobei das System geeignet ist, digitale Repräsentationen von Umgebungslichtabtastungen der digitalen Repräsentationen der abgetasteten Lichtamplituden der zumindest einen ersten und zumindest einen zweiten Lichtquelle (116, 118) zu subtrahieren.

8. System gemäß einem der vorhergehenden Ansprüche, wobei die zumindest eine erste und zumindest eine zweite Lichtquelle (116, 118) Leuchtdioden (LEDs) aufweisen und der zumindest eine Lichtsensor (120) zumindest eine Fotodiode oder Fototransistor aufweist.

9. System gemäß einem der vorhergehenden Ansprüche, wobei der Pseudozufallsrauschgenerator (138), der ADC (106) und die Korrelationsschaltung (108) in einem Mikrocontroller ausgebildet sind.

10. System gemäß Anspruch 9 in Kombination mit Anspruch 6, wobei der Mikrocontroller die ersten und zweiten DACs (130, 134) aufweist, wobei der Mikrocontroller weiterhin aufweist:

zumindest einen ersten Treiber (136), der zum Bereitstellen eines ersten Ansteuersignals für die zumindest eine erste Lichtquelle (116) ausgebildet ist;
zumindest einen zweiten Treiber, der zum Bereitstellen eines zweiten Ansteuersignals für die zumindest eine zweite Lichtquelle (118) ausgebildet ist;
zumindest einen Analogeingang, der mit dem ADC gekoppelt ist, der zum Empfangen eines Ausgangs des zumindest einen Lichtsensors (120) ausgebildet ist.

11. Verfahren zur Messung mehrerer Signale in einem Körper, wobei das Verfahren die folgenden Schritte aufweist:

Erzeugen eines ersten Farblichts mit zumindest einer ersten Lichtquelle (116);
Erzeugen eines zweiten Farblichts mit zumindest einer zweiten Lichtquelle (118);
Erfassen von Lichtamplituden mit zumindest einem Lichtsensor (120), wobei die zumindest eine erste und zumindest eine zweite Lichtquellen (116, 118) und der zumindest eine Lichtsensor (120) dazu geeignet sind, dass sich ein Teil eines Körpers dazwischen befindet;
Ein- und Ausschalten der zumindest einen ersten und zumindest einen zweiten Lichtquellen (116, 118) zu Pseudozufallszeiten, die von einem Pseudozufallsrauschgenerator (138) erzeugt werden, wobei der Pseudozufallsrauschgenerator (138) ein lineares Rückkopplungsschieberegisteraufweist, das ein Taktsignal empfängt, das eine Sequenz maximaler Länge (ML) erzeugt, die zum Ansteuern der Lichtquellen (116; 118) verwendet wird, wobei das Taktsignal auch mit dem ADC (106) gekoppelt ist, wobei die ML-Sequenz für jede der Lichtquellen (116, 118) phasenverschoben ist;
Umwandeln von abgetasteten Lichtamplituden des zumindest einen Lichtsensors in digitale Repräsentationen davon mit einem Analog-Digital-Wandler (ADC, 106); und
Korrelieren der digitalen Repräsentationen der abgetasteten Lichtamplituden unter Verwendung von Phasenteilungsmultiplexing mit einem oder mehreren Ausgängen des Pseudozufallsrauschgenerators(138) für die zumindest eine erste und zumindest eine zweite Lichtquellen (116, 118) unter Verwendung der Pseudozufallszeiten von dem Pseudozufallsrauschgenerator (138).

12. Verfahren gemäß Anspruch 11, das weiterhin den Schritt des Filterns der korrelierten digitalen Repräsentationen mit einem digitalen Filter (110) aufweist.

13. Verfahren gemäß einem der Ansprüche 11 bis 12, das weiterhin den Schritt der Phasenverschiebung der Pseudozufallszeiten von dem Pseudozufallsrauschgenerator (138) aufweist.

14. Verfahren gemäß einem der vorhergehenden Ansprüche 11 bis 13, das weiterhin den Schritt des Bestimmens der Sauerstoffsättigung (SpO_2) von Blut aus den digitalen Repräsentationen der abgetasteten Lichtamplituden aufweist.

15. Verfahren gemäß einem der vorhergehenden Ansprüche 11 bis 14, wobei zur Korrelation:

jede ADC-Abtastung in n + 1 Schieberegister dupliziert wird, wobei n die Anzahl der aktiven Lichtquellen ist;
wobei, wenn eine Lichtquelle eingeschaltet ist, ein zugehöriges Schieberegister auf einen vorherigen Wert des zugeordneten Schieberegisters plus des ADC-Abtastwerts gesetzt wird und wenn und eine Lichtquelle ausgeschaltet ist, ein zugehöriges Schieberegister auf einen vorherigen Wert des zugehörigen Schieberegisters abzüglich des ADC-Abtastwerts gesetzt wird.

Revendications

1. Système pour mesurer des multiples signaux dans un corps, ledit système comprenant :

au moins une première source de lumière (116) générant une première lumière de couleur ;
au moins une seconde source de lumière (118) générant une seconde lumière de couleur ;
au moins un capteur de lumière (120) apte à détecter des amplitudes de lumière, dans lequel ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118) et ledit au moins un capteur de lumière (120) sont adaptés afin qu'une partie d'un corps soit située entre eux ;
un générateur de bruit pseudo-aléatoire (138), comprenant une ou plusieurs sorties, apte à mettre sous tension

et hors tension ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118) à des instants pseudo-aléatoires, dans lequel le générateur de bruit pseudo-aléatoire (138) comprend un registre à décalage à rétroaction linéaire apte à recevoir un signal d'horloge et à générer une séquence de longueur maximale (ML) utilisée pour piloter lesdites première et seconde sources de lumière (116, 118), dans lequel le signal d'horloge est également couplé au convertisseur ADC (106), dans lequel la séquence ML est déphasée pour chacune des sources de lumière (116, 118) ;
un convertisseur analogique-numérique (ADC, 106) apte à convertir des amplitudes de lumière échantillonnées en provenance dudit au moins un capteur de lumière en des représentations numériques connexes ; et
un circuit de corrélation (108) apte à utiliser un multiplexage par répartition en phase couplé à une sortie numérique du convertisseur ADC (106) et au générateur de bruit pseudo-aléatoire (138), dans lequel le circuit de corrélation est apte à associer les représentations numériques à ladite une ou auxdites plusieurs sorties du générateur de bruit pseudo-aléatoire (138) pour ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118).

2. Système selon la revendication 1, comprenant en outre un filtre numérique (110) apte à filtrer les représentations numériques corrélées.

3. Système selon la revendication 1 ou 2, comprenant en outre un circuit de détection de battements cardiaques (112) et/ou un circuit de détermination de saturation en oxygène sanguin (SpO_2) (114) couplé(s) à une sortie du filtre numérique.

4. Système selon l'une quelconque des revendications précédentes, dans lequel le convertisseur ADC (106) est apte à être déclenché sur un front montant positif du signal d'horloge et le générateur de bruit pseudo-aléatoire (138) est apte à être déclenché sur un front montant négatif du signal d'horloge.

5. Système selon la revendication 1, dans lequel le registre à décalage à rétroaction linéaire comprend une pluralité de registres à décalage qui sont aptes à être soit ajoutés à l'échantillon de convertisseur ADC, soit soustraits de celui-ci, sur la base d'une sortie correspondante du générateur de bruit pseudo-aléatoire (138).

6. Système selon l'une quelconque des revendications précédentes, comprenant en outre :

au moins un premier convertisseur numérique-analogique (DAC, 130) présentant une sortie analogique couplée à ladite au moins une première source de lumière ;
au moins un second convertisseur numérique-analogique (DAC, 134) présentant une sortie analogique couplée à ladite au moins une seconde source de lumière ;
dans lequel ledit au moins un premier convertisseur DAC et ledit au moins un second convertisseur DAC (130, 134) sont aptes à commander des intensités lumineuses des première et seconde sources de lumière (116, 118).

7. Système selon l'une quelconque des revendications précédentes, dans lequel le système est apte à soustraire des représentations numériques d'échantillons de lumière ambiante des représentations numériques des amplitudes de lumière échantillonnées provenant de ladite au moins une première source de lumière et de ladite au moins une seconde source de lumière (116, 118).

8. Système selon l'une quelconque des revendications précédentes, dans lequel ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118) comprennent des diodes électroluminescentes (LED) et ledit au moins un capteur de lumière (120) comprend au moins une photodiode ou un phototransistor.

9. Système selon l'une quelconque des revendications précédentes, dans lequel le générateur de bruit pseudo-aléatoire (138), le convertisseur ADC (106) et le circuit de corrélation (108) sont formés dans un microcontrôleur.

10. Système selon la revendication 9, lorsqu'elle dépend de la revendication 6, dans lequel le microcontrôleur comprend lesdits premier et second convertisseurs DAC (130, 134), le microcontrôleur comprenant en outre :

au moins un premier pilote (136) configuré de manière à fournir un premier signal d'attaque pour ladite au moins une première source de lumière (116) ;
au moins un second pilote configuré de manière à fournir un second signal d'attaque pour ladite au moins une seconde source de lumière (118) ;
au moins une entrée analogique couplée audit convertisseur ADC, configurée de manière à recevoir une sortie

en provenance dudit au moins un capteur de lumière (120).

11. Procédé de mesure des multiples signaux dans un corps, ledit procédé comprenant les étapes ci-dessous consistant à :

générer une première lumière de couleur avec au moins une première source de lumière (116) ;
générer une seconde lumière de couleur avec au moins une seconde source de lumière (118) ;
détecter des amplitudes de lumière avec au moins un capteur de lumière (120), dans lequel ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118), et ledit au moins un capteur de lumière (120), sont adaptés afin qu'une partie d'un corps soit située entre eux ;
mettre sous tension et hors tension ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118) à des instants pseudo-aléatoires générés par un générateur de bruit pseudo-aléatoire (138), dans lequel le générateur de bruit pseudo-aléatoire (138) comprend un registre à décalage à rétroaction linéaire recevant un signal d'horloge qui génère une séquence de longueur maximale (ML) utilisée pour piloter lesdites sources de lumière (116, 118), dans lequel le signal d'horloge est également couplé au convertisseur ADC (106), dans lequel la séquence ML est déphasée pour chacune des sources de lumière (116, 118) ;
convertir des amplitudes de lumière échantillonnées provenant dudit au moins un capteur de lumière, en des représentations numériques connexes, avec un convertisseur analogique-numérique (ADC, 106) ; et
corréler les représentations numériques des amplitudes de lumière échantillonnées, en utilisant un multiplexage par répartition en phase avec une ou plusieurs sorties du générateur de bruit pseudo-aléatoire (138) pour ladite au moins une première source de lumière et ladite au moins une seconde source de lumière (116, 118), en utilisant les instants pseudo-aléatoires provenant du générateur de bruit pseudo-aléatoire (138).

12. Procédé selon la revendication 11, comprenant en outre l'étape consistant à filtrer les représentations numériques corrélées, avec un filtre numérique (110).

13. Procédé selon l'une quelconque des revendications 11 à 12, comprenant en outre l'étape consistant à déphaser les instants pseudo-aléatoires provenant du générateur de bruit pseudo-aléatoire (138).

14. Procédé selon l'une quelconque des revendications 11 à 13, comprenant en outre l'étape consistant à déterminer la saturation en oxygène sanguin (SpO_2) à partir des représentations numériques des amplitudes de lumière échantillonnées.

15. Procédé selon l'une quelconque des revendications 11 à 14, dans lequel, pour la corrélation :

chaque échantillon de convertisseur ADC est dupliqué dans n+1 registres à décalage, dans lequel « n » est le nombre de sources de lumière actives ;
dans lequel, si une source de lumière est sous tension, alors un registre à décalage associé est réglé sur une valeur précédente du registre à décalage associé, plus l'échantillon de convertisseur ADC, et si une source de lumière est hors tension, alors un registre à décalage associé est réglé sur une valeur précédente du registre à décalage associé, moins l'échantillon de convertisseur ADC.

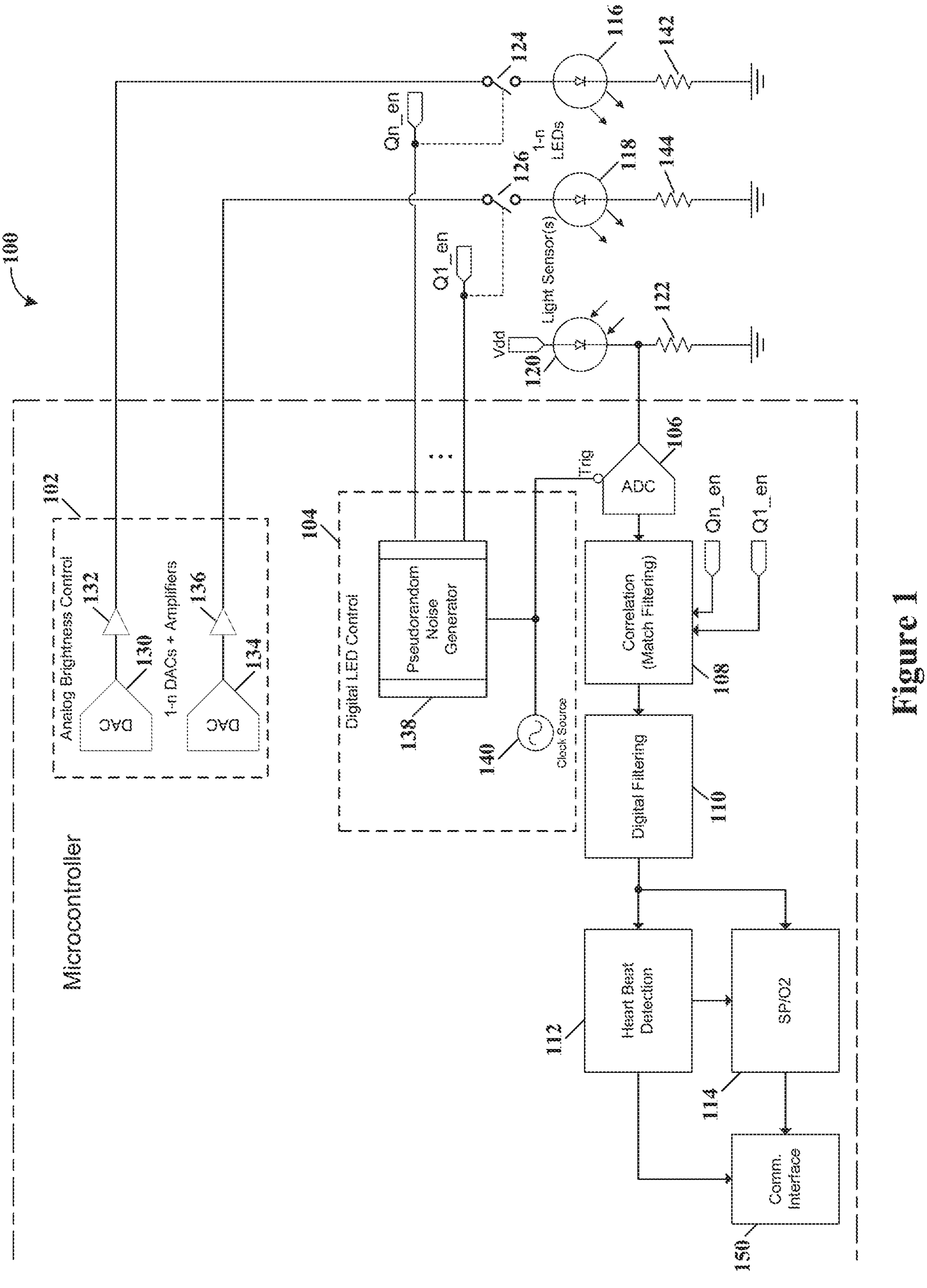

100
Microcontroller
102
Analog Brightness Control
DAC
130
132
1-n DACs + Amplifiers
DAC
134
136
104
Digital LED Control
Pseudorandom Noise Generator
138
Clock Source
140
Trig
ADC
106
Correlation (Match Filtering)
108
Qn_en
Q1_en
Digital Filtering
110
Heart Beat Detection
112
SP/O2
114
Comm. Interface
150
Vdd
120
Light Sensor(s)
122
Q1_en
126
118
144
1-n LEDs
Qn_en
124
116
142

Figure 1

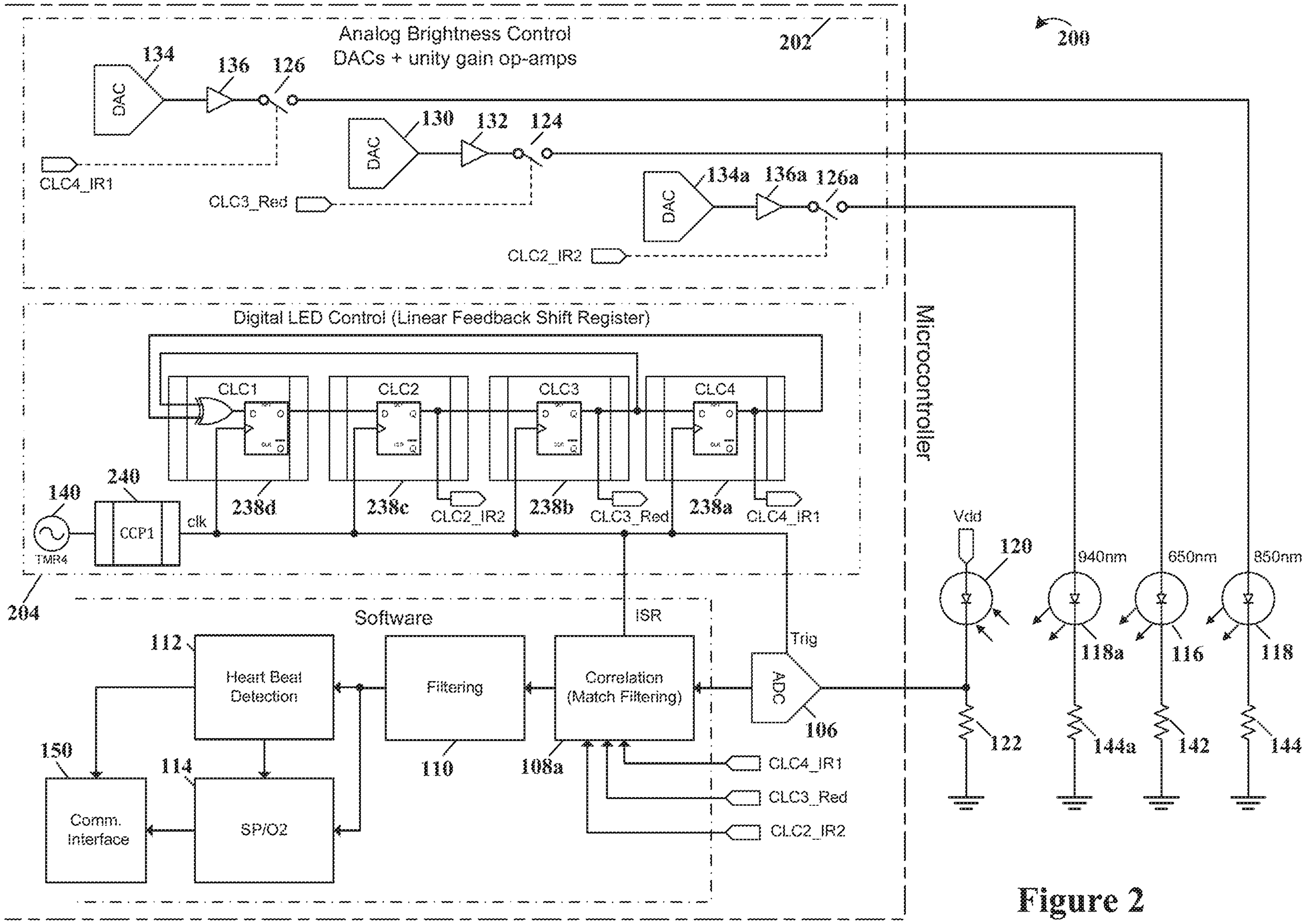

200
202
Analog Brightness Control
DACs + unity gain op-amps
134
DAC
136
126
130
DAC
132
124
134a
DAC
136a
126a
CLC4_IR1
CLC3_Red
CLC2_IR2
Digital LED Control (Linear Feedback Shift Register)
CLC1
CLC2
CLC3
CLC4
238d
238c
238b
238a
CLC2_IR2
CLC3_Red
CLC4_IR1
140
TMR4
240
CCP1
clk
204
Microcontroller
Software
ISR
Trig
ADC
106
Correlation
(Match Filtering)
108a
Filtering
110
Heart Beat
Detection
112
SP/O2
114
Comm.
Interface
150
CLC4_IR1
CLC3_Red
CLC2_IR2
Vdd
120
122
940nm
118a
144a
650nm
116
142
850nm
118
144

Figure 2

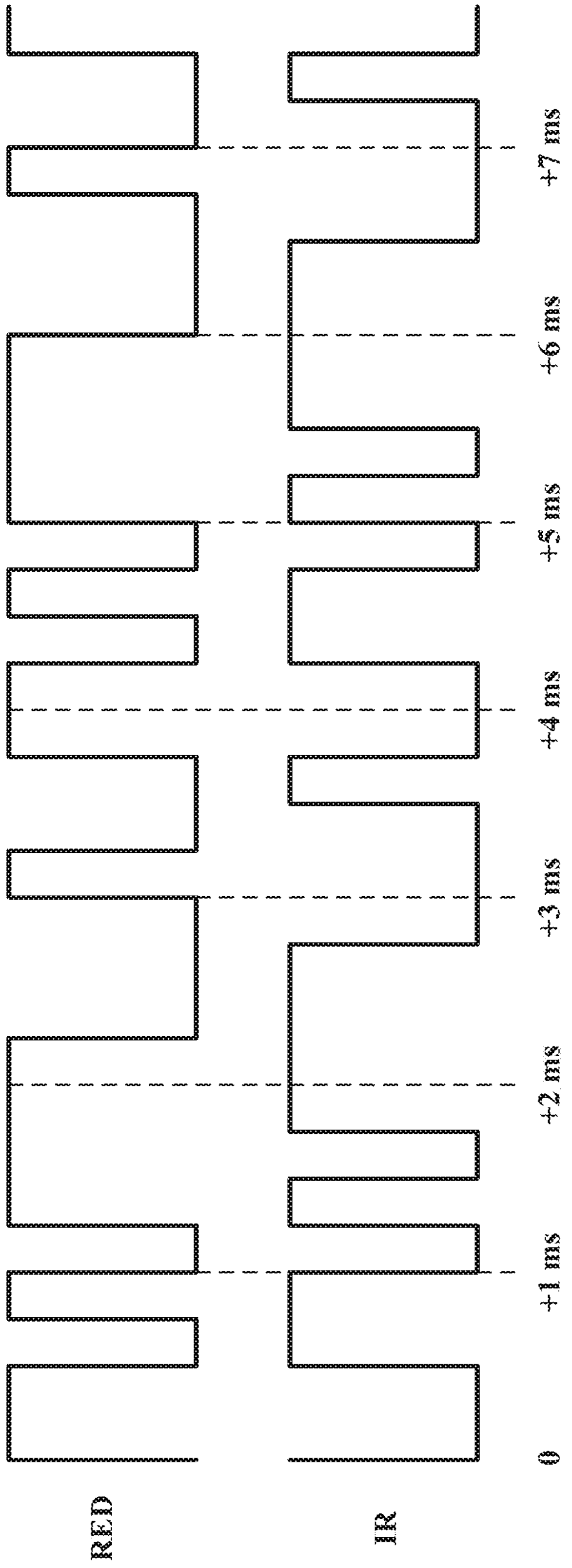


Figure 3

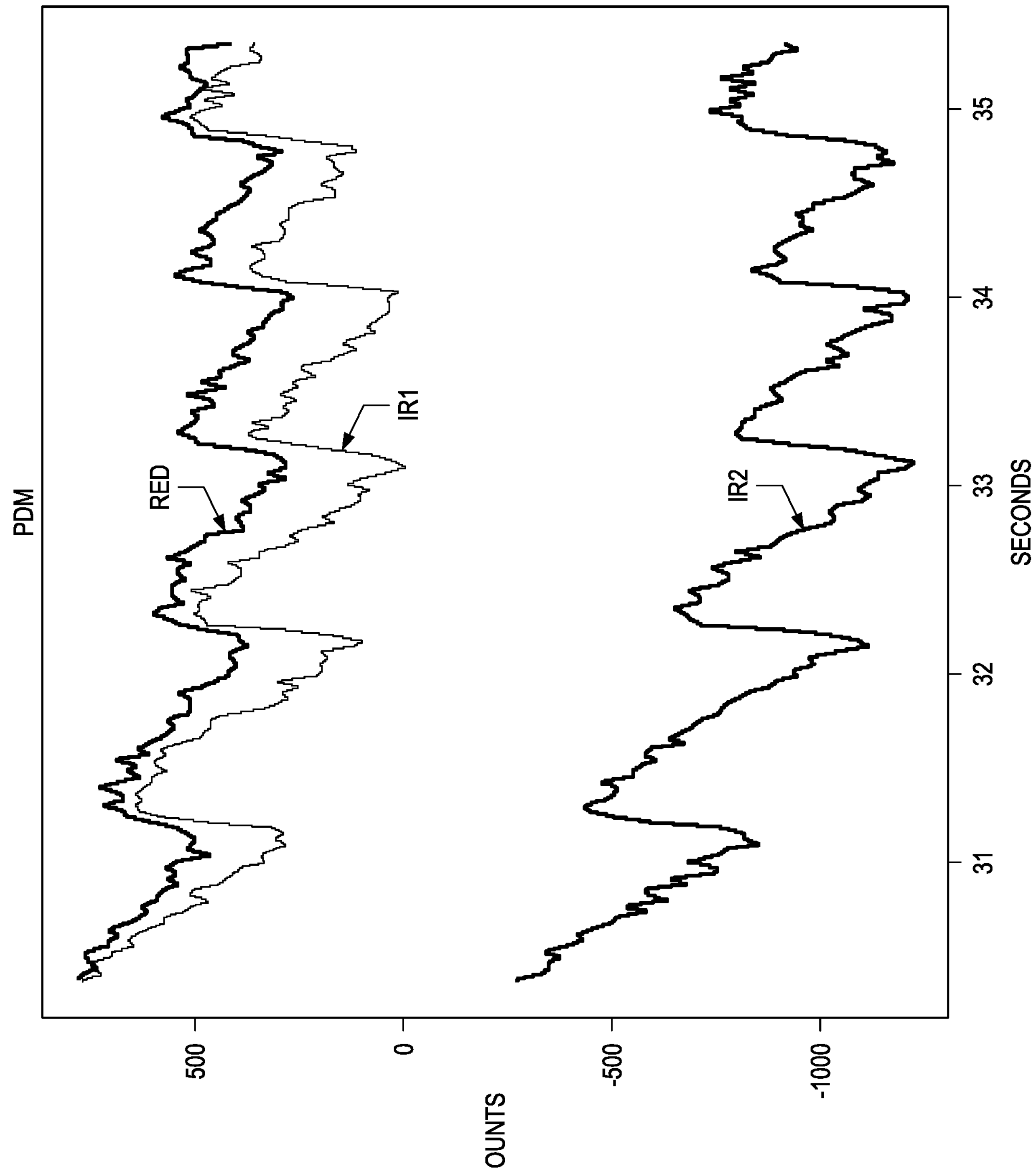


FIG. 4

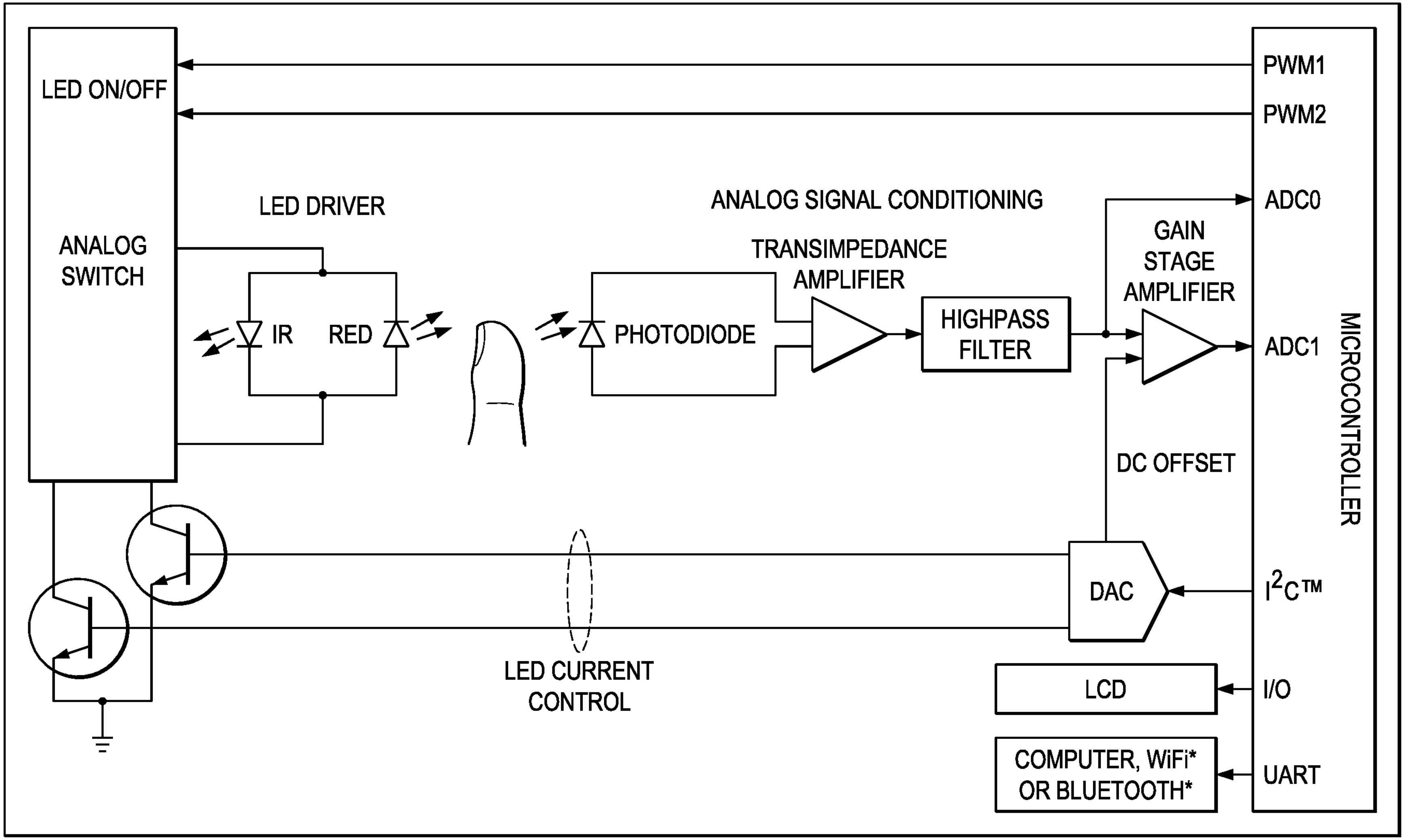


FIG. 5
(PRIOR TECHNOLOGY)

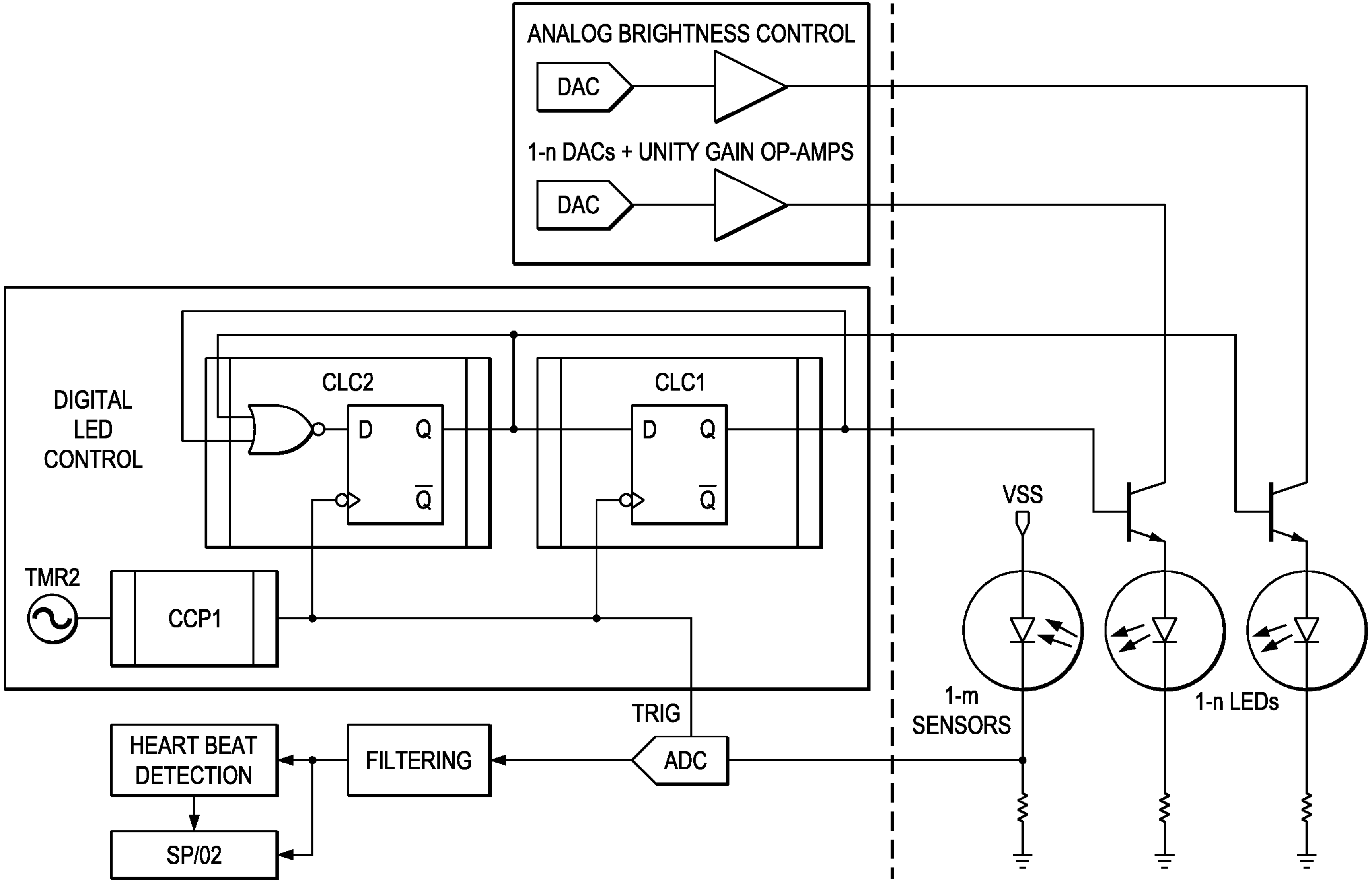


FIG. 6
(PRIOR TECHNOLOGY)

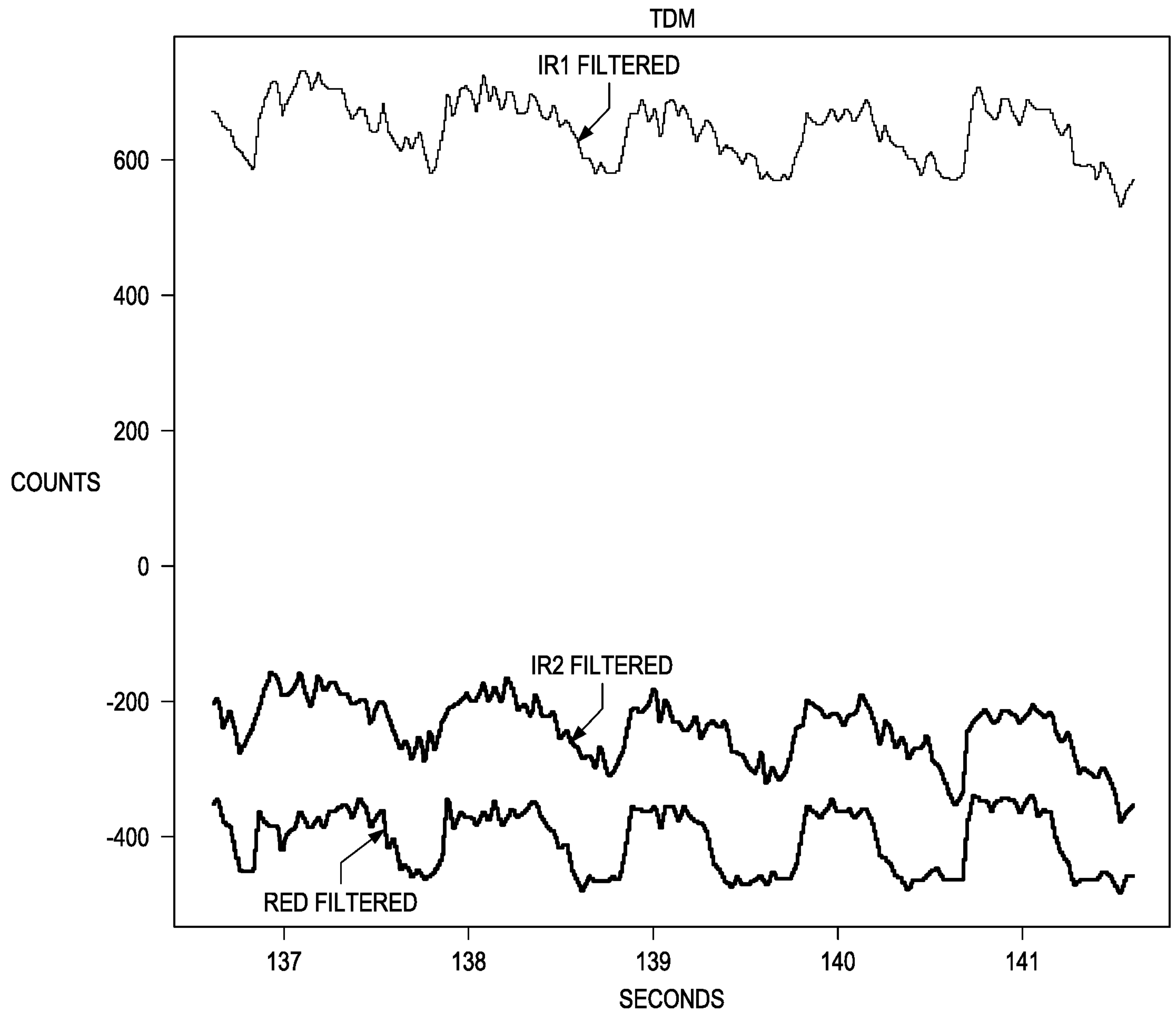
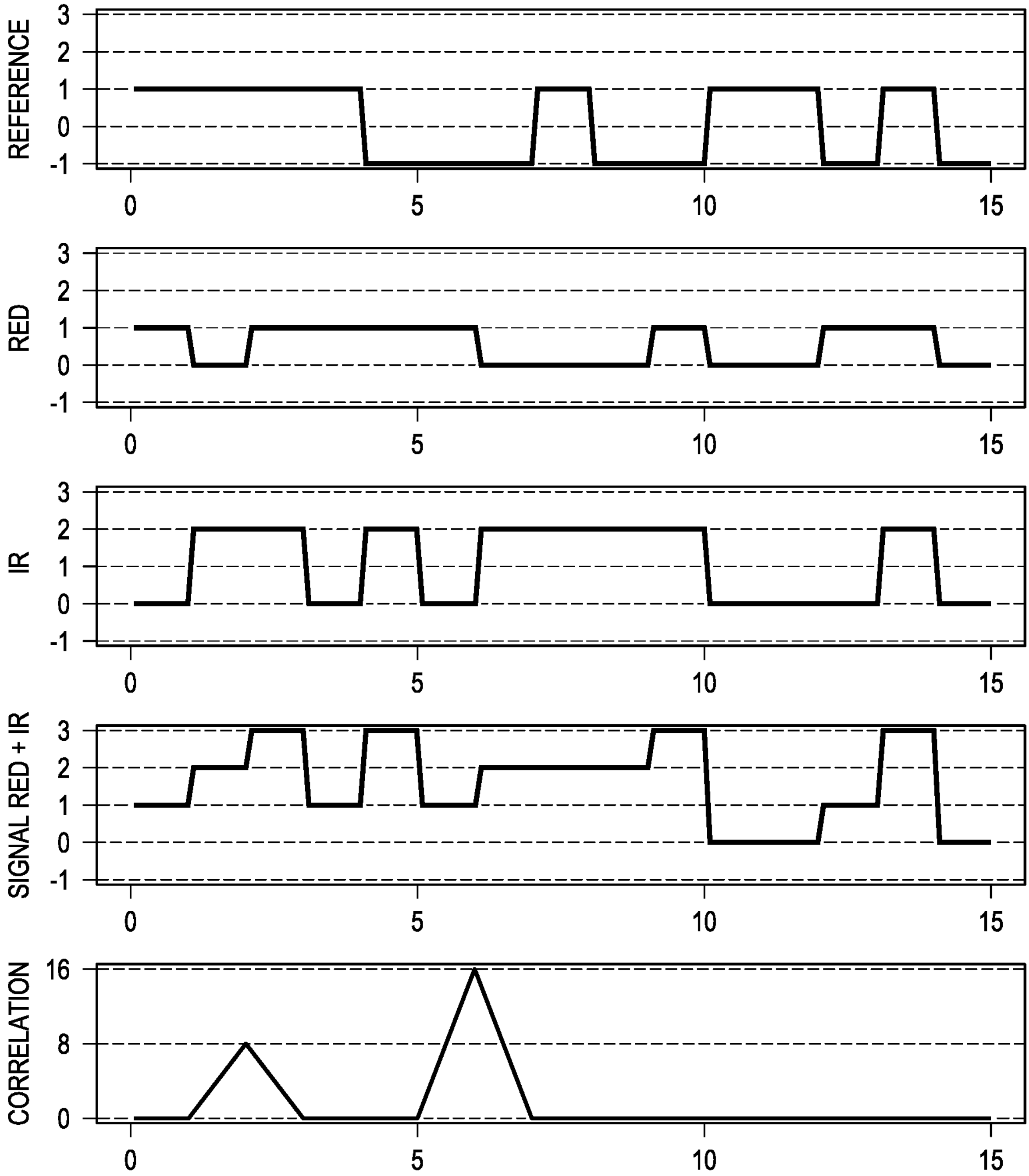


FIG. 7
(PRIOR TECHNOLOGY)

FIG. 8


REFERENCE
RED
IR
SIGNAL RED + IR
CORRELATION
3
2
1
0
-1
16
8
0
0
5
10
15

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专利名称(译)	用于测量身体中的多个信号的方法，系统和设备		
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摘要(译)

脉搏血氧饱和度测量系统使用伪随机噪声发生器来激发一个或多个发光二极管（LED）。 这些LED发出的光的振幅在通过人体的一部分后，将由光电晶体管或光电二极管检测，并通过模数转换器（ADC）进行数字化处理。 数字化的ADC光幅度值与输出的伪随机噪声激励重新关联。 扩频技术因其噪声缓解特性而闻名，并且能够使多个信号通过同一介质而不受干扰。 因此，这些测量可以基本同时地以彼此最小的干扰来执行。 脉搏血氧饱和度测量系统使用伪随机噪声生成和相分多路复用将测得的光强度关联起来，并计算测得的和相关的峰峰值检测光振幅，以获得这些光振幅之间的比率，以确定血液中的氧饱和度 ，也可以用于心率监测。