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(54) **LOW NOISE OXIMETRY CABLE INCLUDING CONDUCTIVE CORDS**

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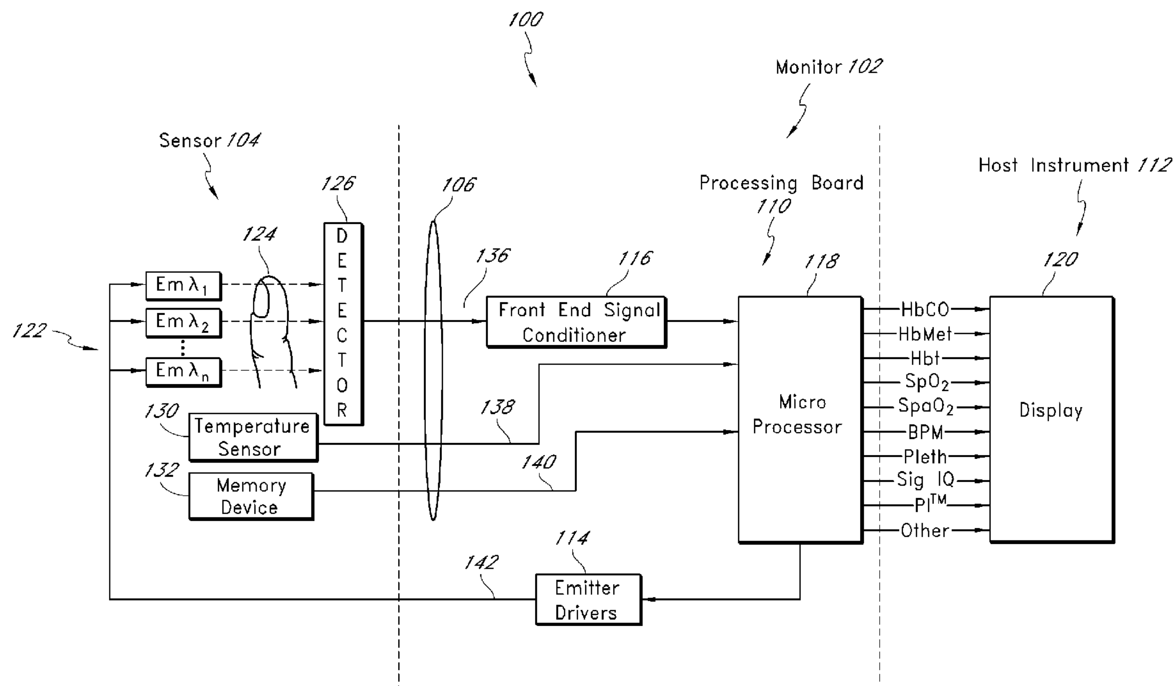
(57) **ABSTRACT**

In an embodiment, one or more conductive cable cords are twisted with the sensitive signal carrying cables. The cords may advantageously comprise dummy wires, or very flexible hollow cables without an inner conductor. As the conductive cords do not carry and inner conductor, the conductive cords are individually flexible and small, resulting in a twisted bundle that more is flexible while potentially having a smaller outer diameter.



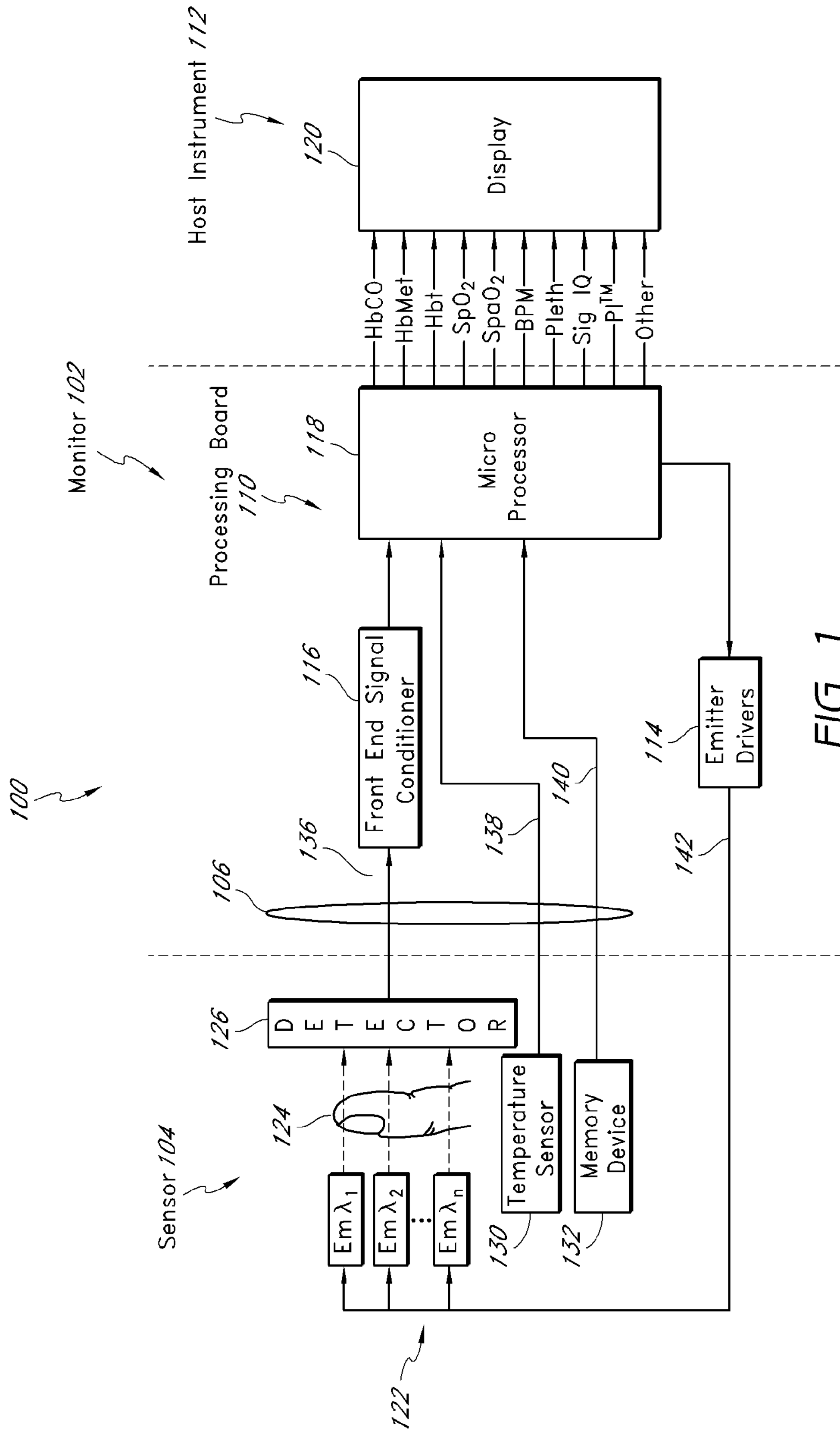

Host Instrument 112
120
Display
HbCO
HbMet
Hbt
SpO2
SpaO2
BPM
Pleth
Sig IQ
PI™
Other
Monitor 102
Processing Board 110
118
Micro Processor
116
Front End Signal Conditioner
114
Emitter Drivers
100
136
138
140
142
106
126
DETECTOR
124
Sensor 104
Emλ1
Emλ2
Emλn
Temperature Sensor
130
Memory Device
132
122

FIG. 1

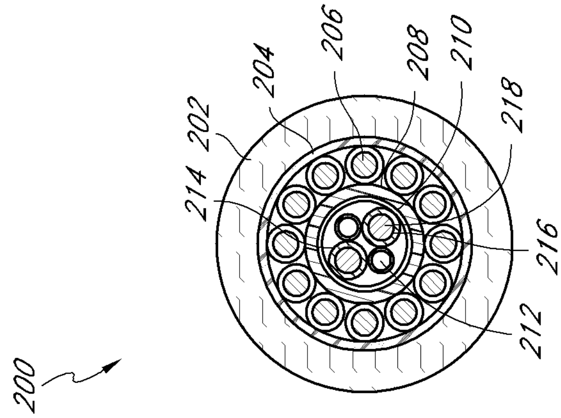

200
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FIG. 2B

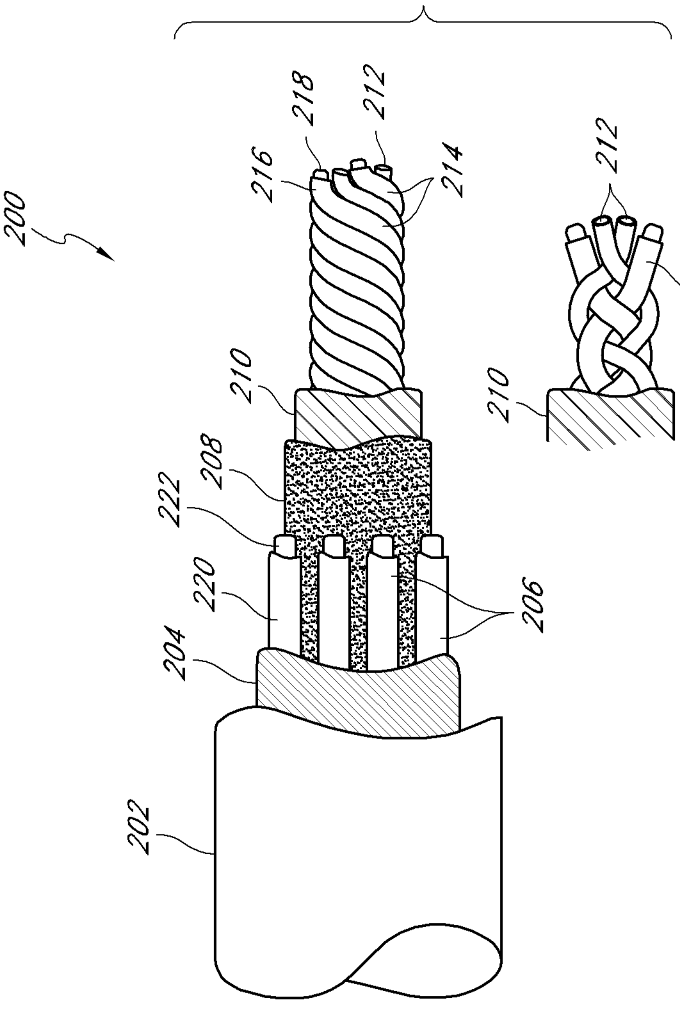
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FIG. 2A

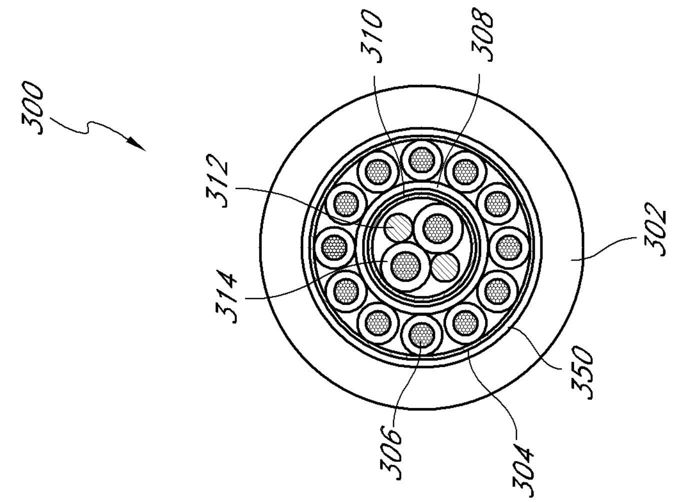
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FIG. 3B

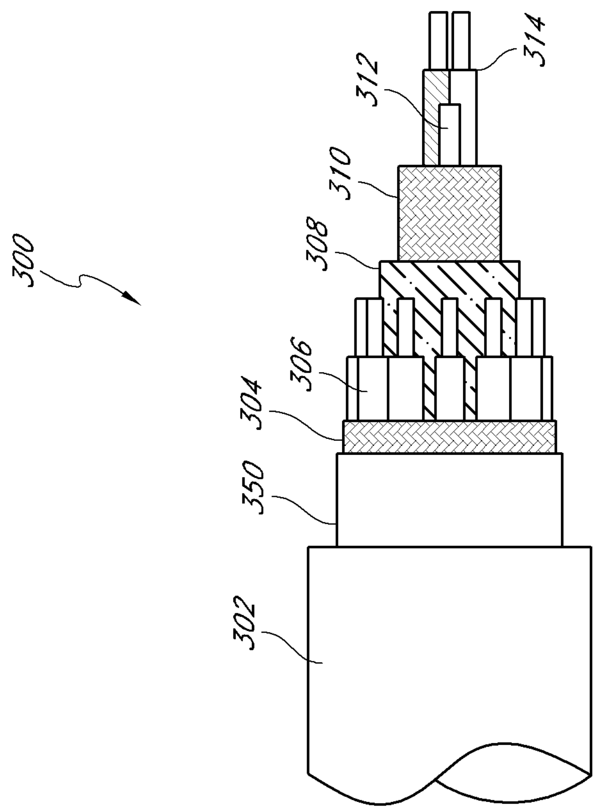
300
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FIG. 3A

LOW NOISE OXIMETRY CABLE INCLUDING CONDUCTIVE CORDS

PRIORITY CLAIM

[0001] The present application claims priority benefit under 35 U.S.C. §120 to, and is a continuation of U.S. patent application Ser. No. 13/079,756, filed Apr. 4, 2011, entitled "Low Noise Oximetry Cable Including Conductive Cords," which is a continuation of U.S. patent application Ser. No. 12/104,350, filed Apr. 16, 2008, now U.S. Pat. No. 7,919,713, entitled "Low Noise Oximetry Cable Including Conductive Cords," which claims a priority benefit of U.S. Provisional Application No. 60/912,139, filed Apr. 16, 2007, entitled "Low Noise Oximetry Cable Including Conductive Cords." The present application thus claims an effective filing date of Apr. 16, 2007 through its parent utility application and through that utility application's provisional application. The foregoing applications are incorporated in their entirety by reference herein.

CROSS-REFERENCE TO RELATED APPLICATIONS

[0002] The present application is related to the disclosure of abandoned U.S. patent application Ser. No. 10/325,602, filed on Dec. 19, 2002, titled "Low Noise Patient Cable," which is incorporated herein by reference. Also, pending U.S. patent application Ser. No. 11/367,013, filed Mar. 1, 2006, titled "Multiple Wavelength Sensor Emitters," is incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

[0003] 1. Field of the Disclosure

[0004] The disclosure relates to improving the performance of patient monitors through low noise cabling.

[0005] 2. Description of the Related Art

[0006] Oximetry utilizes a noninvasive optical sensor to measure physiological parameters of a patient. In general, the sensor has light emitting diodes (LEDs) that transmit optical radiation into a tissue site and a detector that responds to the intensity of the optical radiation after absorption (e.g., by transmission or transreflectance) by, for example, pulsatile arterial blood flowing within the tissue site. Based on this response, a processor determines measurements for oxygen saturation (SpO_2), pulse rate, plethysmograph waveforms, perfusion quality index (e.g., an index that quantifies perfusion), assessments of other blood constituents, parameters or analytes, including for example, a percent value for arterial carbon monoxide saturation (HbCO), a percent value for methemoglobin saturation (a brownish-red form of hemoglobin that cannot function as an oxygen carrier) (HbMet), total hemoglobin (HbT), fractional SpO_2 ($SpaO_2$) or the like. Additionally, caregivers often desire knowledge of HbO_2, Hb, blood glucose (HbGu), water, the presence or absence of therapeutic drugs (aspirin, Dapson, nitrates, or the like) or abusive/recreational drugs (methamphetamine, alcohol, steroids, or the like), concentrations of carbon dioxide (CO_2), oxygen (O_2), oxygen concentration, pH levels, bilirubin, perfusion quality, albumin, cyanmethemoglobin, and sulfhemoglobin (HbSulf), signal quality or the like. It is noted that "oximetry" as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least those noninvasive procedures for measuring parameters of circulating blood through spectroscopy. Moreover, "plethysmograph" as used herein (commonly referred to as "photoplethysmograph"), encompasses its broad ordinary meaning known to one of skill in the art, which includes at least data representative of a change in the absorption of particular wavelengths of light as a function of the changes in body tissue resulting from pulsing blood.

[0007] Oximeters capable of reading many of the foregoing parameters during motion induced noise are available from Masimo Corporation (Masimo) of Irvine, Calif. Moreover, portable and other oximeters are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,157,850, 6,002,952, and 5,769,785, incorporated by reference herein, and others patent publications such as those listed at http://www.masimo.com/patents.htm. Such reading through motion oximeters have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios.

[0008] The detectors of the noninvasive sensors read by many of the foregoing patient monitors generate one or more low-level signals that are susceptible to corruption from various noise, such as electromagnetic interference (EMI) and internal noise that originate in the sensor, cabling and monitors. One internal noise source is due to a triboelectric effect, which includes static charges that build when two materials rub together. For example, when a cable housing detector wires is flexed, impacted, or the like, the detector wires may rub together and triboelectric noise can be induced in the detector signal. These induced triboelectric noise spikes can be orders of magnitude larger than the desired low level detector signals.

[0009] To alleviate the buildup of triboelectric charges, low noise cable manufacturers included graphite coatings exterior to, for example, the cabling configured to communicate detector signals. However, the graphite gel used in the manufacturing process proved difficult to apply and remove. Because of these and other difficulties, manufacturers began substituting the graphite coatings with a coextruded conductive PVC sheath around, for example, their sensitive signal carrying cables.

SUMMARY OF THE DISCLOSURE

[0010] Embodiments of the present disclosure include the realization that coextruding the conductive PVC sheath around detector cables produces unnecessary rigidity in the resulting low noise cables. Accordingly, embodiments of the present disclosure seek to overcome the foregoing and other drawbacks through inclusion of one or more conductive polymer cords with sensitive signal carrying cables, such as, for example, the detector cables. The cords may be disposed around and adapted to drain triboelectric charge away from detector wires communicating low level detector signals from a noninvasive optical sensor. In one embodiment, the detector cables are twisted with the one or more polymer cords. In a particular embodiment, the polymer cords comprise hollow conductive polyvinyl chloride (PVC) tubes, although the cords may also comprise a flexible conductive vinyl or any suitable flexible conductive material recognizable to an artisan from the disclosure herein.

[0011] In other embodiments of the disclosure, some or all of an inner bundle of conductors configured to carry sensitive signals may be assembled marginally twisted or untwisted with one or more conductive cords, may be twisted, marginally twisted, or untwisted around one or more central conductive cords, combinations of the same or the like.

[0012] Accordingly, one embodiment of the disclosure includes an oximetry system capable of acquiring signals indicative of one or more physiological parameters of a patient. The system comprises a noninvasive sensor including a detector configured to detect light attenuated by body tissue and output a detector signal indicative of the detected light. The system also comprises a patient monitor configured to receive the detector signal and determine one or more physiological parameters the patient. The system also comprises a cable comprising an inner bundle including detector wires and at least one hollow conductive cord, the inner bundle being at least partially surrounded by an inner shield encased in an inner jacket, the inner jacket being at least partially surrounded by a plurality of outer wires, an outer shield and an outer jacket.

[0013] Another embodiment includes a cable for communicating sensitive low level signals. The cable comprises at least one wire including a conductor configured to communicate the sensitive signal and an insulator surrounding the conductor, and at least one hollow conductive cord assembled with said at least one wire. The cable also comprises a shield at least partially surrounding said assembly of at least one wire and at least one hollow conductive cord. The cable also comprises a jacket surrounding said shield, wherein said shield is capable of being set to a predetermined voltage to drain potential buildup of triboelectric charge on said jacket.

[0014] Yet another embodiment of the disclosure includes a method of manufacturing a cable comprising assembling an inner bundle including detector wires and at least one hollow conductive cord. The method also comprises at least partially surrounded the inner bundle with an inner shield, and surrounding said inner shield with an inner jacket.

[0015] For purposes of summarization, certain aspects, advantages and novel features are described herein. Of course, it is to be understood that not necessarily all such aspects, advantages or features need to be present in any particular embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The following drawings and the associated descriptions are provided to illustrate embodiments of the present disclosure and do not limit the scope of the claims.

[0017] FIG. **1** is an exemplary block diagram of a patient monitoring system including a patient monitor and a noninvasive optical sensor communicating through a cable, according to an embodiment of the disclosure.

[0018] FIG. **2**A is an exemplary cutaway side-view of the cable of FIG. **1**, according to an embodiment of the disclosure.

[0019] FIG. **2**B is an exemplary cross-sectional view of the cable of FIG. **1**, according to an embodiment of the disclosure.

[0020] FIG. **3**A is an exemplary cutaway side-view of the cable of FIG. **1**, according to an embodiment of the disclosure.

[0021] FIG. **3**B is an exemplary cross-sectional view of the cable of FIG. **1** according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0022] Embodiments of the present disclosure include a low noise oximetry cable configured to communicate low level sensitive signals between a sensor and a patient monitor. In an embodiment, one or more conductive cable cords are twisted with the sensitive signal carrying cables. The cords can advantageously comprise dummy wires, or very flexible hollow cables or tubes without an inner conductor. The conductive cords advantageously reduce interference or noise from corrupting the sensitive signals, by, for example, reducing or draining triboelectric charge buildup from around the sensitive signal carrying cables. Moreover, as the conductive cords do not carry an inner conductor, the conductive cords are individually very flexible, resulting in a twisted bundle that is more flexible and in some embodiments, may have a smaller outer diameter than the PVC sheath discussed above.

[0023] In an embodiment, the number cords twisted within the sensitive signal carrying cables is selected by balancing overall twisted bundle thickness, shape, size such as outer diameter, rigidity or flexibility, conductive or drain performance, cost, and the like. In an embodiment, the low noise cable includes from about one (1) to about eight (8) or more conductive cords twisted with one or more of the sensitive signal carrying cables or conductors. In another embodiment, the low noise cable includes from about two (2) to about seven (7) conductive cords twisted with one or more of the sensitive signal carrying cables or conductors. In yet another embodiment, the low noise cable includes two (2) conductive cords twisted with one or more of the sensitive signal carrying cables or conductors.

[0024] In other embodiments, the cords and/or the sensitive signal carrying cables may be assembled un-twisted or marginally twisted within the bundle, may entirely or partially surround sensitive signal carrying cables within the bundle, or the like. In still additional embodiments, one or more sensitive signal carrying conductors may be twisted, marginally twisted, or untwisted around one or more twisted, marginally twisted, or untwisted central cords.

[0025] To facilitate a complete understanding of the disclosure, the remainder of the detailed description references the drawings, wherein like reference numbers are referenced with like numerals throughout.

[0026] FIG. **1** illustrates an exemplary block diagram of a patient monitoring system **100** including a patient monitor **102** and a noninvasive optical sensor **104** communicating through a cable **106**, according to an embodiment of the disclosure. The monitor **102** includes one or more processing boards **110** communicating with one or more host instruments **112**. According to one embodiment, the board **110** comprises processing circuitry arranged on one or more printed circuit boards capable of installation into a handheld or other monitor, or capable of being distributed as an OEM component for a wide variety of host instruments monitoring a wide variety of patient information. As shown, the board **110** includes one or more emitter driving circuits **114**, a front end **116**, and a microprocessor **118**.

[0027] The emitter driving circuit **114** outputs drive signals to the sensor **104**. In an embodiment, the emitter driving circuit **114** may drive two (2) or more emitters capable of emitting light at two (2) or more wavelengths, or it may drive a matrix of eight (8) to sixteen (16) or more emitters capable of emitting light at eight (8) to sixteen (16) or more wavelengths.

[0028] The front end **116** conditions the signals, applies gain, converts signals to digital information, and the like, although an artisan will recognize from the disclosure herein that any or all of the functions of the drive circuit **114** and the front end **116** could be performed by other software or hardware components, or by the microprocessor **118**. The microprocessor **118** may comprise one or more hardware or software components capable of executing instructions designed to control drive signals and to process incoming signal data related to the drive signals to determine desired physiological parameters of a monitored patient. In an embodiment, such parameters may include one or more of SpO_2, plethysmograph waveforms, perfusion quality index, pulse rate, HbCO, HbMet, HbT, $SpaO_2$, HbO_2, Hb, HbGu, water, the presence or absence of therapeutic drugs or abusive/recreational drugs, CO_2, O_2, pH levels, bilirubin, albumin, cyanmethemoglobin, and HbSulf, signal quality, signal confidence measures, trend data on one, some, all, or combinations of the foregoing, or the like. Moreover, the microprocessor **114** can determine when alarm conditions exist for alerting a caregiver to the current condition of the patient.

[0029] The host instrument **112** includes one or more display devices **120** capable of providing indicia representative of the calculated physiological parameters. In an embodiment, the host instrument **120** may advantageously comprise virtually any housing, including a handheld or otherwise portable monitor capable of conveying one or more of the foregoing measured or calculated parameters to a caregiver. The host instrument **120** may include audio or visual alarms that alert caregivers that one or more physiological parameters are falling below or above predetermined safe thresholds, or are trending in a predetermined direction (good or bad). The host instrument **120** may include indications of the confidence a caregiver should have in the conveyed data.

[0030] In an embodiment, the sensor **104** includes a plurality of emitters **122** irradiating the body tissue **124** with light, and one or more detectors **128** capable of detecting the light after attenuation by the tissue **124**. The sensor **104** can also include a temperature sensor **130**, such as, for example, a thermistor or the like, and a memory device **132**. The memory **132** may comprise any one or more of a wide variety of memory devices known to an artisan from the disclosure herein, including an EPROM, an EEPROM, a flash memory, a ROM, a RAM, single wire memories, combinations, or the like. The memory device **132** can advantageously store some or all of a wide variety data and information, including, for example, information on the type or operation of the sensor, type of patient or body tissue, buyer or manufacturer information, sensor characteristics including the number of wavelengths capable of being emitted, number of emitters, emitter specifications, emitter operational characteristics, emitter drive requirements, history of the sensor temperature, current, or voltage, demodulation data, calculation mode data, calibration data, software such as scripts, executable code, or the like, sensor electronic elements, sensor life data indicating whether some or all sensor components have expired and should be replaced, encryption information, keys, indexes to keys, the parameters the sensor is intended to measure (e.g., HbCO, HbMet, etc.), monitor or algorithm upgrade instructions or data, some or all of parameter equations, combinations of the same, or the like.

[0031] As shown in FIG. **1**, a plurality of conductors communicates signals to and from the sensor **104** and the board **110**. These conductors include detector composite signal conductor(s) **136**, temperature sensor conductor(s) **138**, memory device conductor(s) **140**, emitter drive signal conductor(s) **142**, and the like. In an embodiment, some or all of these conductors are housed by the cable **106**.

[0032] FIGS. **2**A-**2**B illustrate an exemplary embodiment of a low noise patient cable **200**, such as the cable **106** of FIG. **1**, according to an embodiment of the disclosure. As shown, cable **200** includes an outer jacket **202**, an outer shield **204**, outer wires **206**, an inner jacket **208**, an inner shield **210**, polymer cords **212**, and detector wires **214**, with the cords **212** and the detector wires **214** twisted. In an embodiment, the inner shield **210** is wrapped around the twisted bundle of cords **212** and detector wires **214**, which is then encased by the inner jacket **208**. The inner jacket **208** is then circumferentially surrounded by the outer wires **206**, outer shield **204** and outer jacket **202**, respectively.

[0033] As discussed in the foregoing, the number of cords **212** used in the twisted bundle can vary depending upon desired bundle thickness, shape, size such as outer diameter, rigidity or flexibility, conductive performance, cost, and the like. In an embodiment, to create a substantially circular shape to the inner bundle which is smaller than shapes created through the sheath, while maintaining or improving triboelectric drain and substantially improving flexibility, the inner bundle includes two (2) conductive cords **212** with two (2) detector wires **214**, each detector wire comprising its inner conductor **218** and outer insulator **216**. In an embodiment, the cords and wires are wound as if the cords were aligning substantially horizontally and the wires substantially vertically and then the resulting "+" shape was wound.

[0034] In an embodiment, the outer wires include conductors **222** and insulation **220**. The shields **204** and **210** can also advantageously reduce EMI on each of and crosstalk between the outer wires **206** and the detector wires **214**. It will be understood that when the shield **210** is grounded in use, or set to a predetermined threshold, that triboelectric charge buildup is drained off the jacket **208**. The same triboelectric charge drain off the outer jacket **202** can occur when the shield **204** is grounded.

[0035] The outer conductor wires **206** are configured to carry multiple drive signals to the emitters **122**. In an embodiment, the outer wires **206** communicate cathode and anode drive signals or the like. In an embodiment where the emitters **122** comprise a matrix emitter array, the outer wires **206** communicate row and column drive signals. In other embodiments, the outer wires also communicate temperature sensor signals, memory device signals, and the like. The detector wires **214** communicate a low level sensitive detector output signal(s) which is relied upon by the monitor **102** to determine patient physiological parameter data.

[0036] The components described in association with FIGS. **2**A-**2**B can also share properties with the corresponding components described in association with FIGS. **3**A-**3**B that follow below.

[0037] FIGS. **3**A-**3**B illustrate an exemplary embodiment of a low noise patient cable **300**, such as the cable **106** of FIG. **1**, according to an embodiment of the disclosure. As shown, the cable **300** of FIGS. **3**A-**3**B includes an outer jacket **302**, an outer separator **350**, an outer shield **304**, outer wires **306**, an inner jacket **308**, an inner shield **310**, polymer cords **312**, and detector wires **314**, with the cords **312** and the detector wires **314** twisted or otherwise bundled together. In an embodiment, the inner shield **310** is wrapped around the twisted bundle of the cords **312** and the detector wires **314**, which is then encased by the inner jacket **308**. The inner jacket **308** is then circumferentially surrounded by the outer wires **306**, the outer shield **304**, the outer separator **350** and the outer jacket **302**, respectively.

[0038] These components of the cable **300** shown in FIGS. **3A-3B** can be designed, for example, by adjusting size, material, and relative placement, to meet performance or design objectives, such as, for example, outer diameter, flexibility, hardness, cost, degree of reduction of triboelectric noise, matching impedance, or other suitable objectives. Examples of these types of variations are disclosed in the following embodiments.

[0039] The design objectives can influence the outer diameter of the cable **300**. Suitable dimensions for the outer diameter depend, for example, on the properties of the components within the cable. The cable **300** can vary in outer diameter, for example, in an embodiment, between 0.13 inches and 0.25 inches. In a more preferred embodiment, the outer diameter of cable **300** ranges from 0.135 inches to 0.21 inches. In an embodiment, the outer diameter of cable **300** is between 0.165 inches and 0.171 inches. The thickness of outer jacket **302** can also be adjusted, for example, by changing thickness and material to meet design objectives. In an embodiment, the outer jacket **302** has a thickness that ranges from 0.01 inches to 0.06 inches. In an embodiment, the outer jacket **302** has a nominal thickness of 0.022 inches. Outer jacket **302** can be constructed out of jacket materials such as, for example, Teflon®, other fluoropolymers, Polytetrafluoroethelene (PFTE), Perfluoroalkoixy (PFA), Fluorinated ethylene propylene (FEP), Neoflon™, Kynar®, Polyvinylidene Fluride, Polyethylene, Polyvinylchloride (PVC), or other suitable jacket materials. In an embodiment, the outer jacket **302** is PVC. The material and thickness of outer jacket **302** can also be adjusted to meet hardness objectives. In an embodiment, the hardness of outer jacket **302** measures Shore 70A on a durometer using the ASTM D2240 type A scale.

[0040] The outer separator **350** can help provide flexibility to the cable and can also be adjusted to meet design objectives. The outer separator **350** can be made out of materials such as, for example, the jacket materials previously discussed or other suitable materials. The outer separator **350** can, for example, be made out of a material that will increase the flexibility of the cable by allowing the components housed inside the outer separator **350** to move somewhat independently of the outer jacket **302**. In an embodiment, the outer separator **350** is Teflon®. In an embodiment, the outer separator **350** has a thickness that ranges from 0.001 inches to 0.01 inches. In a more preferred embodiment, the outer separator **350** has a thickness that ranges from 0.001 inches to 0.005 inches. In an embodiment, the outer separator **350** has a thickness of 0.002 inches. In an embodiment, the outer separator **350** is approximately 0.004 inches thick PTFE material.

[0041] The outer shield **304** can advantageously reduce EMI on each of and crosstalk between the outer wires **306**. Outer shield **304** can be constructed of conductive materials or other suitable shield materials to meet performance or design objectives. An artisan will recognize from the present disclosure herein that copper, silver, or other suitable materials could be used as materials for the outer shield **304**. In an embodiment, the outer shield **304** is constructed using braided copper strands. In an embodiment, the outer shield **304** is constructed using spiral strands. The thickness of the shield can also be adjusted to meet design objectives. In an embodiment, the outer shield **304** ranges in size from 44 AWG (American Wire Gauge) to 40 AWG. In an embodiment, the outer shield **304** is 44 AWG. In an embodiment, the outer shield **304** is 44 AWG, tinned copper, with a ninety percent minimum coverage.

[0042] The outer wires **306** can also be designed to meet certain performance or design objectives. In an embodiment, the outer wires **306** have an outer diameter that ranges from 0.005 inches to 0.03 inches. In a more preferred embodiment, the outer wires **306** have an outer diameter that ranges from 0.012 inches to 0.025 inches. In an embodiment, the outer wires **306** have an outer diameter of 0.022 inches. In an embodiment, the outer wires **306** are constructed out of wire that ranges in gauge from 32 AWG to 24 AWG. In a more preferred embodiment, the outer wires **306** are constructed out of wire that ranges in gauge from 32 AWG to 28 AWG. In an embodiment, the outer wires **306** are constructed out of 30 AWG wire. In an embodiment, the outer wires **306** have insulation that ranges in thickness from 0.002 inches to 0.01 inches. In an embodiment, the outer wires **306** have 0.005 inches of insulation. In an embodiment, the outer wires **306** are stranded 22/44 tinned copper. In an embodiment, the outer wires **306** are 25/44 tinned copper, insulated by 0.005 inch thick polypropylene, with an outer diameter of 0.022 inches. Although disclosed with reference to copper insulated by polypropylene, an artisan would recognize from the disclosure herein that other materials could also be used to construct the outer wires **306**.

[0043] In addition to the outer wires **306** and inner jacket **308**, the outer separator **350** can house filler materials to help meet design or performance objectives. The filler material can, for example, help create a round shape for the cable. The filler material can be materials such as, for example, Kevlar or other suitable materials. In an embodiment, the outer separator **305** houses Kevlar filler materials.

[0044] The inner jacket **308** can also be designed to meet certain design or performance objectives. The inner jacket **308** can be constructed, for example, out of the jacket materials previously disclosed or other suitable materials. In an embodiment, the inner jacket **308** is constructed from PFTE. The inner jacket can also be constructed by layering materials. In an embodiment, the inner jacket **308** is constructed with a single sintered PFTE wrap plus a single unsintered PFTE wrap. In an embodiment, the inner jacket **308** is PVC with a single PFTE wrap. The inner jacket **308** can also range in size, in an embodiment, from 0.001 inches to 0.01 inches. In a more preferred embodiment, the inner jacket **308** ranges in size from 0.002 inches to 0.008 inches. In an embodiment, the inner jacket **308** is a sintered PFTE film that is approximately 0.0012 inches thick and a single layer of unsintered PFTE film that is approximately 0.004 inches thick. In an embodiment, the overlap is minimized to minimize the overall diameter of the inner jacket **308** and the components it contains.

[0045] The inner shield **310** can advantageously reduce EMI on each of and crosstalk between the detector wires **314** and the outer wires **306**. Inner shield **310** can be constructed of conductive materials or other suitable shield materials to meet performance or design objectives. An artisan will recognize from the present disclosure herein that copper, silver, or other suitable materials could be used as materials for the inner shield **310**. In an embodiment, the inner shield **310** is constructed using braided copper strands. In an embodiment, the inner shield **310** is constructed using spiral copper strands. The thickness of the inner shield **310** can also be adjusted to meet design objectives. In an embodiment, the inner shield **310** ranges in size from 44 AWG to 40 AWG. In an embodiment, the inner shield **310** is 44 AWG, tinned copper, with a ninety percent minimum coverage.

[0046] The cords **312** can also be designed to meet performance or design objectives. The cords **312** can be constructed from semi-conductive PVC or other suitable materials. The material can be chosen or arranged, such as, for example, by twisting, to enhance low-noise characteristics. In an embodiment, the cords **512** are semi-conductive PVC and twisted. In an embodiment, the cords **312** have a size that ranges from 0.01 inches to 0.02 inches. In a more preferred embodiment, the cords have a size that ranges from 0.012 inches to 0.015 inches. The cords **312** In an embodiment, the cords **312** are approximately 0.015 inches plus or minus 0.003 inches.

[0047] The detector wires **314** can also be designed to meet performance or design objectives. The detector wires **314** can share properties with the outer wires **306**. The thickness of the detector wires **314** can influence the performance or design objectives. In an embodiment, the gauge of the detector wires **314** ranges from 32 AWG to 24 AWG. In a more preferred embodiment, the gauge of the detector wires **314** ranges from 32 AWG to 28 AWG. In an embodiment, the detector wires are 30 AWG. In an embodiment, the detector wires are 28 AWG. In an embodiment, the outer wires **306** are constructed out of 30 AWG wire. In an embodiment, the detector wires **314** have insulation that ranges in thickness from 0.002 inches to 0.01 inches. In an embodiment, the detector wires **314** are have 0.007 inches of insulation. The detector wires **314** can be constructed out of materials such as, copper, silver, or other suitable materials. In an embodiment, the detector wires **314** are stranded 22/44 tinned copper. The insulation for detector wires **314** can be constructed out of materials such as polypropylene or other suitable materials. In an embodiment, the detector wires are 25/44 tinned copper, insulated by 0.007 inch thick polypropylene, with a nominal outer diameter of 0.027 inches.

[0048] The conductive cords have several advantages over a deposited graphite coatings and a coextruded PVC sheath for reducing triboelectric noise. For example, the cords may drain triboelectric induced charges away from the detector wire insulation **216** as well as or better than the graphite coating and PVC sheath. As with the PVC sheath, grouping of the cords with the detector wires **214** can increase the eventual signal quality output from signal processing circuitry, such as, for example, a differential amplifier. For example, use of the cords in a manner that maintains the close physical proximity of detector wires **214** tends to ensure external noise applied to the cable **200** is applied substantially equally (or common) to each conductor of the detector wires **214**. Thus, a differential amplifier (not shown) of the monitor **102** can effectively filter the applied external noise through, for example, the amplifier's common mode rejection.

[0049] Thus, while exhibiting the same or superior advantageous characteristics of the coating or sheath, the cords are also easier to control, cause less rigidity (e.g., result in a more flexible bundle), and provide more straightforward processes during manufacturing that the coating or sheath. For example, the cords may be simply cut away at points of connectivity for the detector conductors **218** to circuit substrates or other electrical components. Moreover, inner bundles made with the hollow cords are often thinner than the foregoing coatings or sheath. For these and other reasons, the cords also advantageously provide less expensive manufacturing processes.

[0050] FIG. **2**A also shows a braided inner bundle as an alternative to the twisted or wound inner bundle, the braided inner bundle having the cords **212** and the detector cables **214** braided together. However, an artisan will recognize from the disclosure herein that the inner bundle could advantageously be assembled in any manner of configuration to reduce costs, increase drain potential, create desired shapes, or the like. For example, the cords may be assembled braided, marginally braided, twisted, marginally twists, unbraided and untwisted, individually combined, twisted or braided, combinations of the same, or the like.

[0051] Although the low noise oximetry cable including conductive cords is disclosed with reference to its preferred embodiment, the disclosure is not intended to be limited thereby. Rather, a skilled artisan will recognize from the disclosure herein a wide number of alternatives for the cable. For example, the cords may not be hollow, may include a conductor or other conductive materials, may comprise only conductors of any suitably flexible material. Moreover, use of blank hollow cords may advantageously apply flexibility in a wide variety of applications, including cabling for virtually any medically monitored signals such as those invasively or noninvasively acquired signals relating to heart or brain activity or condition, spinal activity or condition, circulation parameters, tissue health, or the like. Moreover, an artisan will recognize from the disclosure herein that the cabling may comprises only one or more portions of the communication link between sensor components and monitor electronics. The cable may also be an integral part of a reusable, disposable or combination sensor. Moreover, the addition of conductive cords for shielding sensitive cabling may advantageously be applied generally to any and all cabling environments, and particularly in environments susceptible to triboelectric noise.

[0052] Additionally, other combinations, omissions, substitutions and modifications will be apparent to the skilled artisan in view of the disclosure herein. Accordingly, the present disclosure is not intended to be limited by the reaction of the preferred embodiments, but is to be defined by reference to the appended claims.

[0053] Additionally, all publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

What is claimed is:

1. A cable for communicating sensitive low level signals, the cable comprising:

at least one wire including a conductor configured to communicate the sensitive signal and an insulator surrounding the conductor;

at least one hollow conductive cord assembled with said at least one wire; and

a shield at least partially surrounding said assembly of at least one wire and at least one hollow conductive cord; and

a jacket surrounding said shield, wherein said shield is capable of being set to a predetermined voltage to drain potential buildup of triboelectric charge on said jacket.

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