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Otis et al.

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(45) **Date of Patent: Jul. 26, 2016**

(54) **CANCELLATION OF A BASELINE CURRENT SIGNAL VIA CURRENT SUBTRACTION WITHIN A LINEAR RELAXATION OSCILLATOR-BASED CURRENT-TO-FREQUENCY CONVERTER CIRCUIT**

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(73) Assignee: **Verily Life Sciences LLC**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 745 days.

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A61B 5/145 (2006.01)
G02C 7/04 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 5/14532*** (2013.01); *A61B 5/6821* (2013.01); *G02C 7/04* (2013.01)

(58) **Field of Classification Search**
USPC 320/166–167
See application file for complete search history.

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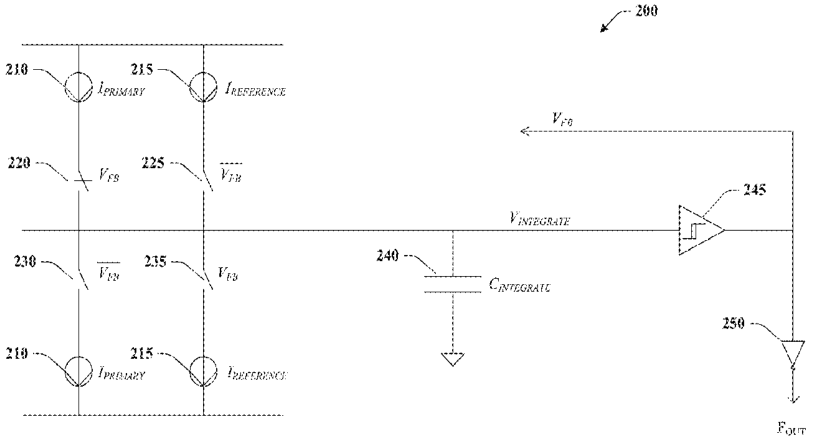
(57) **ABSTRACT**

This disclosure relates to systems and/or methods for subtracting in the current domain an output current primary signal from a primary sensor from an output current reference signal from a reference sensor to produce a frequency output signal indicative of the difference between the output current primary signal and the output current reference signal.

16 Claims, 9 Drawing Sheets



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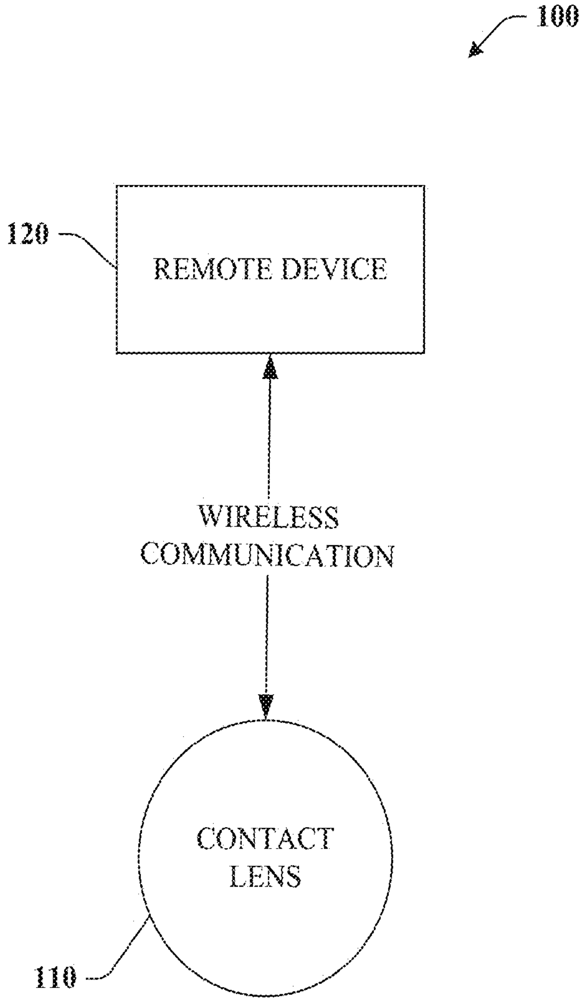
100
120
REMOTE DEVICE
WIRELESS
COMMUNICATION
CONTACT
LENS
110

FIG. 1A

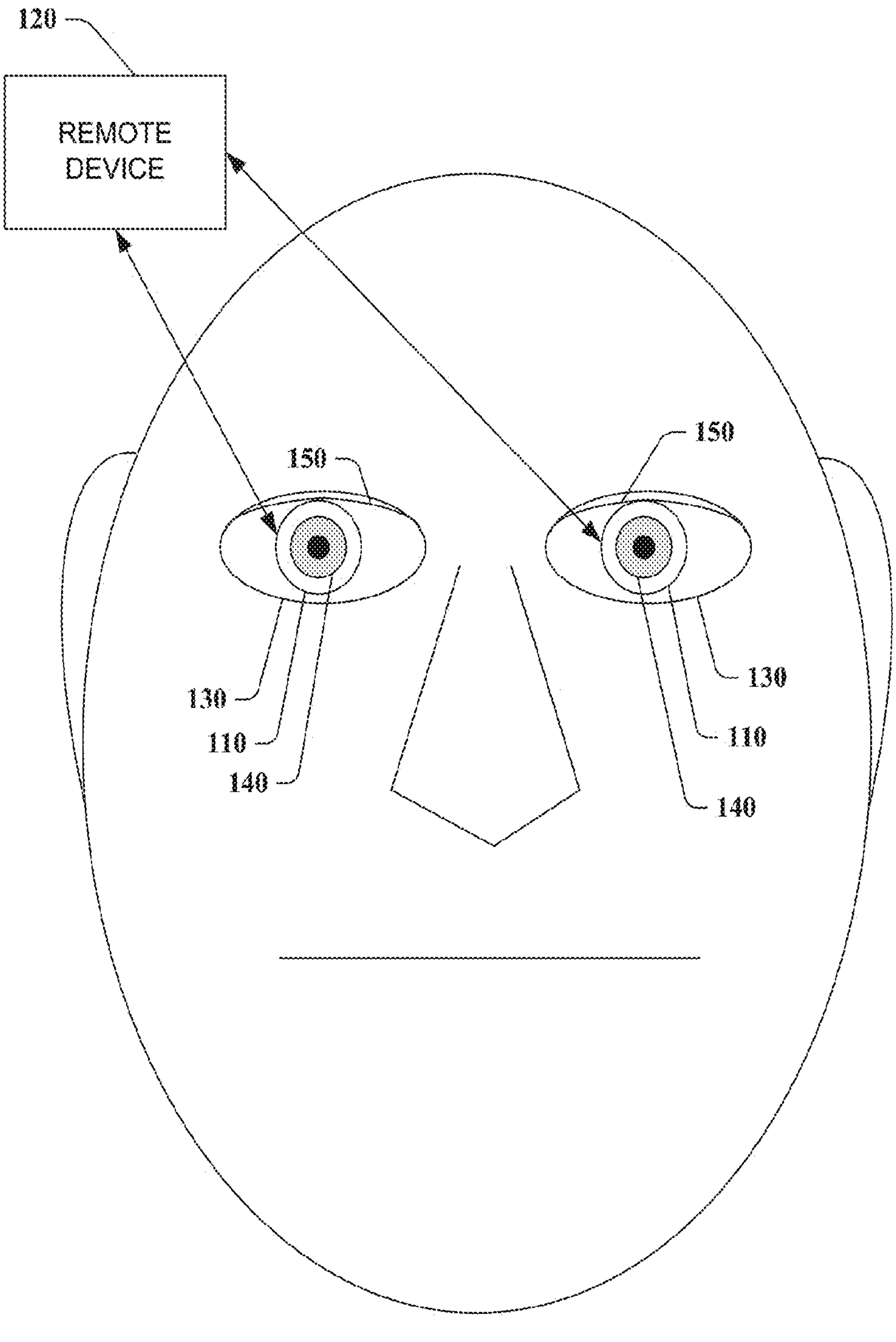

FIG. 1B

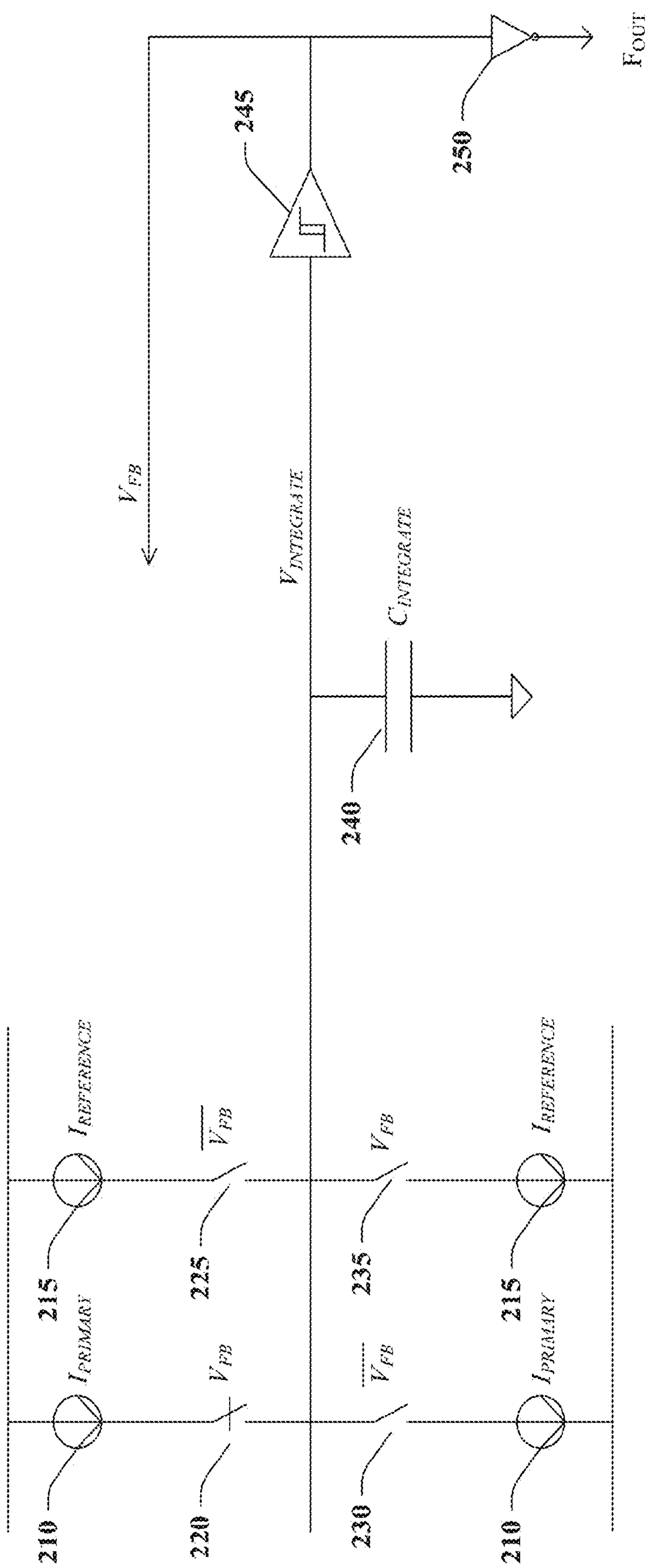
200
245
250
F_{OUT}
V_{FB}
$V_{INTEGRATE}$
$C_{INTEGRATE}$
240
$I_{REFERENCE}$
$\overline{V_{FB}}$
V_{FB}
$I_{REFERENCE}$
215
225
235
215
$I_{PRIMARY}$
V_{FB}
$\overline{V_{FB}}$
$I_{PRIMARY}$
210
220
230
210

FIG. 2A

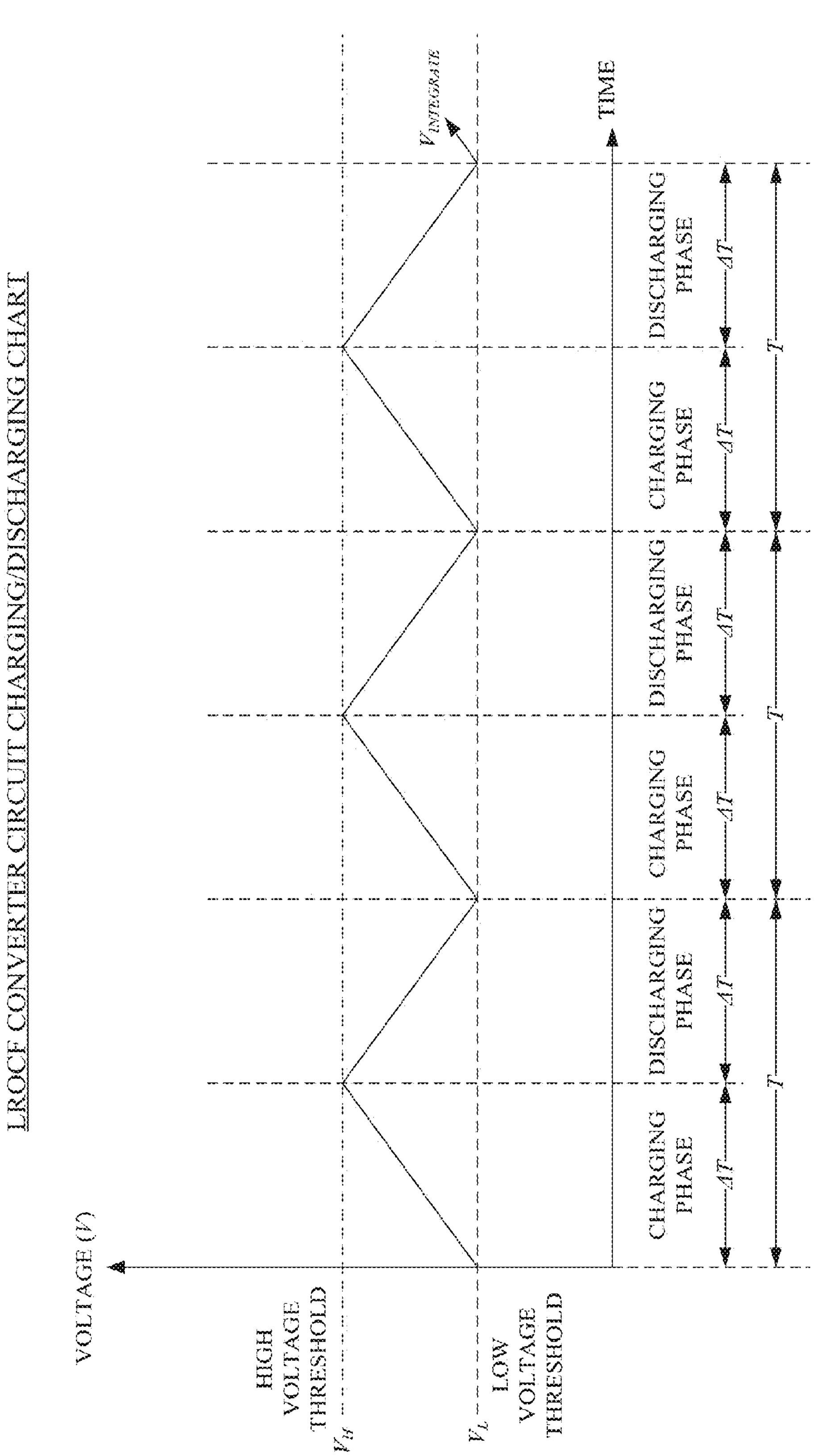
LROCF CONVERTER CIRCUIT CHARGING/DISCHARGING CHART
VOLTAGE (V)
HIGH VOLTAGE THRESHOLD
V_H
V_L
LOW VOLTAGE THRESHOLD
$V_{INTEGRATE}$
TIME
CHARGING PHASE
DISCHARGING PHASE
CHARGING PHASE
DISCHARGING PHASE
CHARGING PHASE
DISCHARGING PHASE
ΔT
T

FIG. 2B

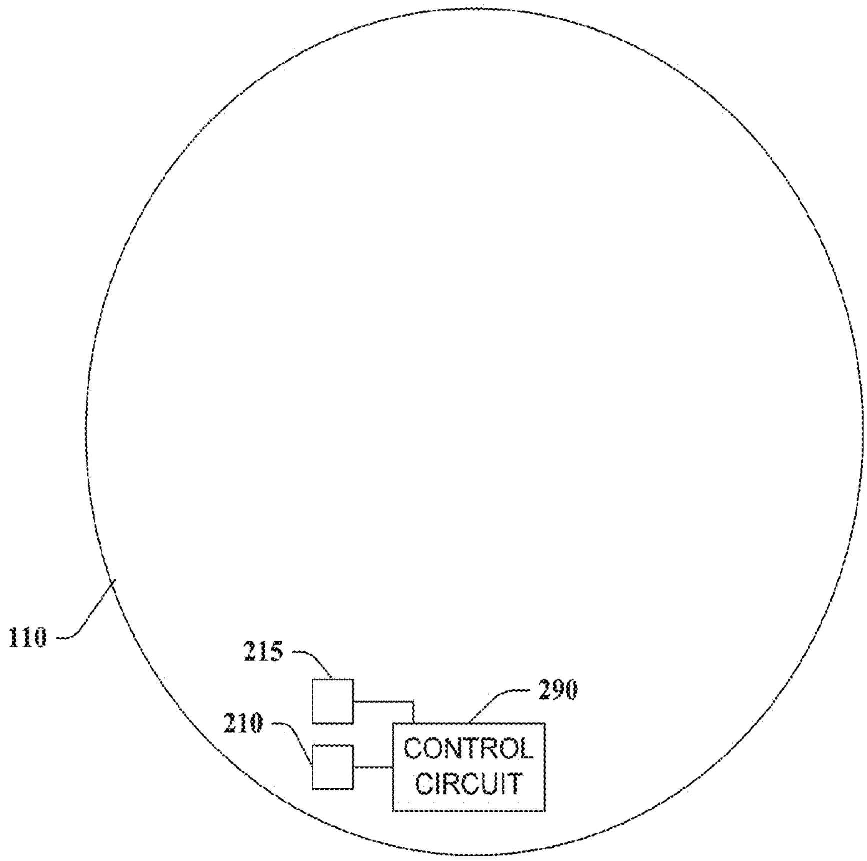

FIG. 2C

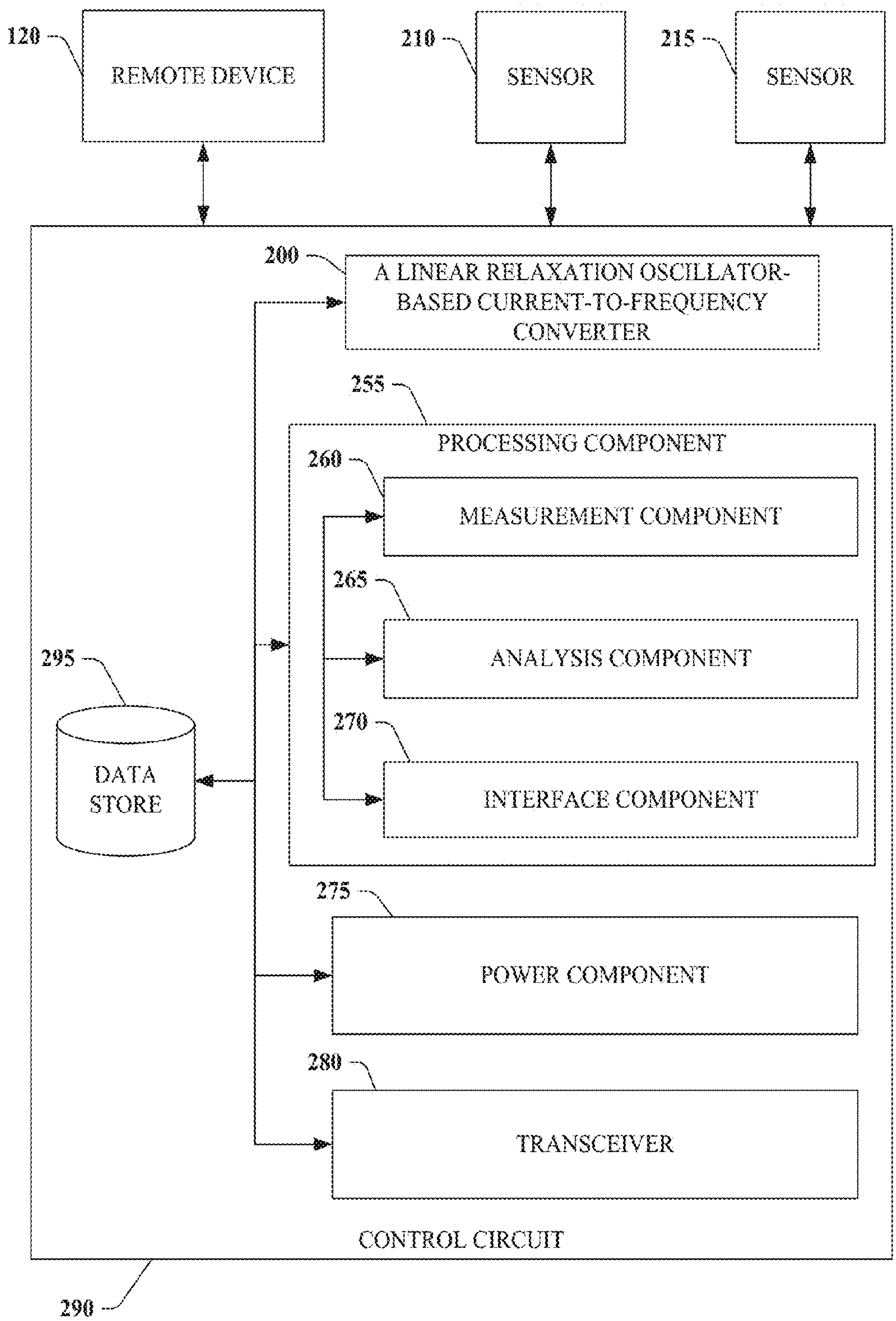
120
REMOTE DEVICE
210
SENSOR
215
SENSOR
200
A LINEAR RELAXATION OSCILLATOR-BASED CURRENT-TO-FREQUENCY CONVERTER
255
PROCESSING COMPONENT
260
MEASUREMENT COMPONENT
265
ANALYSIS COMPONENT
270
INTERFACE COMPONENT
295
DATA STORE
275
POWER COMPONENT
280
TRANSCEIVER
CONTROL CIRCUIT
290

FIG. 2D

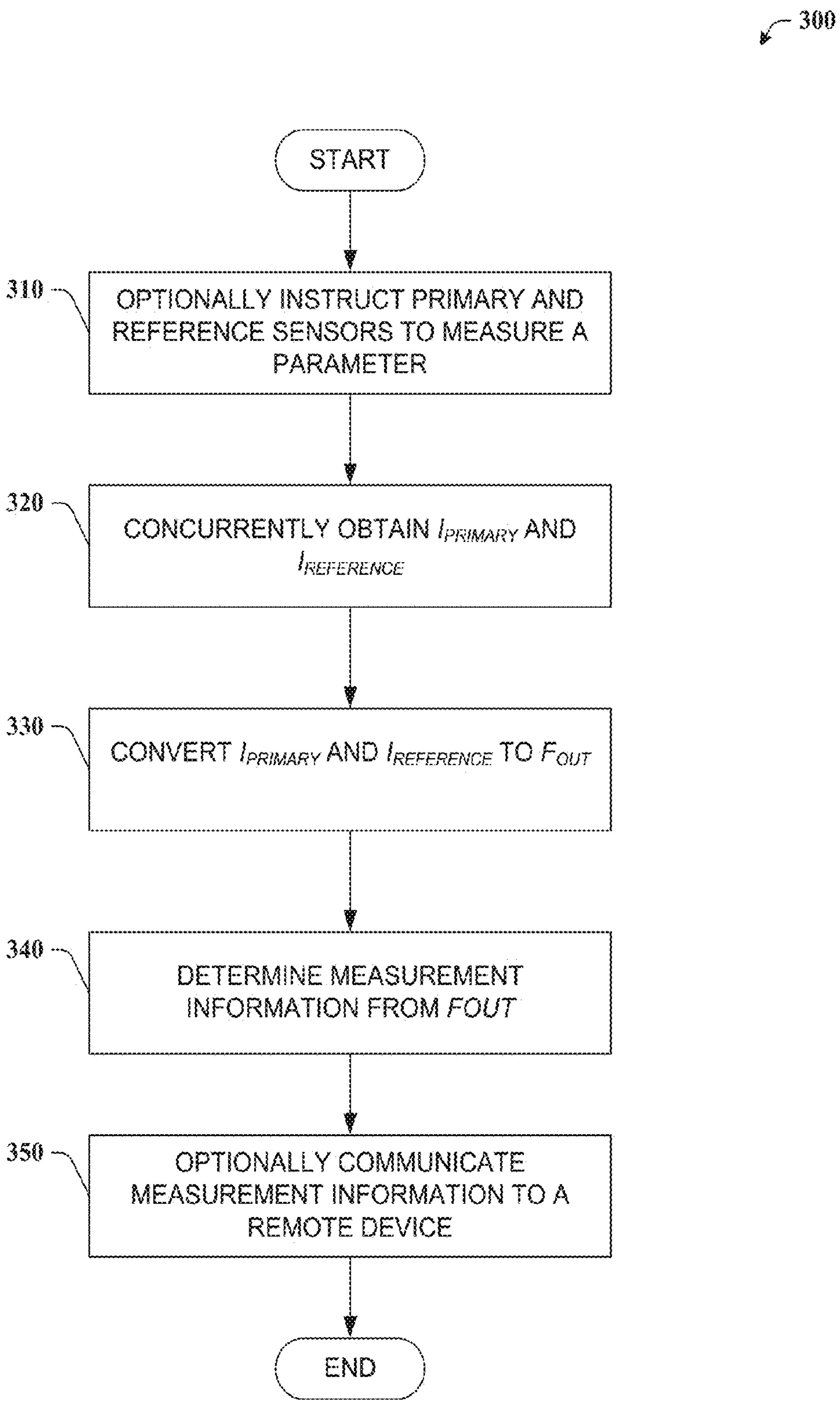
300
START
310
OPTIONALLY INSTRUCT PRIMARY AND REFERENCE SENSORS TO MEASURE A PARAMETER
320
CONCURRENTLY OBTAIN $I_{PRIMARY}$ AND $I_{REFERENCE}$
330
CONVERT $I_{PRIMARY}$ AND $I_{REFERENCE}$ TO F_{OUT}
340
DETERMINE MEASUREMENT INFORMATION FROM *FOUT*
350
OPTIONALLY COMMUNICATE MEASUREMENT INFORMATION TO A REMOTE DEVICE
END

FIG. 3

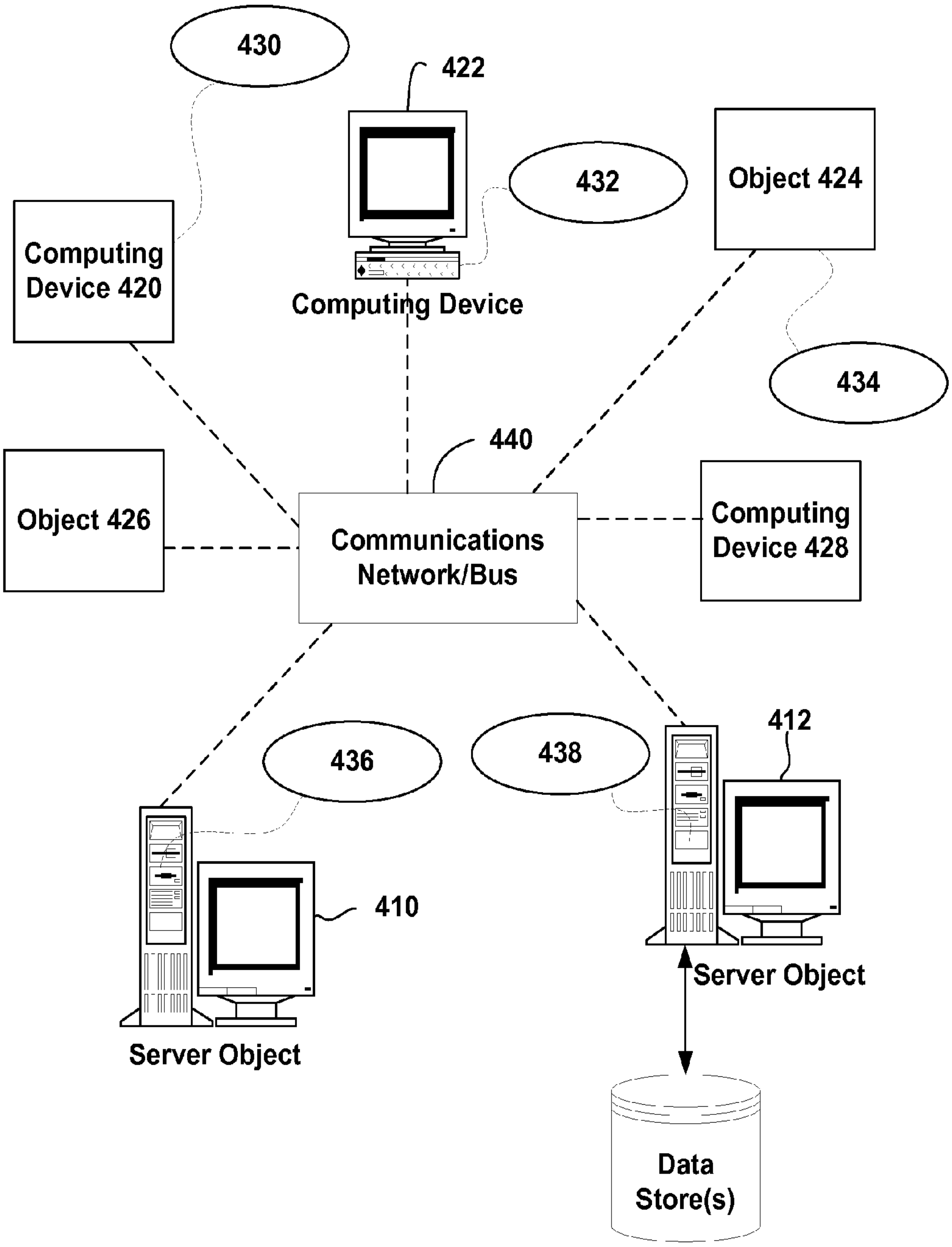
430
422
432
Object 424
Computing
Device 420
Computing Device
434
440
Object 426
Communications
Network/Bus
Computing
Device 428
412
436
438
410
Server Object
Server Object
Data
Store(s)

FIG. 4

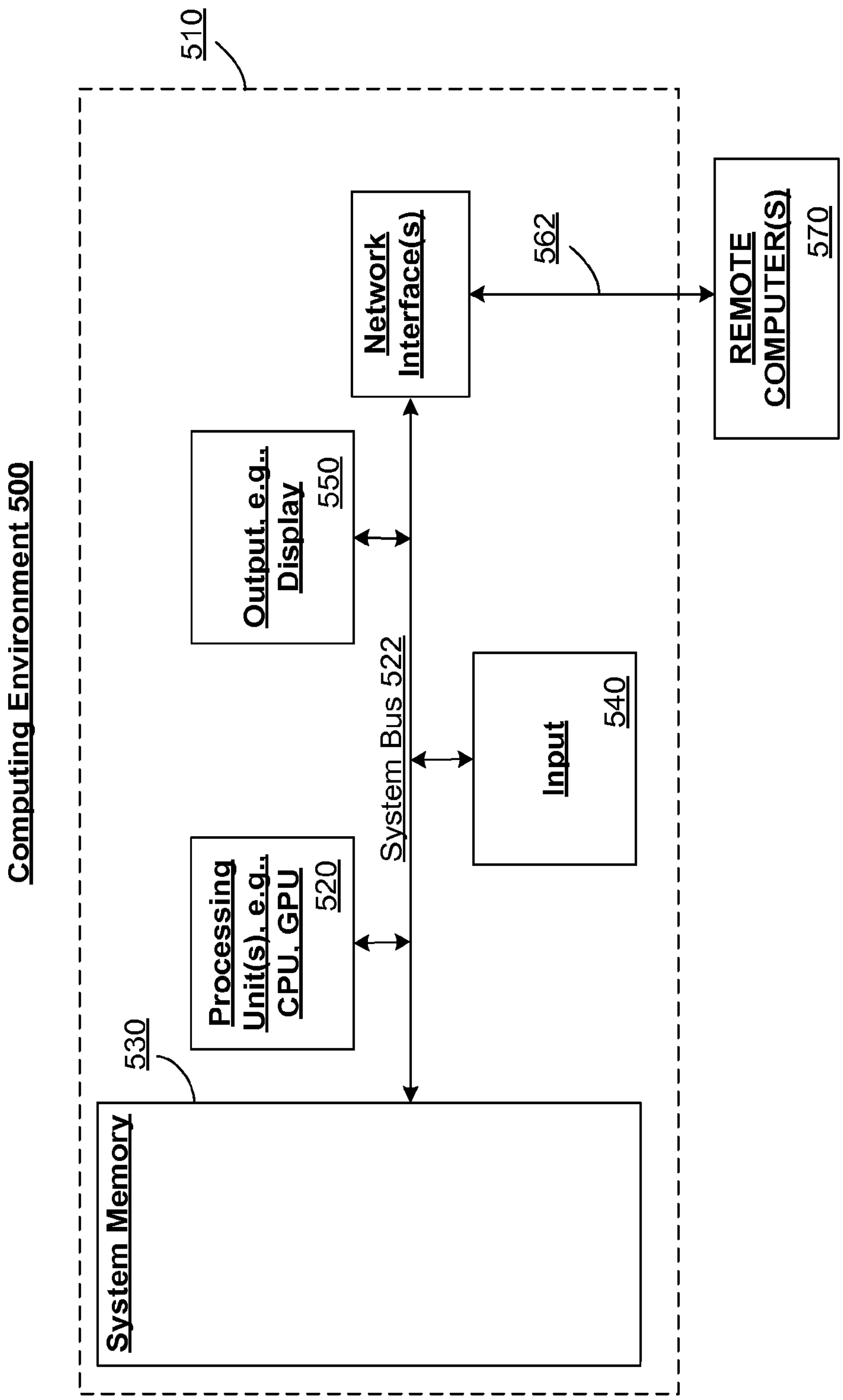
Computing Environment 500
510
System Memory
530
Processing Unit(s), e.g., CPU, GPU
520
System Bus 522
Input
540
Output, e.g., Display
550
Network Interface(s)
562
REMOTE COMPUTER(S)
570

FIG. 5

CANCELLATION OF A BASELINE CURRENT SIGNAL VIA CURRENT SUBTRACTION WITHIN A LINEAR RELAXATION OSCILLATOR-BASED CURRENT-TO-FREQUENCY CONVERTER CIRCUIT

TECHNICAL FIELD

This disclosure generally relates to systems and/or methods for subtracting in the current domain an output current primary signal from a primary sensor from an output current reference signal from a reference sensor to produce a frequency output signal indicative of the difference between the output current primary signal and the output current reference signal.

BACKGROUND OF THE INVENTION

Electrochemical sensors typically have a baseline output signal that fluctuates over time, temperature, and voltage potential. This baseline signal is generally undesirable since it is often indistinguishable from a signal produced by a parameter being measured by the electrochemical sensor. Conventionally, such baseline signal is removed by employing a reference electrochemical sensor that produces the baseline signal, but does not produce the signal associated with the parameter being measured, in conjunction with a primary electrochemical sensor that produces a total signal comprising the baseline signal and the signal associated with the parameter being measured. The difference between the total signal produced by the primary electrochemical sensor and the signal produced by the reference electrochemical sensor is the signal associated with the measured parameter. Conventionally, electrochemical sensors produce output current signals that are converted to voltage or a digital format for analysis, such as subtracting a primary signal from a reference signal as discussed above. This generally requires the primary electrochemical sensor and the reference electrochemical sensor to each have a separate readout circuit to convert the output current signal. This is not an issue in an environment where power requirements and physical space are not limiting factors, such as a non-portable electrochemical sensing device. However, where power requirements and physical space are limited (e.g., such as with respect to a contact lens), employment of multiple readout circuits can be problematic.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A illustrates a diagram of an exemplary non-limiting system for system for detecting (or inferring) measurement of a parameter associated with a wearer of the contact lens in accordance with an implementation of this disclosure.

FIG. **1**B illustrates a diagram of the exemplary non-limiting system of FIG. **1**A worn on both eyes of a human user in accordance with an implementation of this disclosure.

FIG. **2**A illustrates a diagram of an exemplary non-limiting linear relaxation oscillator-based current-to-frequency converter circuit accordance with an implementation of this disclosure.

FIG. **2**B illustrates a diagram of an exemplary non-limiting chart associated with operation of the linear relaxation oscillator-based current-to-frequency converter circuit with respect to feedback voltage and charging/discharging phases of integration capacitor in accordance with an implementation of this disclosure.

FIG. **2**C illustrates a diagram of an exemplary non-limiting contact lens from FIG. **1**A in accordance with an implementation of this disclosure.

FIG. **2**D illustrates a diagram of an exemplary non-limiting control circuit that determines (or infers) measurement information associated with a measured parameter in accordance with an implementation of this disclosure.

FIG. **3** illustrates an exemplary non-limiting flow diagram for detecting (or inferring) measurement of a parameter in accordance with an implementation of this disclosure.

FIG. **4** is a block diagram representing an exemplary non-limiting networked environment in which the various embodiments can be implemented.

FIG. **5** is a block diagram representing an exemplary non-limiting computing system or operating environment in which the various embodiments can be implemented.

DETAILED DESCRIPTION

Overview

Various aspects or features of this disclosure are described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In this specification, numerous specific details are set forth in order to provide a thorough understanding of this disclosure. It should be understood, however, that certain aspects of this disclosure may be practiced without these specific details, or with other methods, components, materials, etc. In other instances, well-known structures and devices are shown in block diagram form to facilitate describing this disclosure.

In accordance with various disclosed aspects, a linear relaxation oscillator-based current-to-frequency converter circuit (hereinafter referred to as "LROCF converter circuit") is provided for subtracting in the current domain an output current primary signal associated with a primary sensor from an output current reference signal associated with a reference sensor to produce a frequency output signal indicative of the difference between the output current primary signal and the output current reference signal.

It is to be appreciated that, while embodiments disclosed herein refer to electrochemical sensors, any suitable sensors that produce an output current signal can be employed. Furthermore, example embodiments herein refer to electrochemical sensors for measuring glucose level. However, sensors for measuring any suitable parameter can be employed, non-limiting examples of which include: temperature, moisture, acidity, or specific minerals, gases, chemicals, biological agents, or proteins, etc. Additionally, example embodiments herein refer to a contact lens, however, any suitable device can employ the linear relaxation oscillator-based current-to-frequency converter circuit, non-limiting examples of which include: a skin patch, a wearable device, a non-wearable device, a portable device, or a non-portable device.

Referring now to the drawings, FIG. **1**A depicts a system **100** for detecting (or inferring) measurement of a parameter (e.g., glucose level) associated with a wearer of the contact lens. System **100** includes a contact lens **110** that determines (or infers) information related to measurement of a parameter (hereinafter referred to as "measurement information"), such as glucose level of the wearer of the contact lens. In addition, contact lens **110** can utilize the measurement information locally to control features of contact lens **110** (e.g., issuing commands, adjusting content presentation, activating or deactivating options or components (e.g., high/low glucose warning LED indicators), or any other suitable function). Furthermore, contact lens **110** can optionally communicate measurement information to a remote device **120** for employment in connection with operations associated with the remote device **120** (e.g., analyzing measurement information, adjusting content presentation, activating or deactivating options or components (e.g., a wearable insulin pump), requesting instructions or information, issuing commands, or any other suitable function). Contact lens **110** and remote device **120** can also receive input from users, for example to control interaction with and presentation of content, or operation of contact lens **110** or remote device **120**, see e.g., FIG. **5** and corresponding disclosure.

Contact lens **110** and remote device **120**, respectively include a memory that stores computer executable components and a processing circuit, which can include a processor, that executes computer executable components stored in the memory (see e.g., FIG. **5**). Contact lens **110** and remote device **120** can communicate via a wireless network. It is to be appreciated that while only one remote device **120** is depicted, contact lens **110** can communicate with any suitable number of remote devices **120** concurrently, serially, an ad hoc manner, or in accordance with any suitable protocol. Additionally, remote device **120** can communicate with any suitable number of contact lenses **110** concurrently, serially, an ad hoc manner, or in accordance with any suitable protocol.

Remote device **120**, can include a wearable device or a non-wearable device. Wearable device can include, for example, heads-up display glasses, a monocle, eyeglasses, sunglasses, a headset, a visor, a cap, a helmet, a mask, a headband, clothing, or any other suitable device that can be worn by a human or non-human user and can communicate with contact lens **110** remotely. Non-wearable device can include, for example, a mobile device, a mobile phone, a camera, a camcorder, a video camera, personal data assistant, laptop computer, tablet computer, desktop computer, server system, cable set top box, satellite set top box, cable modem, television set, monitor, media extender device, blu-ray device, DVD (digital versatile disc or digital video disc) device, compact disc device, video game system, portable video game console, audio/video receiver, radio device, portable music player, navigation system, car stereo, or any suitable device that can communicate with a contact lens **110** remotely. Moreover, remote device **120** and contact lens **110** can include a display and/or user interface (e.g., a web browser or application), that can generate, receive and/or present graphical indicia (e.g., displays, text, video . . .) generated locally or remotely.

Referring to FIG. **1**B, system **100** is depicted on a human user. Contact lenses **110** are shown worn on both eyes **130**, covering irises **140** while eyelids **150** are open. Remote device **120** is shown with one or more transceivers (not shown) arranged to communicate wirelessly with contact lenses **110**. It is to be further appreciated that respective transceivers of remote device **120** can have transmission power and/or signal reception sensitivity suitable for transmitting a signal to and/or receiving a signal from an associated contact lenses **110** on an eye without interfering with another contact lenses **110** on another eye. While FIG. **1**B depicts a contact lenses **110** arrangement in both eyes, it is to be appreciated that an arrangement with a contact lens **110** on one eye can be employed.

Referring to FIG. **2**A, an LROCF converter circuit **200** is depicted for subtracting an output current primary signal $I_{PRIMARY}$ from a primary sensor **210** from an output current reference signal $I_{REFERENCE}$ from a reference sensor **215** in the current domain to produce an output frequency signal F_{OUT} indicative of the difference between $I_{PRIMARY}$ and $I_{REFERENCE}$. Primary sensor **210** is a sensor that produces an output current signal during measurement of a parameter. In an embodiment, primary sensor **210** is an electrochemical sensor for measuring a parameter, such as glucose level in tears produced by eye **130**. An enzyme in primary sensor **210** reacts with glucose in the tears to produce a measurement current signal indicative of amount of glucose in the tears. Primary sensor **210** also produces a baseline current signal that fluctuates over time, temperature, and voltage potential. As such, $I_{PRIMARY}$ comprises the baseline current signal and the measurement current signal. Reference sensor **215** can be any suitable sensor that produces a baseline current signal substantially similar to the baseline current signal produced by primary sensor **210**, but does not produce the measurement current signal in the presence of the measured parameter (e.g., glucose in the tears). In an embodiment, reference sensor **215** is an electrochemical sensor, but it should be appreciated that reference sensor **215** does not have to be an electrochemical sensor and does not have to match a sensor type of the primary sensor **210**. The difference between $I_{PRIMARY}$ and $I_{REFERENCE}$ represents measurement current signal I_{NET} indicative of measurement of the parameter (e.g., amount of glucose in the tears). LROCF converter circuit **200** includes inverter **250**. LROCF converter circuit **200** also includes switches **220**, **225**, **230**, and **235** whose state is based upon feedback voltage V_{FB} derived from a voltage $V_{INTEGRATE}$ on integration capacitor **240** having a capacitance $C_{INTEGRATE}$. LROCF converter circuit **200** further includes amplifier **245** that is employed to generate V_{FB} from $V_{INTEGRATE}$. In an embodiment, amplifier **245** is employed that has hysteresis designed therein, such as a Schmitt trigger. It should be noted that other embodiments can employ an amplifier without hysteresis.

Referring to FIG. **2**B, a chart is illustrated that is associated with operation of LROCF converter circuit **200** with respect to $V_{INTEGRATE}$ and charging/discharging phases of integration capacitor **240**. As current signals $I_{PRIMARY}$ and $I_{REFERENCE}$ are produced during measurement of the parameter, LROCF converter circuit **200** enters a charging phase where $I_{PRIMARY}$ is pushed into integration capacitor **240** while $I_{REFERENCE}$ is concurrently pulled from integration capacitor **240**. This creates voltage $V_{INTEGRATE}$ on integration capacitor **240**. When $V_{INTEGRATE}$ reaches a high voltage threshold V_H the state of switches **220**, **225**, **230**, and **235** change in response to V_{FB} such that LROCF converter circuit **200** enters a discharging phase where $I_{PRIMARY}$ is pulled from integration capacitor **240** while $I_{REFERENCE}$ is concurrently pushed onto integration capacitor **240**. As a result, voltage $V_{INTEGRATE}$ decreases until reaching a low voltage threshold V_H, at which switches **220**, **225**, **230**, and **235** change in response to V_{FB} such that LROCF converter circuit **200** enters the charging phase again. While $I_{PRIMARY}$ and $I_{REFERENCE}$ are produced during measurement of the parameter, LROCF converter circuit **200** continuously alternates between charging and discharging phases which causes the LROCF converter circuit **200** to produce output frequency signal F_{OUT} shown in FIG. 2A. The following equations illustrate the relationship between F_{OUT}, $I_{PRIMARY}$, and $I_{REFERENCE}$.

$$I_{NET}=I_{PRIMARY}-I_{REFERENCE} \quad \text{Equation (1)}$$

$$\Delta V=V_H-V_L \quad \text{Equation (2)}$$

$$I_{NET}=C_{INTEGRATE}\frac{\Delta V}{\Delta T} \quad \text{Equation (3)}$$

$$\Delta T = C_{INTEGRATE}\frac{\Delta V}{I_{NET}} \qquad \text{Equation (4)}$$

$$T = 2\frac{C_{INTEGRATE}\Delta V}{I_{NET}}, \qquad \text{Equation (5)}$$

where T is the time period of oscillation

$$F_{OUT} = \frac{I_{NET}}{2C_{INTEGRATE}\Delta V} \qquad \text{Equation (6)}$$

$$I_{NET}=F_{OUT}2C_{INTEGRATE}\Delta V \qquad \text{Equation (7)}$$

As such, output frequency signal F_{OUT} is linear with measurement current signal I_{NET}. Therefore, the output frequency signal F_{OUT} can be employed given known values of $C_{INTEGRATE}$, V_H, and V_L associated with LROCF converter circuit **200** to determine I_{NET}, e.g., using equation (7). In an embodiment, the value of I_{NET} can be employed to determine (of infer) a value associated with the measured parameter (e.g. glucose level), for example using a function, lookup table, or any suitable mechanism that relates values of I_{NET} to corresponding values of the measured parameter. In another embodiment, the value of F_{OUT} can be employed to determine (of infer) a value associated with the measured parameter, for example using a function, lookup table, or any suitable mechanism that relates values of F_{OUT} to corresponding values of the measured parameter.

Referring to FIG. **2**C, contact lens **110** is depicted that includes, disposed on or within its substrate, a control circuit **290**, primary sensor **210**, and reference sensor **215**. Control circuit **290** is coupled via wire to primary sensor **210** and reference sensor **215** to receive output current signals. It is to be further appreciated that different aspects of interaction between control circuit **290**, and primary sensor **210** and reference sensor **215** may be respectively coupled via wire or wirelessly. In one example, all interactions are coupled via wire. In a further example, some interactions are coupled wirelessly, while other interactions are coupled via wire. For example, communication interaction may be coupled wirelessly, while power supply interactions and current signals may be coupled via wire. It is to be appreciated that primary sensor **210** and reference sensor **215** can respectively be uniquely identifiable to control circuit **290**, for example, via an identifier signal or identifying information conveyed respectively from primary sensor **210** and reference sensor **215** to control circuit **290**. It is also to be appreciated that control circuit **290**, primary sensor **210**, and reference sensor **215** can be located at any suitable locations of contact lens **110**.

Referring to FIG. **2**D, is depicted control circuit **290** that includes processing component **255** that determines (or infers) measurement information associated with a measured parameter of primary sensor **210**, and communicates with remote device **120**, primary sensor **210**, and reference sensor **215**. Control circuit **290** also includes LROCF converter circuit **200** that converts current signals $I_{PRIMARY}$ and $I_{REFERENCE}$ from primary sensor **210** and reference sensor **215** respectively into an output frequency signal F_{OUT} indicative of the difference between $I_{PRIMARY}$ and $I_{REFERENCE}$ as disclosed above. In addition, control circuit **290** can include

power component **275** that manages, receives, generates, stores, and/or distributes usable electrical power to other components of contact lens **110**. Control circuit **290** can also include one or more transceivers **280** for transmitting or receiving signals to or from remote device **120**, primary sensor **210**, or reference sensor **215**. It is to be appreciated that primary sensor **210** or reference sensor **215** may interface directly with processing component **255** without need to employ transceiver **280**, for example through a wired coupling. Additionally, control circuit **290** can include a data store **295** that can store data from processing component **255**, LROCF converter circuit **200**, power component **275**, transceiver **280**, remote device **120**, primary sensor **210**, or reference sensor **215**. Data store **295** can reside on any suitable type of storage device, non-limiting examples of which are illustrated with reference to FIGS. **4** and **5**, and corresponding disclosure.

With continued reference to FIG. **2**D, processing component **255** includes measurement component **260** that instructs primary sensor **210** or reference sensor **215** to measure a parameter concurrently. It is to be appreciated that one or both of primary sensor **210** or reference sensor **215** can continuously or periodically at predetermined intervals measure the parameter, thereby not requiring instructions from measurement component **260**. It is to be appreciated that any suitable interval for measuring the parameter can be employed.

During measurement of the parameter, LROCF converter circuit **200** produces output frequency signal F_{OUT} which is analyzed by analysis component **265** to determine (or infer) measurement information. It is to be appreciated that measurement information can include, a frequency value corresponding to F_{OUT}, an amount of current corresponding to I_{NET}, a value for the measured parameter based upon F_{OUT} or I_{NET} as discussed above, or any other suitable information related to or derived from measurement of the parameter. It is to be appreciated that analysis component **265** can employ various algorithms and mathematical functions to determine (or infer) measurement information. In an embodiment, analysis component **265** can determine (or infer) measurement information by employing data from F_{OUT} in conjunction with a threshold. It is to be appreciated that a threshold can be any suitable condition, for example, a greater than condition, less than condition, equal to condition, one or more ranges, or function. For example, specific frequency ranges can correspond to specific glucose levels. In addition, analysis component **265** can employ measurement information obtained at multiple points in time to track measurement values of the parameter. For example, glucose level can be tracked by time of day to monitor spikes after meal times. In another example, glucose level can be tracked over several days to determine an average glucose level. In a further example, analysis component **265** can track measurement over a period of time to identify patterns associated with the measured parameter. It is further to be appreciated that analysis of measurement information can be performed by remote device **120**.

Continuing with reference to FIG. **2**D, interface component **270** can communicate measurement information to remote device **120** using one or more transceivers **280**. Furthermore, interface component **270** can receive data or commands from remote device **120** using the one or more transceivers **280**. For example, interface component **270** can receive a request for measurement information from remote device **120** and respond to the request with measurement information. In another example, interface component **270**, can receive a command from remote device **120** for measurement component **260** to instruct primary sensor **210** or reference sensor **215** to measure a parameter concurrently. In a further example, analysis by remote device **120** of measurement information can indicate a problem and remote device **120** can send a command to interface component **270** for processing component **255** to present a warning indication or message on a display integrated into contact lens **110**.

Power component **275** can include any suitable power source that can manage, receive, generate, store, and/or distribute necessary electrical power for the operation of various components of multi-sensor contact lens **110**. For example, power component **275** can include but is not limited to a battery, a capacitor, a solar power source, radio frequency power source, electrochemical power source, temperature power source, or mechanically derived power source (e.g., MEMs system). In another example, power component **275** receives or generates usable electrical power from signals from one or more sensors (e.g., photodiode, pressure, heat, conductivity, electric field, magnetic, electrochemical, etc.) integrated into contact lens **110**. Transceiver **280** can transmit and receive information to and from, or within contact lens **110**. In some embodiments, transceiver **280** can include an RF antenna.

It is to be appreciated that in accordance with one or more implementations described in this disclosure, users can opt-in or opt-out of providing personal information, demographic information, location information, proprietary information, sensitive information, or the like in connection with data gathering aspects. Moreover, one or more implementations described herein can provide for anonymizing collected, received, or transmitted data.

FIG. **3** illustrates various methodologies in accordance with certain disclosed aspects. While, for purposes of simplicity of explanation, the methodologies are shown and described as a series of acts, it is to be understood and appreciated that the disclosed aspects are not limited by the order of acts, as some acts may occur in different orders and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology can alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with certain disclosed aspects. Additionally, it is to be further appreciated that the methodologies disclosed hereinafter and throughout this disclosure are capable of being stored on an article of manufacture to facilitate transporting and transferring such methodologies to computers.

Referring to FIG. **3**, an exemplary method **300** for determining measurement information is depicted. At reference numeral **310**, an optional act of instructing a primary sensor and reference sensor to concurrently measure a parameter is performed (e.g. by a measurement component **260** or control circuit **290**). As noted above, it is to be appreciated that one or both of the primary sensor or reference sensor can continuously or periodically measure the parameter. At reference numeral **320**, current signals $I_{PRIMARY}$ and $I_{REFERENCE}$ from a primary sensor and reference sensor respectively are obtained associated with a measured parameter (e.g. by a measurement component **260**, LROCF converter circuit **200**, processing component **255**, or control circuit **290**). At reference numeral **330**, $I_{PRIMARY}$ and $I_{REFERENCE}$ are converted into an output frequency signal F_{OUT} indicative of the difference between $I_{PRIMARY}$ and $I_{REFERENCE}$ (e.g. by a LROCF converter circuit **200**). At reference numeral **340**, measurement information for the measured parameter is determined (or inferred) based on the output frequency signal F_{OUT} (e.g. by an analysis component **265** or control circuit **290**). At reference numeral **350**, an optional act of communicating measurement information to a remote device and/or receiving information from a remote device is performed (e.g. by an interface component **270** or control circuit **290**).

Exemplary Networked and Distributed Environments

One of ordinary skill in the art can appreciate that the various embodiments described herein can be implemented in connection with any computer or other client or server device, which can be deployed as part of a computer network or in a distributed computing environment, and can be connected to any kind of data store where media may be found. In this regard, the various embodiments described herein can be implemented in any computer system or environment having any number of memory or storage units, and any number of applications and processes occurring across any number of storage units. This includes, but is not limited to, an environment with server computers and client computers deployed in a network environment or a distributed computing environment, having remote or local storage.

Distributed computing provides sharing of computer resources and services by communicative exchange among computing devices and systems. These resources and services include the exchange of information, cache storage and disk storage for objects, such as files. These resources and services can also include the sharing of processing power across multiple processing units for load balancing, expansion of resources, specialization of processing, and the like. Distributed computing takes advantage of network connectivity, allowing clients to leverage their collective power to benefit the entire enterprise. In this regard, a variety of devices may have applications, objects or resources that may participate in the various embodiments of this disclosure.

FIG. **4** provides a schematic diagram of an exemplary networked or distributed computing environment. The distributed computing environment comprises computing objects **410**, **412**, etc. and computing objects or devices **420**, **422**, **424**, **426**, **428**, etc., which may include programs, methods, data stores, programmable logic, etc., as represented by applications **430**, **432**, **434**, **436**, **438**. It can be appreciated that computing objects **410**, **412**, etc. and computing objects or devices **420**, **422**, **424**, **426**, **428**, etc. may comprise different devices, such as personal digital assistants (PDAs), audio/video devices, mobile phones, MP3 players, personal computers, laptops, tablets, etc.

Each computing object **410**, **412**, etc. and computing objects or devices **420**, **422**, **424**, **426**, **428**, etc. can communicate with one or more other computing objects **410**, **412**, etc. and computing objects or devices **420**, **422**, **424**, **426**, **428**, etc. by way of the communications network **440**, either directly or indirectly. Even though illustrated as a single element in FIG. **4**, network **440** may comprise other computing objects and computing devices that provide services to the system of FIG. **4**, and/or may represent multiple interconnected networks, which are not shown. Each computing object **410**, **412**, etc. or computing objects or devices **420**, **422**, **424**, **426**, **428**, etc. can also contain an application, such as applications **430**, **432**, **434**, **436**, **438**, that might make use of an API, or other object, software, firmware and/or hardware, suitable for communication with or implementation of various embodiments of this disclosure.

There are a variety of systems, components, and network configurations that support distributed computing environments. For example, computing systems can be connected together by wired or wireless systems, by local networks or widely distributed networks. Currently, many networks are coupled to the Internet, which provides an infrastructure for widely distributed computing and encompasses many different networks, though any suitable network infrastructure can be used for exemplary communications made incident to the systems as described in various embodiments herein.

Thus, a host of network topologies and network infrastructures, such as client/server, peer-to-peer, or hybrid architectures, can be utilized. The "client" is a member of a class or group that uses the services of another class or group. A client can be a computer process, e.g., roughly a set of instructions or tasks, that requests a service provided by another program or process. A client process may utilize the requested service without having to "know" all working details about the other program or the service itself.

In a client/server architecture, particularly a networked system, a client can be a computer that accesses shared network resources provided by another computer, e.g., a server. In the illustration of FIG. **4**, as a non-limiting example, computing objects or devices **420**, **422**, **424**, **426**, **428**, etc. can be thought of as clients and computing objects **410**, **412**, etc. can be thought of as servers where computing objects **410**, **412**, etc. provide data services, such as receiving data from client computing objects or devices **420**, **422**, **424**, **426**, **428**, etc., storing of data, processing of data, transmitting data to client computing objects or devices **420**, **422**, **424**, **426**, **428**, etc., although any computer can be considered a client, a server, or both, depending on the circumstances. Any of these computing devices may be processing data, or requesting transaction services or tasks that may implicate the techniques for systems as described herein for one or more embodiments.

A server is typically a remote computer system accessible over a remote or local network, such as the Internet or wireless network infrastructures. The client process may be active in a first computer system, and the server process may be active in a second computer system, communicating with one another over a communications medium, thus providing distributed functionality and allowing multiple clients to take advantage of the information-gathering capabilities of the server. Any software objects utilized pursuant to the techniques described herein can be provided standalone, or distributed across multiple computing devices or objects.

In a network environment in which the communications network/bus **440** is the Internet, for example, the computing objects **410**, **412**, etc. can be Web servers, file servers, media servers, etc. with which the client computing objects or devices **420**, **422**, **424**, **426**, **428**, etc. communicate via any of a number of known protocols, such as the hypertext transfer protocol (HTTP). Objects **410**, **412**, etc. may also serve as client computing objects or devices **420**, **422**, **424**, **426**, **428**, etc., as may be characteristic of a distributed computing environment.

Exemplary Computing Device

As mentioned, advantageously, the techniques described herein can be applied to any suitable device. It is to be understood, therefore, that handheld, portable and other computing devices and computing objects of all kinds are contemplated for use in connection with the various embodiments. Accordingly, the computer described below in FIG. **5** is but one example of a computing device that can be employed with implementing one or more of the systems or methods shown and described in connection with FIGS. **1**-**5**. Additionally, a suitable server can include one or more aspects of the below computer, such as a media server or other media management server components.

Although not required, embodiments can partly be implemented via an operating system, for use by a developer of services for a device or object, and/or included within application software that operates to perform one or more functional aspects of the various embodiments described herein. Software may be described in the general context of computer executable instructions, such as program modules, being executed by one or more computers, such as client workstations, servers or other devices. Those skilled in the art will appreciate that computer systems have a variety of configurations and protocols that can be used to communicate data, and thus, no particular configuration or protocol is to be considered limiting.

FIG. **5** thus illustrates an example of a suitable computing system environment **500** in which one or aspects of the embodiments described herein can be implemented, although as made clear above, the computing system environment **500** is only one example of a suitable computing environment and is not intended to suggest any limitation as to scope of use or functionality. Neither is the computing environment **500** be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in the exemplary operating environment **500**.

With reference to FIG. **5**, an exemplary computing device for implementing one or more embodiments in the form of a computer **510** is depicted. Components of computer **510** may include, but are not limited to, a processing unit **520**, a system memory **530**, and a system bus **522** that couples various system components including the system memory to the processing unit **520**.

Computer **510** typically includes a variety of computer readable media and can be any available media that can be accessed by computer **510**. The system memory **530** may include computer storage media in the form of volatile and/or nonvolatile memory such as read only memory (ROM) and/or random access memory (RAM). By way of example, and not limitation, system memory **530** may also include an operating system, application programs, other program modules, and program data.

A user can enter commands and information into the computer **510** through input devices **540**, non-limiting examples of which can include a keyboard, keypad, a pointing device, a mouse, stylus, touchpad, touchscreen, trackball, motion detector, camera, microphone, joystick, game pad, scanner, or any other device that allows the user to interact with computer **510**. A monitor or other type of display device is also connected to the system bus **522** via an interface, such as output interface **550**. In addition to a monitor, computers can also include other peripheral output devices such as speakers and a printer, which may be connected through output interface **550**.

The computer **510** may operate in a networked or distributed environment using logical connections to one or more other remote computers, such as remote computer **570**. The remote computer **570** may be a personal computer, a server, a router, a network PC, a peer device or other common network node, or any other remote media consumption or transmission device, and may include any or all of the elements described above relative to the computer **510**. The logical connections depicted in FIG. **5** include a network **562**, such local area network (LAN) or a wide area network (WAN), but may also include other networks/buses e.g., cellular networks.

As mentioned above, while exemplary embodiments have been described in connection with various computing devices and network architectures, the underlying concepts may be applied to any network system and any computing device or system in which it is desirable to publish or consume media in a flexible way.

Also, there are multiple ways to implement the same or similar functionality, e.g., an appropriate API, tool kit, driver code, operating system, control, standalone or downloadable software object, etc. which enables applications and services to take advantage of the techniques described herein. Thus, embodiments herein are contemplated from the standpoint of an API (or other software object), as well as from a software or hardware object that implements one or more aspects described herein. Thus, various embodiments described herein can have aspects that are wholly in hardware, partly in hardware and partly in software, as well as in software.

The word "exemplary" is used herein to mean serving as an example, instance, or illustration. For the avoidance of doubt, the aspects disclosed herein are not limited by such examples. In addition, any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs, nor is it meant to preclude equivalent exemplary structures and techniques known to those of ordinary skill in the art. Furthermore, to the extent that the terms "includes," "has," "contains," and other similar words are used in either the detailed description or the claims, for the avoidance of doubt, such terms are intended to be inclusive in a manner similar to the term "comprising" as an open transition word without precluding any additional or other elements.

Computing devices typically include a variety of media, which can include computer-readable storage media and/or communications media, in which these two terms are used herein differently from one another as follows. Computer-readable storage media can be any available storage media that can be accessed by the computer, is typically of a non-transitory nature, and can include both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer-readable storage media can be implemented in connection with any method or technology for storage of information such as computer-readable instructions, program modules, structured data, or unstructured data. Computer-readable storage media can include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disk (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or other tangible and/or non-transitory media which can be used to store desired information. Computer-readable storage media can be accessed by one or more local or remote computing devices, e.g., via access requests, queries or other data retrieval protocols, for a variety of operations with respect to the information stored by the medium.

On the other hand, communications media typically embody computer-readable instructions, data structures, program modules or other structured or unstructured data in a data signal such as a modulated data signal, e.g., a carrier wave or other transport mechanism, and includes any information delivery or transport media. The term "modulated data signal" or signals refers to a signal that has one or more of its characteristics set or changed in such a manner as to encode information in one or more signals. By way of example, and not limitation, communication media include wired media, such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media.

As mentioned, the various techniques described herein may be implemented in connection with hardware or software or, where appropriate, with a combination of both. As used herein, the terms "component," "system" and the like are likewise intended to refer to a computer-related entity, either hardware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on computer and the computer can be a component. One or more components may reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers. Further, a "device" can come in the form of specially designed hardware; generalized hardware made specialized by the execution of software thereon that enables the hardware to perform specific function (e.g., coding and/or decoding); software stored on a computer readable medium; or a combination thereof.

The aforementioned systems have been described with respect to interaction between several components. It can be appreciated that such systems and components can include those components or specified sub-components, some of the specified components or sub-components, and/or additional components, and according to various permutations and combinations of the foregoing. Sub-components can also be implemented as components communicatively coupled to other components rather than included within parent components (hierarchical). Additionally, it is to be noted that one or more components may be combined into a single component providing aggregate functionality or divided into several separate sub-components, and that any one or more middle layers, such as a management layer, may be provided to communicatively couple to such sub-components in order to provide integrated functionality. Any components described herein may also interact with one or more other components not specifically described herein but generally known by those of skill in the art.

In order to provide for or aid in the numerous inferences described herein (e.g. inferring relationships between metadata or inferring topics of interest to users), components described herein can examine the entirety or a subset of the data to which it is granted access and can provide for reasoning about or infer states of the system, environment, etc. from a set of observations as captured via events and/or data. Inference can be employed to identify a specific context or action, or can generate a probability distribution over states, for example. The inference can be probabilistic—that is, the computation of a probability distribution over states of interest based on a consideration of data and events. Inference can also refer to techniques employed for composing higher-level events from a set of events and/or data.

Such inference can result in the construction of new events or actions from a set of observed events and/or stored event data, whether or not the events are correlated in close temporal proximity, and whether the events and data come from one or several event and data sources. Various classification (explicitly and/or implicitly trained) schemes and/or systems (e.g., support vector machines, neural networks, expert systems, Bayesian belief networks, fuzzy logic, data fusion engines, etc.) can be employed in connection with performing automatic and/or inferred action in connection with the claimed subject matter.

A classifier can map an input attribute vector, x=(x1, x2, x3, x4, xn), to a confidence that the input belongs to a class, as by f(x)=confidence(class). Such classification can employ a probabilistic and/or statistical-based analysis (e.g., factoring into the analysis utilities and costs) to prognose or infer an action that a user desires to be automatically performed. A support vector machine (SVM) is an example of a classifier that can be employed. The SVM operates by finding a hypersurface in the space of possible inputs, where the hypersurface attempts to split the triggering criteria from the non-triggering events. Intuitively, this makes the classification correct for testing data that is near, but not identical to training data. Other directed and undirected model classification approaches include, e.g., naïve Bayes, Bayesian networks, decision trees, neural networks, fuzzy logic models, and probabilistic classification models providing different patterns of independence can be employed. Classification as used herein also is inclusive of statistical regression that is utilized to develop models of priority.

In view of the exemplary systems described above, methodologies that may be implemented in accordance with the described subject matter will be better appreciated with reference to the flowcharts of the various figures. While for purposes of simplicity of explanation, the methodologies are shown and described as a series of blocks, it is to be understood and appreciated that the claimed subject matter is not limited by the order of the blocks, as some blocks may occur in different orders and/or concurrently with other blocks from what is depicted and described herein. Where non-sequential, or branched, flow is illustrated via flowchart, it can be appreciated that various other branches, flow paths, and orders of the blocks, may be implemented which achieve the same or a similar result. Moreover, not all illustrated blocks may be required to implement the methodologies described hereinafter.

In addition to the various embodiments described herein, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiment(s) for performing the same or equivalent function of the corresponding embodiment(s) without deviating there from. Still further, multiple processing chips or multiple devices can share the performance of one or more functions described herein, and similarly, storage can be effected across a plurality of devices. Accordingly, the invention is not to be limited to any single embodiment, but rather can be construed in breadth, spirit and scope in accordance with the appended claims.

What is claimed is:

1. A device, comprising:

a contact lens comprising:

a substrate;

a first sensor disposed on or within the substrate of the contact lens configured to produce a first current signal during measurement of at least one parameter, wherein the first current signal comprises a measurement current signal associated with the at least one parameter and a baseline current signal; and

a second sensor disposed on or within the substrate of the contact lens configured to produce a second current signal during the measurement of the at least one parameter, wherein the second current signal comprises the baseline current signal and does not include the measurement current signal associated with the at least one parameter;

a linear relaxation oscillator-based current-to-frequency converter comprising an integration capacitor and a plurality of switches, wherein the integration capacitor has a first terminal connected to the first and second sensors via the plurality of switches and has a second terminal connected to ground, wherein the linear relaxation oscillator-based current-to-frequency converter produces an output frequency signal having a frequency related to a net current corresponding to a difference between the first current signal and the second current signal, wherein the output frequency signal comprises alternating charging phases and discharging phases, wherein during the charging phases the switches connect the first terminal of the integration capacitor to the first and second sensors such that the net current flows into the integration capacitor, and wherein during the discharging phases the switches connect the first terminal of the integration capacitor to the first and second sensors such that the net current flows out from the integration capacitor; and

a processing component disposed on or within the substrate and connected to the first sensor, the second sensor, and the linear relaxation oscillator-based current-to-frequency converter, the processing component comprising:

an analysis component configured to receive and analyze the output frequency signal.

2. The device of claim **1**, wherein the first sensor is an electrochemical sensor.

3. The device of claim **2**, wherein the second sensor is an electrochemical sensor.

4. The device of claim **1**, wherein the baseline current signal varies over at least one of time, temperature, or voltage potential during measurement of the at least one parameter.

5. The device of claim **1**, wherein the analysis component is further configured to analyze the output frequency signal to determine a glucose level.

6. The device of claim **1**, further comprising:

a power component disposed on the substrate configured to capture energy wirelessly and convert the captured energy to usable electric power;

wherein at least one of the processing component, the first sensor, the second sensor, or the linear relaxation oscillator-based current-to-frequency converter is configured to employ the usable electric power.

7. The device of claim **6**, further comprising:

wherein the energy comprises radio frequency signals; and

wherein the power component comprises:

at least one radio frequency receiver configured to receive the radio frequency signals; and

a power conversion component configured to convert the radio frequency signals to the usable electric power.

8. The device of claim **6**, further comprising:

wherein the energy comprises solar energy; and

wherein the power component comprises:

at least one solar cell configured to receive the solar energy; and

a power conversion component configured to convert the solar energy to the usable electric power.

9. The device of claim **6**, wherein the power component is further configured to store the usable electric power.

10. The device of claim **1**, wherein the processing component further comprises an interface component configured to communicate with a remote device.

11. The device of claim **10**, wherein the interface component is further configured to transmit a result of the analysis to the remote device.

12. The device of claim **1**, wherein the switches are controlled by a feedback voltage derived from a voltage on the integration capacitor.

13. The device of claim **12**, wherein the linear relaxation oscillator-based current-to-frequency converter further comprises an amplifier configured to generate the feedback voltage from the voltage on the integration capacitor.

14. The device of claim **13**, wherein the amplifier is a Schmitt trigger.

15. The device of claim **1**, wherein the plurality of switches include a first switch configured to connect a current output of the first sensor to the integration capacitor, a second switch configured to connect a current output of the second sensor to the integration capacitor, a third switch configured to connect a current input of the first sensor to the integration capacitor, and a fourth switch configured to connect a current input of the second sensor to the integration capacitor.

16. The device of claim **15**, wherein during the charging phases the first and fourth switches are closed and the second and third switches are open, and wherein during the discharging phases the second and third switches are closed and the first and fourth switches are open.

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专利名称(译)	在基于线性张弛振荡器的电流 - 频率转换器电路内通过电流减法消除基线电流信号		
公开(公告)号	US9398868	公开(公告)日	2016-07-26
申请号	US13/610788	申请日	2012-09-11
[标]申请(专利权)人(译)	OTIS BRIAN 普莱彻NATHAN		
申请(专利权)人(译)	OTIS，BRIAN 普莱彻，NATHAN		
当前申请(专利权)人(译)	实实在在的生命科学LLC		
[标]发明人	OTIS BRIAN PLETCHER NATHAN		
发明人	OTIS, BRIAN PLETCHER, NATHAN		
IPC分类号	A61B5/00 A61B5/145 G02C7/04		
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摘要(译)

本公开涉及用于在电流域中从来自参考传感器的输出电流参考信号中减去来自主传感器的输出电流主信号以产生指示输出电流主信号之间的差异的频率输出信号的系统和/或方法。和输出电流参考信号。