Universidad de Valparaíso
CHILE

Sistemas de medición biomédica

Mediciones Biomédicas
Ingeniería Civil Biomédica

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Lectura complementaria:

Capítulo 1, J.G. Webster, Medical Instrumentation: Application and Design, 4th Edition, 2010.

Descripción

Proporcionar los conocimientos sobre los tipos de sensores más importantes usados en dispositivos biomédicos.

- Principios de funcionamiento.
- Interfaces electrónicas.

Apnea Monitors

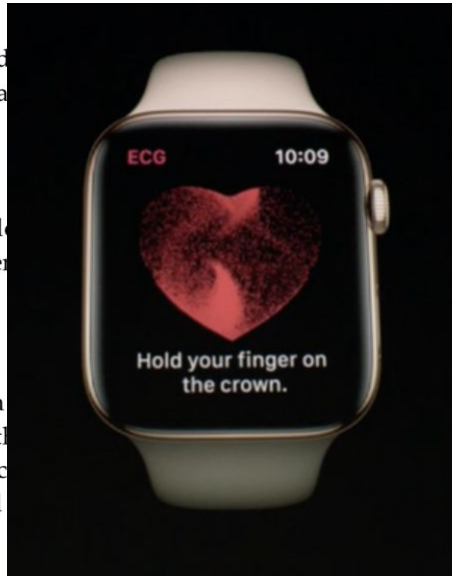
Scope of this Product Comparison

This Product Comparison covers modular and stand-alone apnea monitors to be used in hospitals (e. intensive care units) or in homes; some models listed in the chart have documentation capabilities. Thos exclusively for diagnosing sleep disorders and/or assessing pulmonary function and those without alar been excluded. Some physiologic monitoring systems may perform apnea monitoring. For devices that multiple parameters, see the Product Comparison titled Physiologic Monitoring Systems, Acute Care; N ECG Monitors; Monitors, Central Station. For more information on the treatment of obstructive sleep ap the Product Comparison titled Continuous Positive Airway Pressure Units.

These devices are also called: cardiorespiratory monitors.

Purpose

Apnea monitors detect the cessation of breathing (apnea) in infants and adults who are at risk of respiratory failure and alert the parent or attenda to the condition. Apnea has three classifications: central, obstructive, and mixed. Central apnea occurs when the brain stops sending signals to the respiratory muscles, even though the patient has apparently normal - physiologic respiratory mechanisms. Obstructive apnea occurs when airfl is cut off because of an upper-airway obstruction. Mixed apnea has eleme of both central and obstructive apnea. Although there are some definable patient groups who are at risk of respiratory failure, no clear underlying pathology to breathing disorders such as apnea has been discovered.



Some prolonged respiratory pauses result in low oxygen concentration levels in the body, which can lead to irreversible brain damage and, ultimately, death. Premature and low-birt weight infants are particularly likely to exhibit apneic breathing patterns, but patients with disorders that affec respiratory control or that obstruct the respiratory passageway are also susceptible, as are those being weaned from respiratory suppressant drug therapy. Because the onset of apnea is unpredictable and its effects can be devastating, apnea monitors are believed necessary to provide constant monitoring of those at risk.

Blood Glucose Monitors

Scope of this Product Comparison

This Product Comparison covers portable blood glucose moni
emergency vehicles, or hospitals. It is limited to monitors that use
photometry, or electrochemistry. This report excludes portable ar
chemistry analyzers with glucose-testing capabilities; for informa
Comparisons:

- Clinical Chemist
- Clinical Chemist
- Glycohemoglobi
- Point-of-Care Ar
- Point-of-Care Ar

These devices are a
photometers, glucomet
detection units.

Purpose

BGMs measure bloo
cartridge, or cuvette ar
puncture. (Some units can also use venous and/or arterial blood.)
diabetes use these battery-powered monitors to manage diabetes
glucose levels (e.g., during surgery).

Blood Gas/pH Analyzers

Scope of this Product Comparison

This Product Comparison covers blood gas analyzers that directly measure the pH,
oxygen (PO_2), and the partial pressure of carbon dioxide (PCO_2) of an externally drawn
Some blood gas analyzers also provide additional calculated parameters and electrolyt
hematologic determinations (e.g., glucose, hematocrit). Several analyzers are portable,
models that are used at the patient bedside; for more information on POC analyzers, se
titled Point-of-Care Analyzers, Blood Gas/pH; Chemistry; Electrolyte.

Purpose

Blood gas/pH analyzers measure pH, PC
arterial blood sample. They are used in resp
departments, clinical and cardiopulmonary
units, surgical suites, physician offices, and
monitor patients' acid-base balance and oxy
(CO_2) exchange, providing the clinician wit
patient diagnosis and regulation of therapy.

During respiration, there is an exchange
pulmonary capillaries and the alveoli in the
bloodstream and is bound to and transported by the hemoglobin in red blood cells; a s
dissolves in the plasma. O_2 dissociates from hemoglobin, enters the tissues, and is used
metabolism. CO_2, a waste product of metabolism, is transported back to the lungs in co
the form of bicarbonate (HCO_3^-), dissolved in plasma, or joined with the amino groups
molecule.


tytocare
LUNGS
HEART
SKIN
EARS
THROAT
TEMP


tytocare


9:41
Dr. Amanda Clark

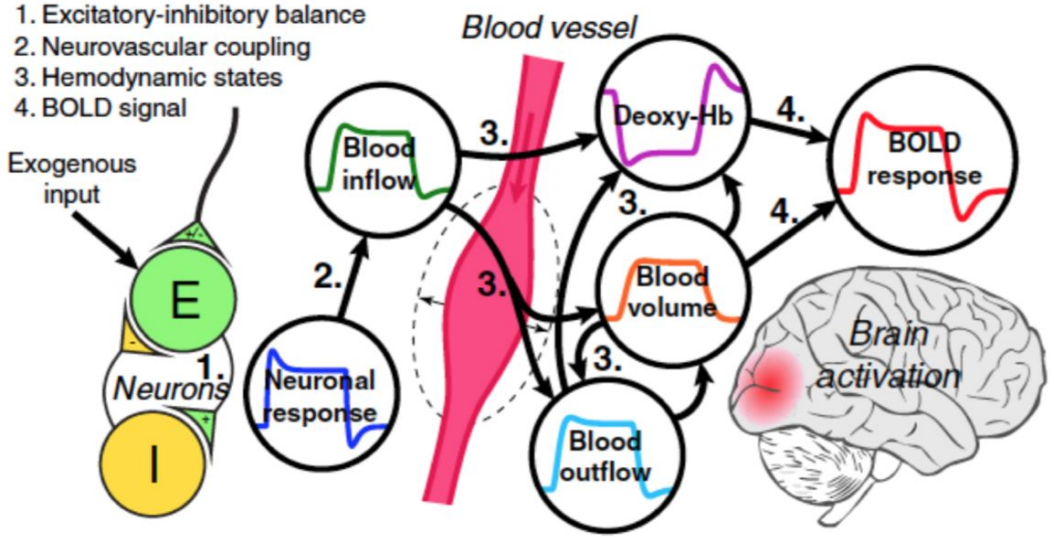
Scanning Systems, Magnetic Resonance Imaging

Scope of this Product Comparison

This Product Comparison covers stationary magnetic resonance imaging (MRI) units, including models capable of magnetic resonance angiography (MRA), echo planar imaging (EPI), and spectroscopy. Models for imaging the whole body, as well as models dedicated to imaging only the head, breasts, and/or extremities, are listed in the chart. Open MRI systems and systems dedicated to neurosurgery are included.

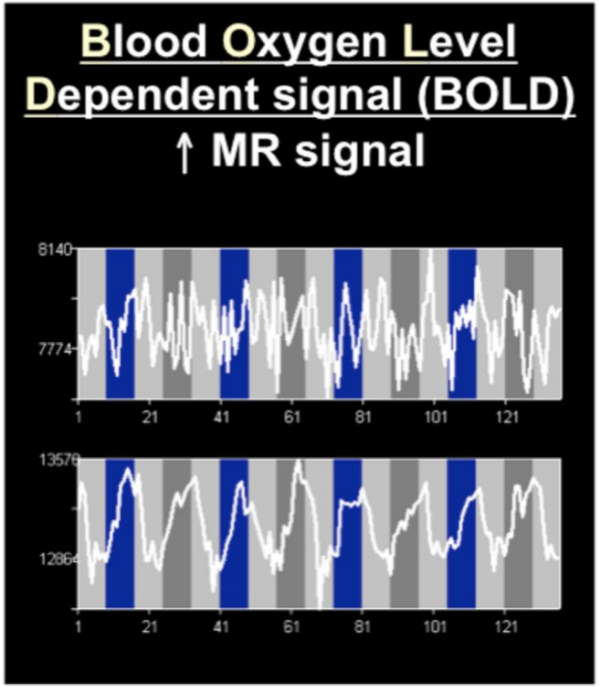
Purpose

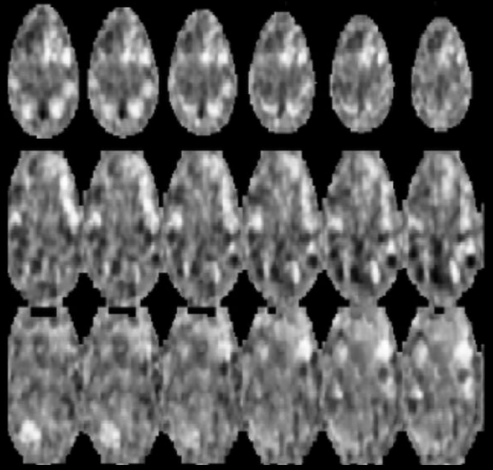
MRI units use strong electromagnetic fields and radio-frequency (RF) radiation to translate hydrogen nuclei distribution in body tissue into computer-generated images of anatomic structures. Magnetic resonance (MR) images have excellent contrast, which allows clinicians to clearly see the details of tissue structure, including soft tissue, and to distinguish normal from diseased tissue in order to diagnose and track the progress and treatment of disease. MRI units can acquire images in slices from 0.1 to 400 mm thick in the transaxial (transverse), sagittal, and coronal planes of the body. Oblique, multiangle oblique, and radial slice orientations are also possible. A principal advantage of MRI over radiographic imaging methods such as computed tomography (CT) is that it does not use ionizing radiation. Magnetic fields of the strength used in clinical MRI produce no known significant deleterious biological side effects.

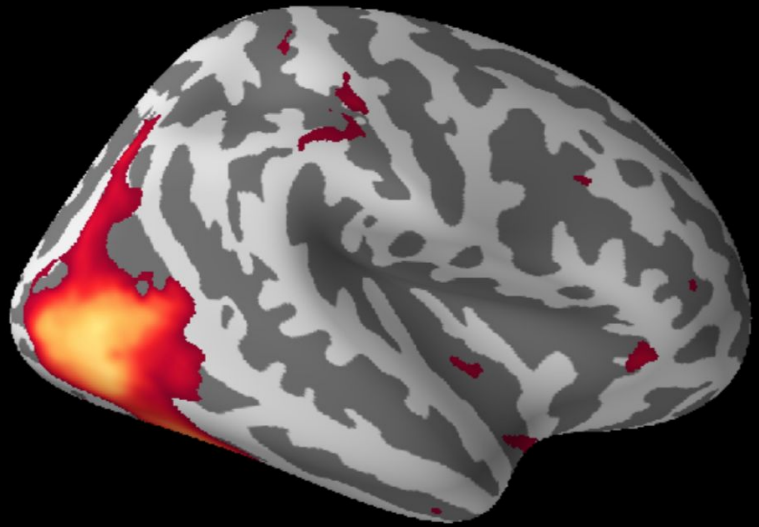


(Havlicek 2015)

(Culham 2017)







Objetivo general:

Comprender y aplicar los conceptos fundamentales relacionados con sensores biomédicos y mediciones biomédicas.

Objetivos específicos:

- Comprender principios de bioinstrumentación relacionados con las mediciones biomédicas.
- Comprender bloques funcionales de todo instrumento de medición biomédica.
- Comprender especificaciones técnicas necesarias en aplicaciones de mediciones biomédicas.

Contenidos

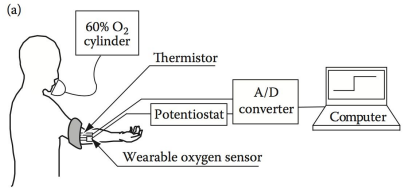
- Parámetros estáticos y dinámicos de sensores.
- Modelos de dispositivos de medición.
- Principios de sensores físicos y químicos: impedancia (termoeléctrico, termorresistivo, piezoeléctrico), electroquímico, fotoquímico, etc.
- Sensores de temperatura, mecánicos, de radiación, magnéticos.
- Sensores usados en imagenología, químicos, biosensores.
- Señales biomédicas, sistemas de adquisición y acondicionamiento.
- El bioamplificador y electrodos.

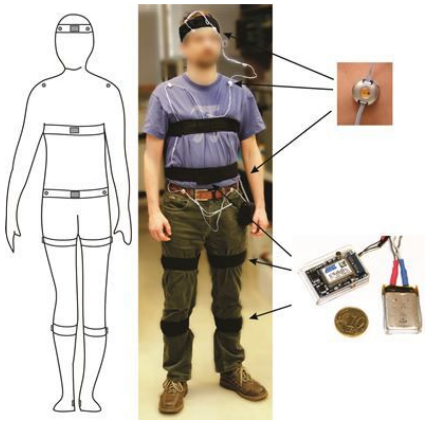
Important milestones in the development of medical instruments…

- **Thermometer**
  - 1603, Galileo
  - 1625, body temperature measurement
- **Optical lens**
  - 1666, Newton
  - 1850-, ophthalmoscope, Helmholtz
- **Stethoscope**
  - 1819, hollow tube
  - 1851, binaural stethoscope
- **Hypodermic syringe**
  - 1853, Wood
- **X-ray**
  - 1895, Roentgen
  - 1896, in diagnosis and therapy
- **Radioactivity**
  - 1896, Curie
  - 1903, in therapy
- **Electrocardiograph**
  - 1887, Waller, capillary meter
  - 1903, Einthoven,
  - galvanometer 1928, vacuum tube
- **Electroencephalograph**
  - 1924, Berger
- **pH electrode**
  - 1906, Cremer
- **Electrical surgical unit, 1928**

- **Cyclotron, artificial radionuclides**
  - 1936, Lawrence
- **Assisting ventilator**
  - 1928, "iron lung"
  - 1945, positive pressure
- **Ultrasonic imaging**
  - pulse-echo, 1947
  - Doppler, 1950s
- **Magnetic Resonance Imaging (MRI)**
  - NRM, Bloch, Purcell, 1946
  - MRI, 1982
- **Computed tomography**
  - 1969, Cormack, Hounsfield
- **Electrical heart defibrillator**
  - 1956, Zoll
  - 1980, implanted
- **Implanted electrical heart pacemaker**
  - 1960, Greatbatch
- **Heart valves, 1975**
- **Cardiac catheter, 1975**
- **Artificial kidney (dialysis), 1960**
- **Artificial heart, 1984**

Fig. 1.11 Laennec, inventor of the stethoscope, applies his ear to the chest of a patient (Chartran 1849–1907)





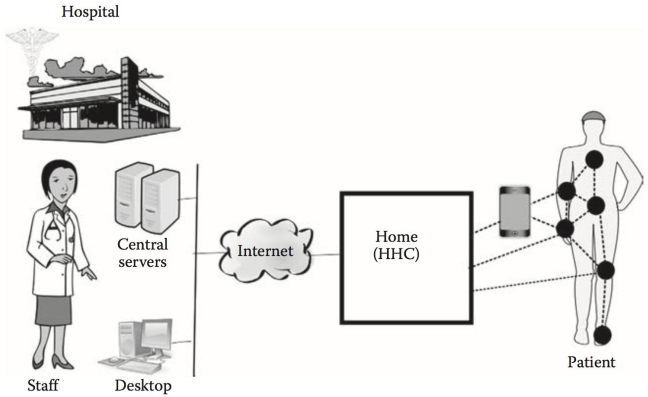
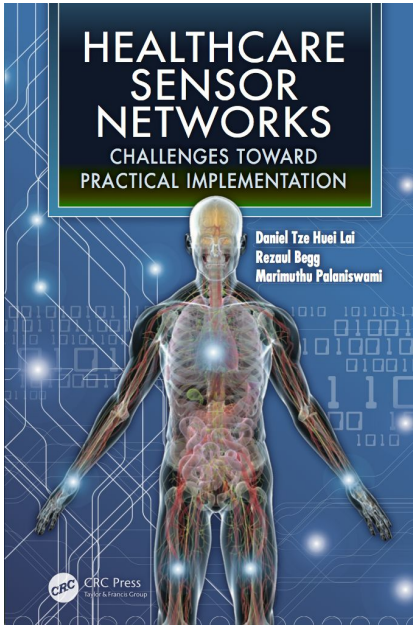
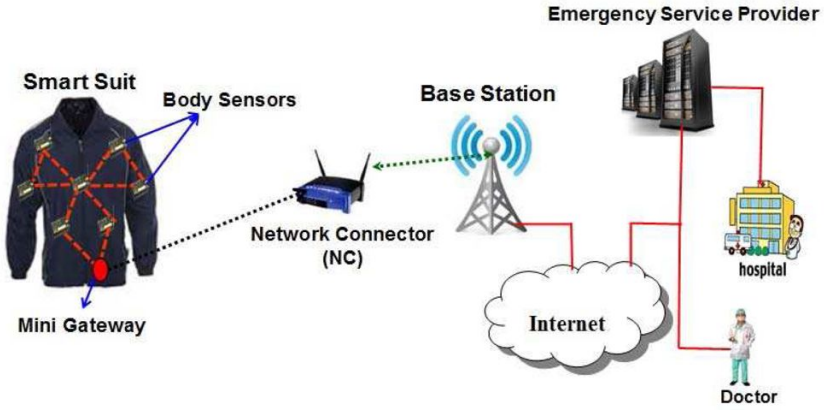


FIGURE 5.2
Architecture and service platform of a body sensor network (BSN) for telemedicine and home healthcare.


Rosie Funk
4:21
Wed, Oct 2
Phone
Passbook
Weather
0:96
7'27"
105
7:09


HEALTHCARE SENSOR NETWORKS
CHALLENGES TOWARD PRACTICAL IMPLEMENTATION
Daniel Tze Huei Lai
Rezaul Begg
Marimuthu Palaniswami
CRC Press
Taylor & Francis Group


Emergency Service Provider
Smart Suit
Body Sensors
Base Station
Network Connector
(NC)
hospital
Internet
Doctor
Mini Gateway

¿Qué es un sensor biomédico?

- Cualquier sistema de instrumentación puede ser descrito por tres componentes:
  - un sensor
  - un procesador de señal
  - y una pantalla y/o almacenamiento.

- El sensor tiene una función especial – interactúa con el sistema que se está midiendo.
- En el caso de la instrumentación biomédica, un sensor biomédico es la interfaz entre componentes electrónicos y el sistema biológico.

Consideraciones importantes

1. El sensor puede afectar el comportamiento del sistema medido,
   - los sensores son diseñados para minimizar su interacción con el organismo.
   - Es importante que la presencia del sensor no afecte a la variable que se está midiendo.

2. El sistema biológico puede afectar al rendimiento del sensor.
   - Reacción a cuerpo extraño podría causar en el sistema huésped la necesidad de eliminarlo. Sistema huésped puede degradar el sensor, afectando su funcionamiento.

Restricciones en las mediciones biomédicas

J Ultrasound Med. 2008 Apr;27(4):541-59; quiz 560-3.

Fetal thermal effects of diagnostic ultrasound.

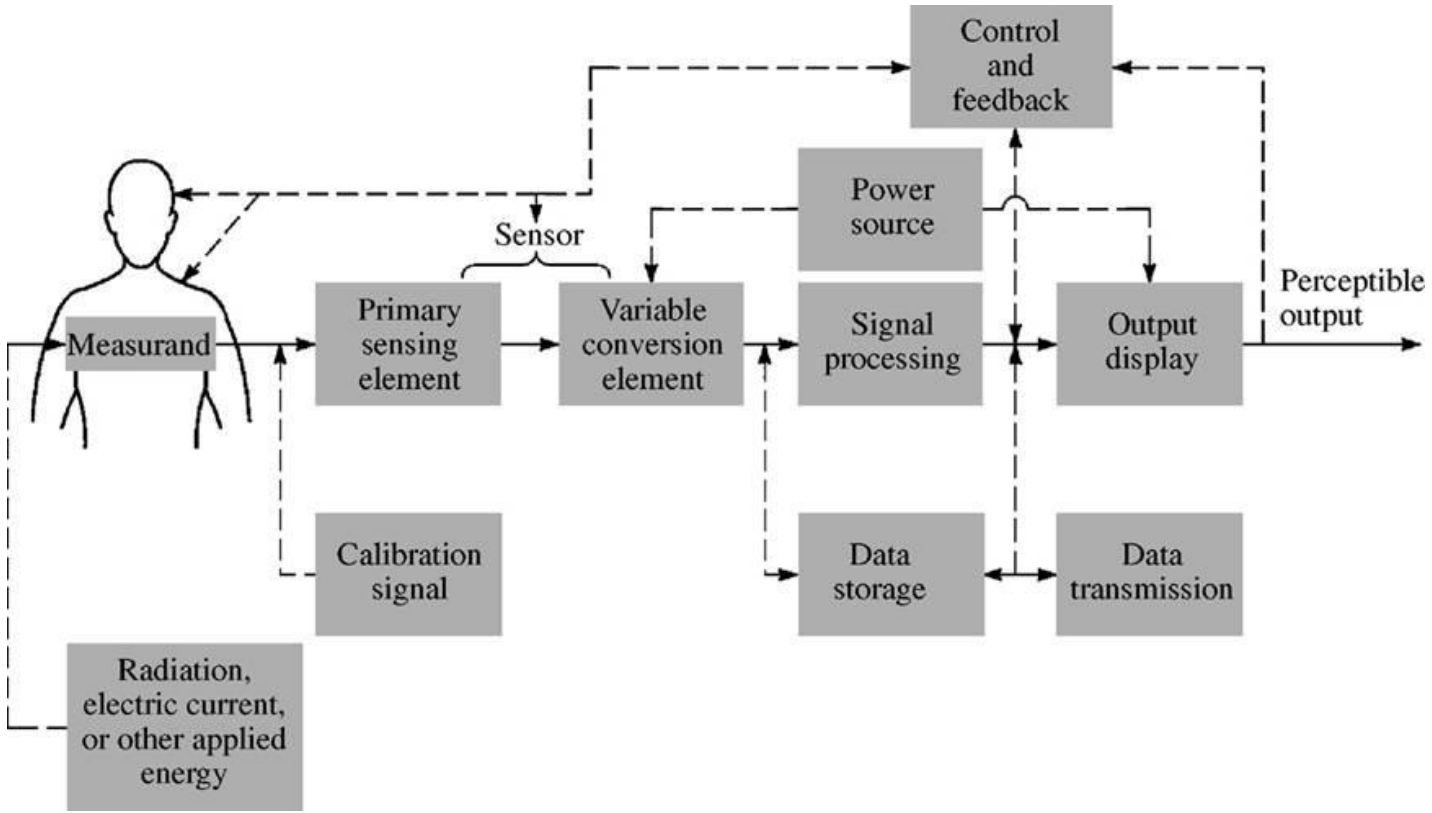
Abramowicz JS[1], Barnett SB, Duck FA, Edmonds PD, Hynynen KH, Ziskin MC.

Author information

Abstract

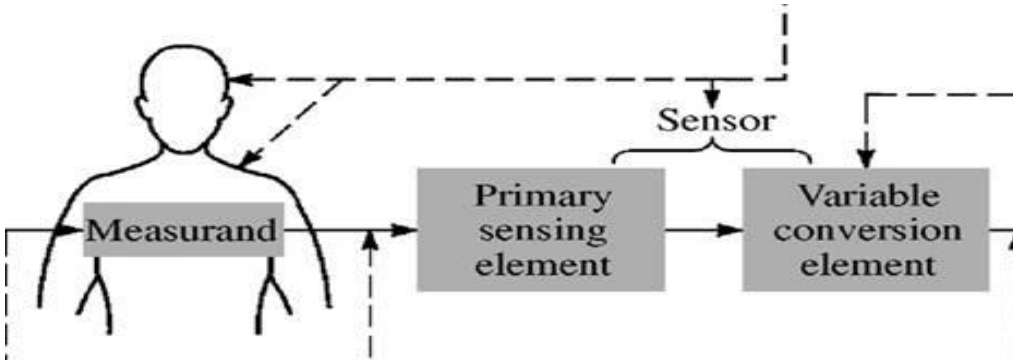
Processes that can produce a biological effect with some degree of heating (ie, about 1 degrees C above the physiologic temperature) act via a thermal mechanism. Investigations with laboratory animals have documented that pulsed ultrasound can produce elevations of temperature and damage in biological tissues in vivo, particularly in the presence of bone (intracranial temperature elevation). Acoustic outputs used to induce these adverse bioeffects are within the diagnostic range, although exposure times are usually considerably longer than in clinical practice. Conditions present in early pregnancy, such as lack of perfusion, may favor bioeffects. Thermally induced teratogenesis has been shown in many animal studies, as well as several controlled human studies; however, human studies have not shown a causal relationship between diagnostic ultrasound exposure during pregnancy and adverse biological effects to the fetus. All human epidemiologic studies, however, were conducted with commercially available devices predating 1992, that is, with acoustic outputs not exceeding a spatial-peak temporal-average intensity of 94 mW/cm2. Current limits in the United States allow a spatial-peak temporal-average intensity of 720 mW/cm2 for fetal applications. The synergistic effect of a raised body temperature (febrile status) and ultrasound insonation has not been examined in depth. Available evidence, experimental or epidemiologic, is insufficient to conclude that there is a causal relationship between obstetric diagnostic ultrasound exposure and obvious adverse thermal effects to the fetus. However, very subtle effects cannot be ruled out and indicate a need for further research, although research in humans may be extremely difficult to realize.

Instrumento de medición biomédica



Mensurando

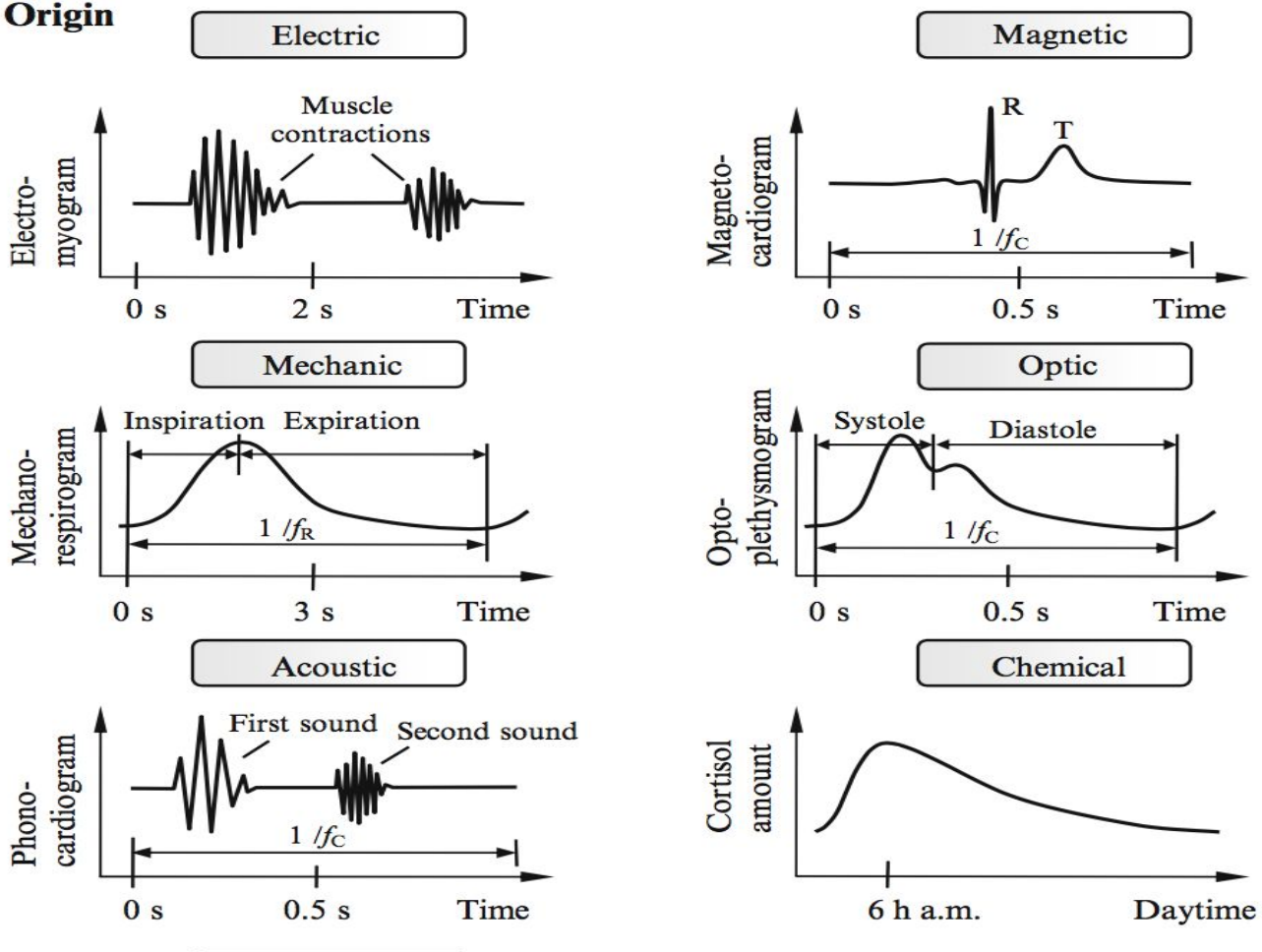
La cantidad física, propiedad o condición que el sistema mide.



- Interna (presión sanguínea).
- Superficie del cuerpo (electrocardiograma).
- Emanado desde el cuerpo (radiación infrarroja).
- Derivado desde un parte del cuerpo que es removida (sangre o biopsia).

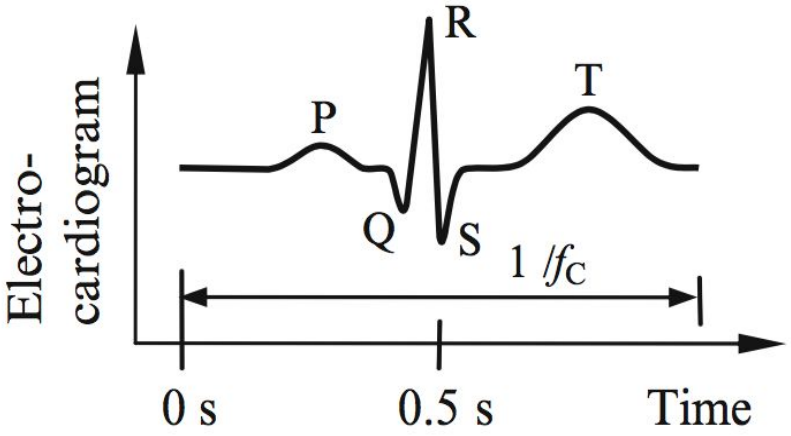
Categorías de mensurandos:
biopotenciales, presión, flujo, dimensiones (imágenes), desplazamiento (velocidad, aceleración, fuerza), impedancia, temperatura, concentración química.

Origin

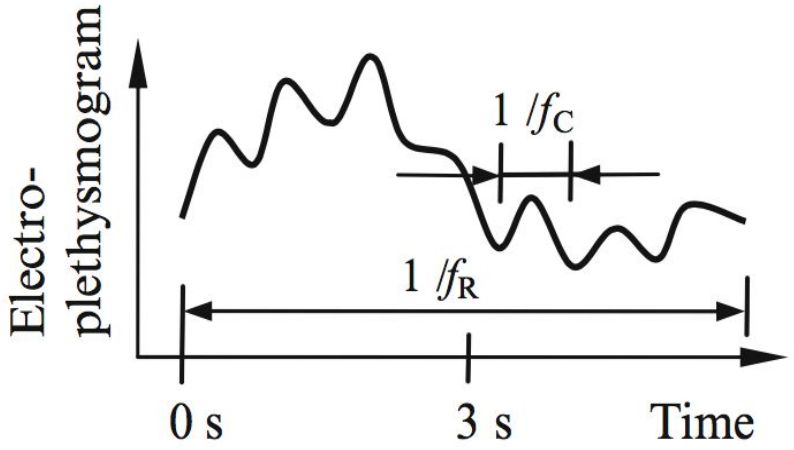

Electric
Electro-myogram
Muscle contractions
0 s
2 s
Time
Magnetic
Magneto-cardiogram
R
T
1 /fC
0 s
0.5 s
Time
Mechanic
Mechano-respirogram
Inspiration
Expiration
1 /fR
0 s
3 s
Time
Optic
Opto-plethysmogram
Systole
Diastole
1 /fC
0 s
0.5 s
Time
Acoustic
Phono-cardiogram
First sound
Second sound
1 /fC
0 s
0.5 s
Time
Chemical
Cortisol amount
6 h a.m.
Daytime

Existence

Permanent

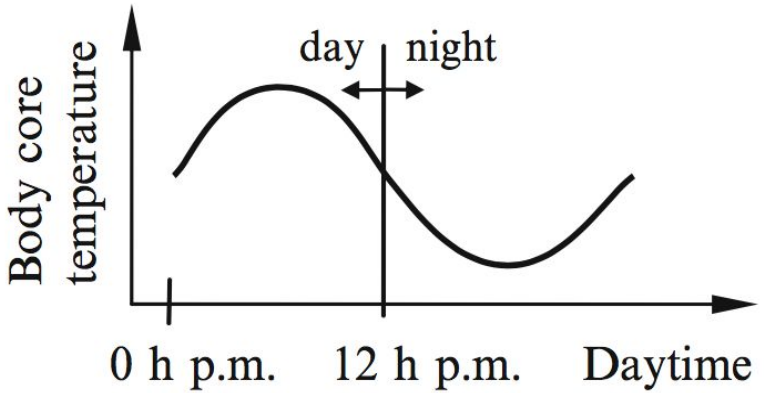


Induced

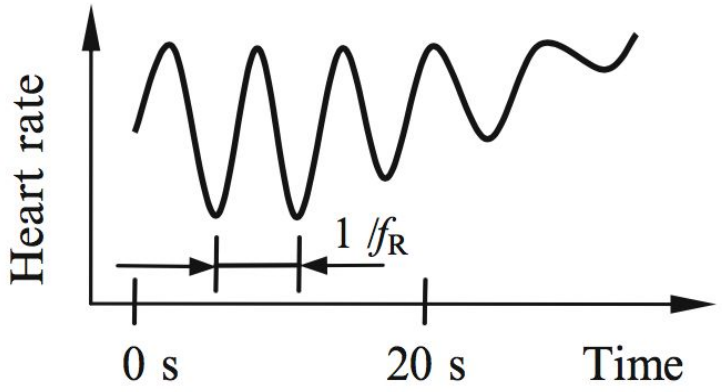


Dynamic

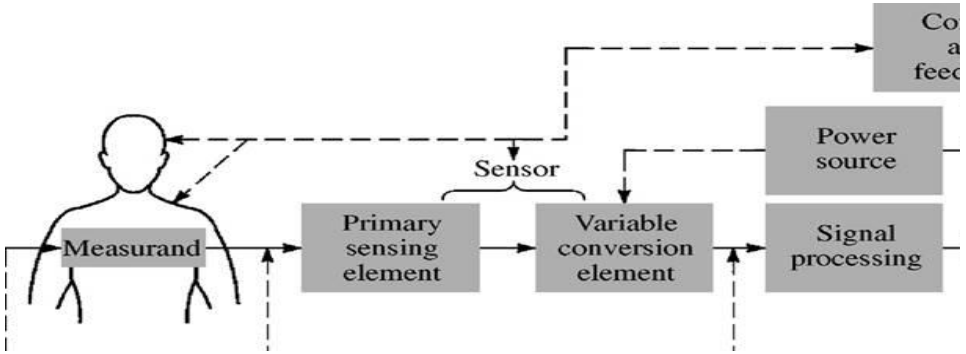
(Quasi) static



Dynamic



Sensores y transductores

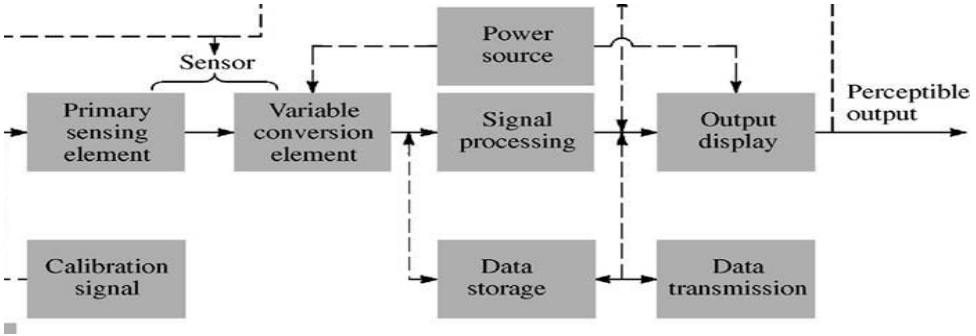


Generalmente, el término transductor se refiere a un dispositivo que convierte una forma de energía a otra.

Un sensor convierte un mensurando físico a una señal eléctrica.

Un sensor posee un elemento de censado primario, por ejemplo, un diafragma que convierte presión a desplazamiento. Un elemento secundario convierte este desplazamiento a un voltaje eléctrico (galgas extensiométricas).

Acondicionamiento de señal

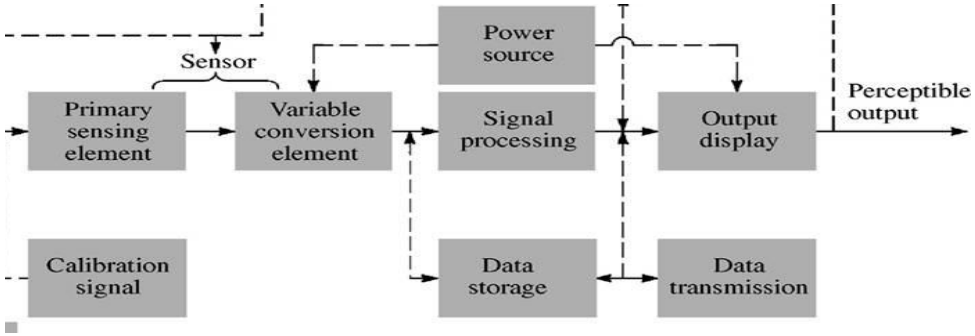


El acoplamiento de la salida
de un sensor a un dispositivo
de visualización (display)
requiere un acondicionamiento previo de la señal.

Filtros analógicos.
Conversores análogo-digitales.
Microcircuitos.

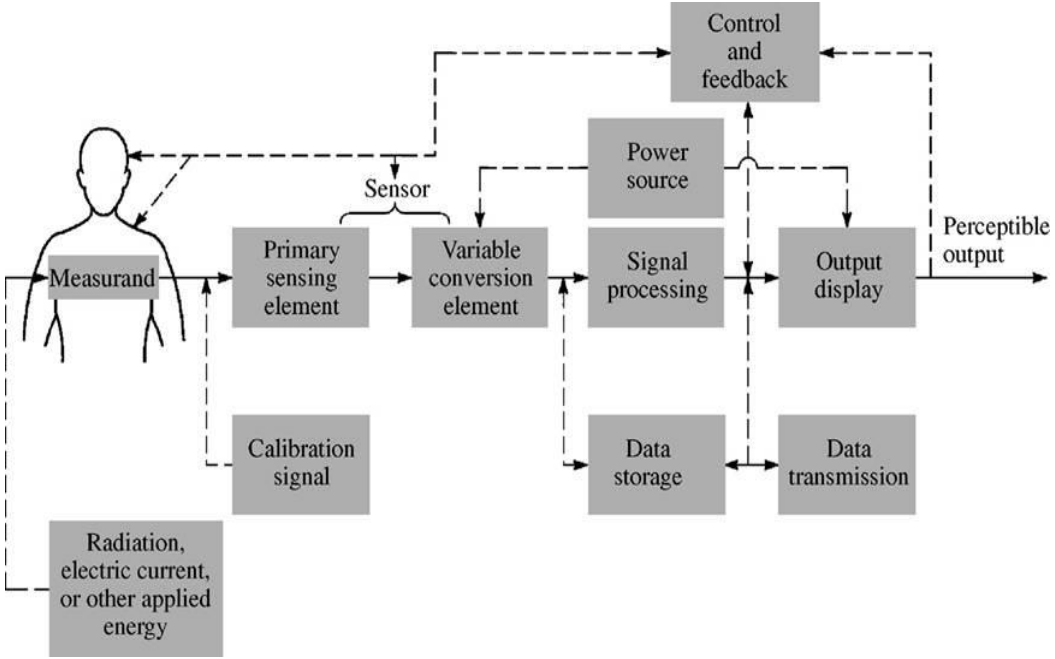
Displays

Human factors engineering guidelines and preferred practices for the design of medical devices (AAMI, 1993).



Elementos auxiliares

- Señal de calibración.
- Feedback and control.
- Almacenamiento de datos.
- Comunicación de datos.



Modos operacionales

Directo – indirecto

- El caso ideal es que el mensurando corresponda a la variable que interesa. Esta es accesible o existen métodos con invasividad aceptable que podemos usar. **Este es un modo directo de medición.**

- Si no es posible tener acceso a una variable de interés, a menudo se usa otro mensurando accesible, cuyo comportamiento dinámico está relacionado con la variable de interés. **Este es un modo indirecto de medición.**

Modos operacionales

- Gasto cardíaco (volumen de sangre bombeado por el corazón en un minuto), determinado mediante la respiración y la concentración de gases en la sangre o mediante la dilución de colorantes.

- Morfología de órganos internos determinada mediante la proyección de rayos X en los mismos.

- Volúmenes pulmonares determinados mediante la medición de la impedancia de la cavidad torácica por pletismografía.

Modos operacionales

Modo continuo y muestreado

- Algunas cantidades cambian muy lentamente, por ejemplo, temperatura o concentración de iones.

- Otras como el eletrocardiograma o el flujo de aire por la respiración cambian rápidamente.

- El contenido de frecuencia de mensurando, el objetivo de la medición, la condición del paciente determinan cuan frecuente se adquiere una medición.

Modos operacionales

Modo digital y analógico.

- Las señales que generan las mediciones son, en su mayoría, analógicas. Esto significa que son señales continuas y pueden tomar cualquier valor dentro de un rango dinámico.

- En el modo digital las señales son discretas y pueden tomar un número finito de valores.

- Modo digital: menor resolución, menor susceptibilidad a interferencias.

Modos operacionales

Tiempo real y retrasado (delayed-time)

Tiempo real: señales eletrofisiológicas en general.

Delayed-time: procesos que requieren extracción de muestras, fMRI, etc.

Restricciones en las mediciones biomédicas

- Muchos de los parámetros fisiológicos adoptan valores muy bajos, bajas frecuencias, etc.
- Muchas de las variables importantes no son accesibles directamente. La generación de la interface mensurando-sensor tiene como consecuencia algún daño al organismo vivo.
- Las señales fisiológicas son raramente deterministas. Variabilidad intersujeto e intrasujeto.
- Muchas mediciones biomédicas dependen de alguna forma de energía aplicada al organismo vivo, ultrasonido, rayos X, etc. En muchos casos no se conocen muchos de los mecanismos de daño de los tejidos ante la exposición de ciertos niveles de energía.
- Otras restricciones adicionales: confiabilidad, fácil de operar, resistente, minimizar los riesgos de shocks eléctricos.

Algunos parámetros fisiológicos

Table 1.1 Medical and Physiological Parameters

Parameter or Measuring Technique	Principal Measurement Range of Parameter	Signal Frequency Range, Hz	Standard Sensor or Method
Ballistocardiography (BCG)	0–7 mg	dc–40	Accelerometer, strain gage
	0–100 μm	dc–40	Displacement linear variable differential transformer (LVDT)
Bladder pressure	1–100 cm H_2O	dc–10	Strain-gage manometer
Blood flow	1–300 ml/s	dc–20	Flowmeter (electromagnetic or ultrasonic)
Blood pressure, arterial			
Direct	10–400 mm Hg	dc–50	Strain-gage manometer
Indirect	25–400 mm Hg	dc–60	Cuff, auscultation
Blood pressure, venous	0–50 mm Hg	dc–50	Strain gage
Blood gases			
P_{O_2}	30–100 mm Hg	dc–2	Specific electrode, volumetric or manometric
P_{CO_2}	40–100 mm Hg	dc–2	Specific electrode, volumetric or manometric
P_{N_2}	1–3 mm Hg	dc–2	Specific electrode, volumetric or manometric
P_{CO}	0.1–0.4 mm Hg	dc–2	Specific electrode, volumetric or manometric

Algunos parámetros fisiológicos

Blood pH	6.8–7.8 pH units	dc–2	Specific electrode
Cardiac output	4–25 liter/min	dc–20	Dye dilution, Fick
Electrocardiography (ECG)	0.5–4 mV	0.01–250	Skin electrodes
Electroencephalography (EEG)	5–300 μV	dc–150	Scalp electrodes
(Electrocorticography and brain depth)	10–5000 μV	dc–150	Brain-surface or depth electrodes
Electrogastrography (EGG)	10–1000 μV	dc–1	Skin-surface electrodes
	0.5–80 mV	dc–1	Stomach-surface electrodes
Electromyography (EMG)	0.1–5 mV	dc–10,000	Needle electrodes
Eye potentials			
Electro-oculogram (EOG)	50–3500 μV	dc–50	Contact electrodes
Electroretinogram (ERG)	0–900 μV	dc–50	Contact electrodes
Galvanic skin response (GSR)	1–500 kΩ	0.01–1	Skin electrodes
Gastric pH	3–13 pH units	dc–1	pH electrode; antimony electrode

Table 1.1 *(Continued)*

Parameter or Measuring Technique	Principal Measurement Range of Parameter	Signal Frequency Range, Hz	Standard Sensor or Method
Gastrointestinal pressure	0–100 cm H_2O	dc–10	Strain-gage manometer
Gastrointestinal forces	1–50 g	dc–1	Displacement system, LVDT
Nerve potentials	0.01–3 mV	dc–10,000	Surface or needle electrodes
Phonocardiography	Dynamic range 80 dB, threshold about 100 μPa	5–2000	Microphone
Plethysmography (volume change)	Varies with organ measured	dc–30	Displacement chamber or impedance change
Circulatory	0–30 ml	dc–30	Displacement chamber or impedance change
Respiratory functions	0–600 liter/min	dc–40	Pneumotachograph head and differential pressure
Pneumotachography (flow rate)			
Respiratory rate	2–50 breaths/min	0.1–10	Strain gage on chest, impedance, nasal thermistor
Tidal volume	50–1000 ml/breath	0.1–10	Above methods
Temperature of body	32–40 °C 90–104 °F	dc–0.1	Themistor, thermocouple

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Clasificación de dispositivos de instrumentación biomédica.

Cuatro puntos de vista.

De acuerdo a la cantidad que es medida:

Presión, flujo o temperatura.

De acuerdo al principio de transducción:

Resistivo, inductivo, capacitivo, ultrasónico o electroquímico.

De acuerdo al órgano o sistema donde se encuentra el mensurando:

Sistema cardiovascular, pulmonar, nervioso, endocrino, etc.

De acuerdo al daño que producen:

Sensores no invasivos: permiten medir la variable de interés sin contacto o con contacto superficial.

E.g. sensores de calor, ultrasonido, electrodos de biopotenciales, medidores de deformación colocados en la piel.

Sensores mínimamente invasivos: se colocan en una cavidad corporal natural que comunica con el exterior.

E.g. termómetros oral-rectales, transductores de presión intrauterina y sensores de pH del estómago.

De acuerdo a las cantidades que miden:

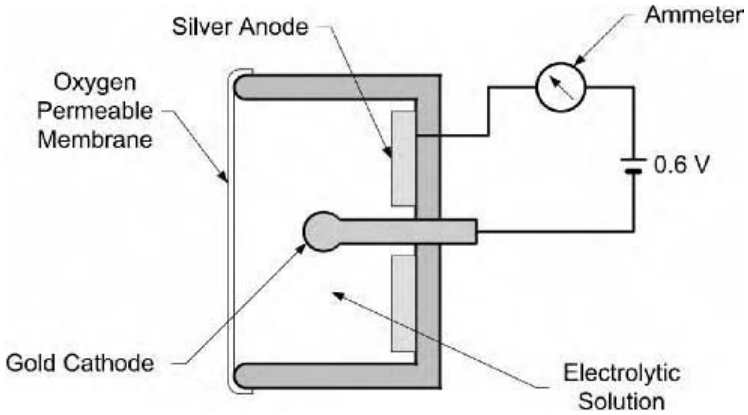
Sensores físicos: se utilizan en la medición de cantidades físicas tal como el desplazamiento, presión y flujo.

Sensores químicos: se utilizan para determinar la concentración de sustancias químicas dentro del huésped.

Biosensores: Se utilizan para medir algunas cantidades internas como enzimas.

Sensores químicos (bioanalíticos)

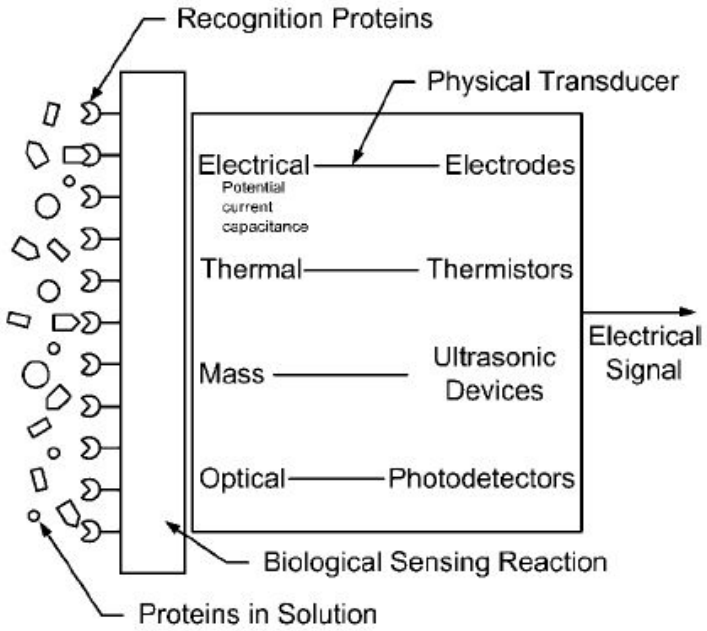
- Un electrodo amperométrico Clark para medir oxígeno.



$$O2 + 2H2O \rightarrow 4e^- + 4OH^-$$

Biosensor

- Estructura básica



Aprovechan de una de las siguiente reacciones bioquímicas:

(1) enzima-sustrato.

(2) antígeno-anticuerpo.

(3) ligando-receptor.

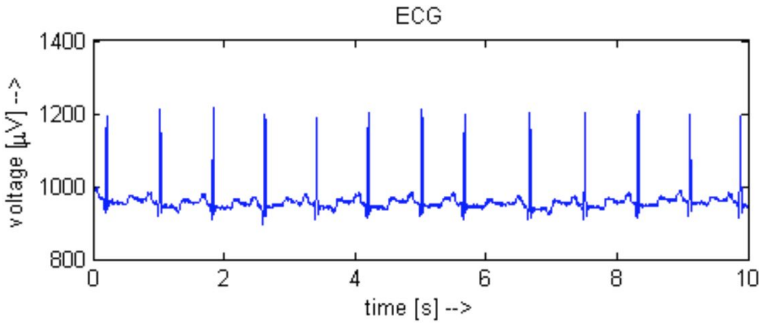
Altamente sensibles y selectivos.

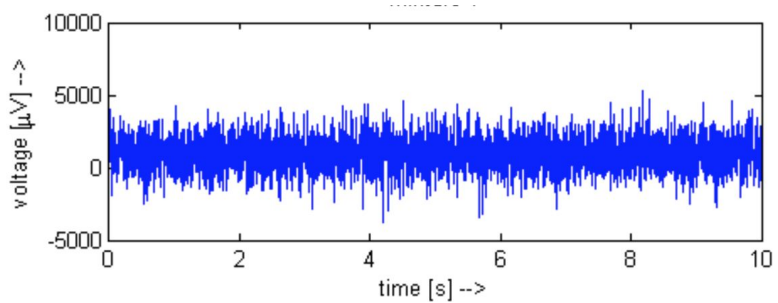
Inestables.

Interferencias y señales modificantes modificantes.

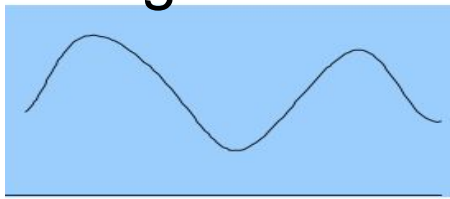
Fuentes:

- Movimiento de electrodos pueden introducir voltajes no deseados (artefactos).
- Línea de alimentación puede inducir voltajes indeseados (interferencia).
- Efectos térmicos en dispositivos semiconductores puede causar adición de voltajes aleatorios (ruido).
- Variaciones de temperatura en componentes electrónicos puede adicionar deriva (drift).

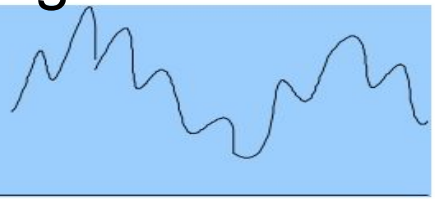




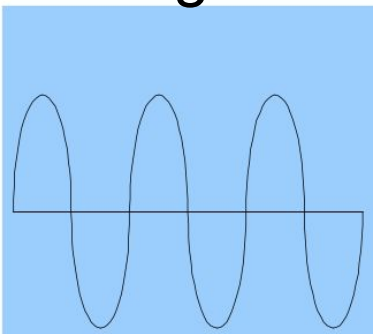
original



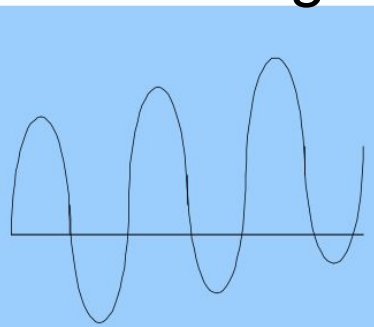
original + interferencia



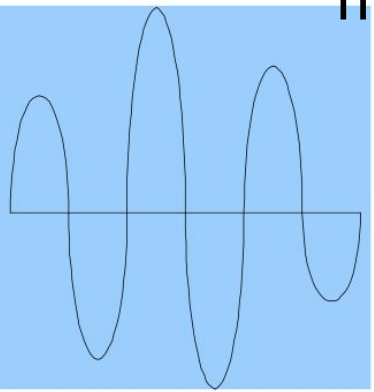
original



original + drift



original + entrada modificante



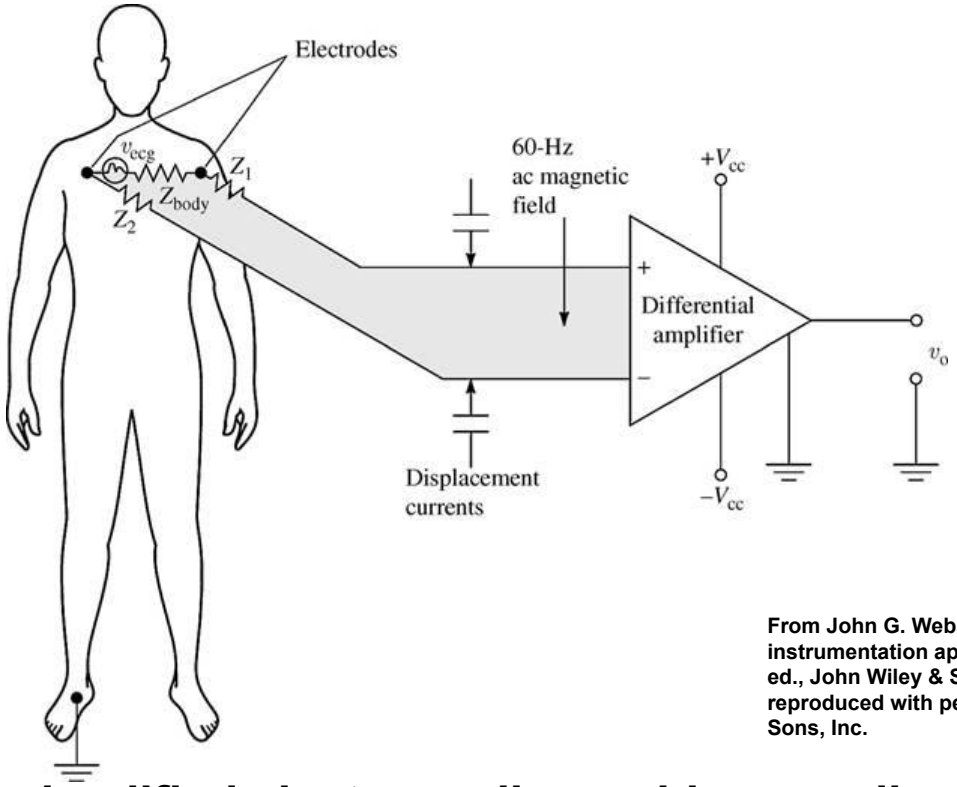


Figure 1.2 simplified electrocardiographic recording system Two possible interfering inputs are stray magnetic fields and capacitively coupled noise. Orientation of patient cables and changes in electrode-skin impedance are two possible modifying inputs. *Z*1 and *Z*2 represent the electrode-skin interface impedances.

Compensación

- Insensibilidad inherente o especificidad del sensor.
- Retroalimentación negativa.
- Filtrado.
- Interferencia destructiva (opposing inputs).