Lecture One, Part 2

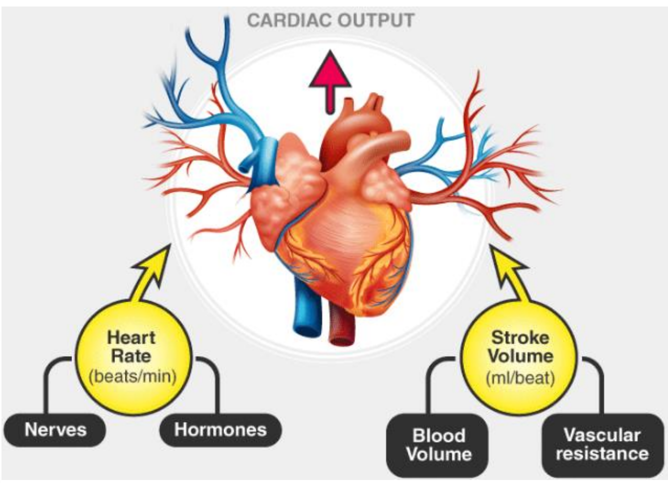
Medical Devices: Modes of operation

Direct and indirect Modes.

Frequently the chosen measurand can be interfaced directly to a sensor because the measurand is readily available or because suitable invasive techniques are presented. When the desired measurand is unavailable, we can use either an alternative measurand that tolerates a known relation to the desired one or some form of energy or material that interrelates with the desired measurand to create a measurand that is accessible. Examples include cardiac output (volume of blood pump per minute from the heart), determined from respiration and blood gas concentration or from dye dilution; morphology of internal organs, determined from x-ray shadows; and pulmonary volumes, determined from variations in thoracic impedance plethysmography.

CO = HR X SV

CARDIAC OUTPUT The amount of blood pumped by each ventricle in 1 minute	=	HEART RATE The number of contractions of the ventricles each minute	X	STROKE VOLUME The amount of blood ejected from each ventricle with each contraction
AVERAGE 4000 — 5000 ml	=	70	X	70 ml
Factors affecting Cardiac Output	=	Sympathetic nervous system Epinephrine	X	Venous return (preload) Blood Volume Sympathetic nervous system (contractility) Peripheral resistance (afterload)

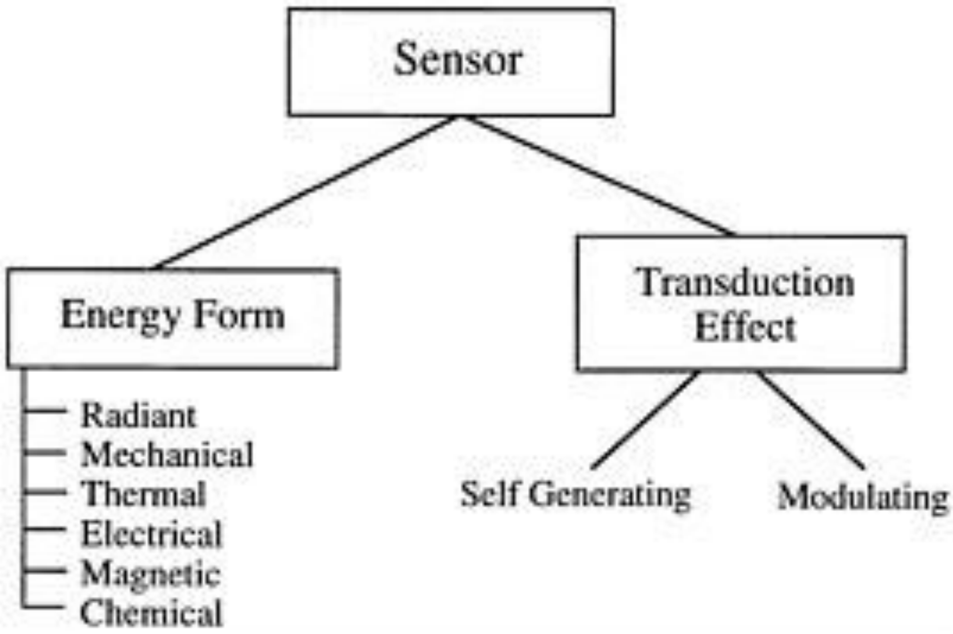


Sampling and continuous modes

Some measurand similar to body temperature and ion concentrations variated so slowly that they may be sampled rarely. Other measures, for example, the electrocardiogram and respiratory gas flow, may need continuous observation. The frequency content of the measurand, the objective of the measurements, the patient's state, and the physician's potential responsibility all guide how often medical data are requisite.

Generating and modulating sensors:

Generating sensors produce their signal output from the energy taken straightly from the measurand itself, like piezoelectric sensors. While in modulating sensors, the measurand modulates the flow of energy from an external source in a means that affects the output of the sensor, like the IR sensor. The photovoltaic cell is a generating sensor because it delivers an output voltage correlated to its irradiation without any other external energy source. Though a photoconductive cell is a modulating sensor to measure its change in resistance with irradiation, we must apply external energy to the sensor.



Analog and digital modes:

Signals that carry measurement data are either analog, meaning continuous, and capable of taking on any value within the dynamic range, or digital, meaning discrete and able to take on only a finite number of different values. Most presently available sensors operate in the analog mode, while some integrally digital measuring devices have been developed.

Enlarged use of digital signal processing had essential simultaneous use of analog to digital (AD) and digital to analog (DA) converters to interface computers with analog sensors and analog devices. Researchers have developed indirect digital indirect sensors that use analog primary sensing elements and digital variable conversion elements (optical shaft encoders). Also, quasi-digital sensors, such as quartz crystal thermometer, give outputs with varying frequency, pulse rate, or pulse duration that is easily converted to digital signals.

Real and Delayed Timed Modes:

Certainly, sensors must obtain signals in real-time as the signals really occur. The output of the measurement system may not display the result immediately, though, because some types of signal processing, such as averaging and transformations, need significant input before any results can be produced. Often, such short delays are suitable unless urgent feedback and control tasks depend on the output. In the case of some measurements, such as cell cultures, several days may be required before an output is obtained.

Medical Instrumentation Constraints.

Nearly all biomedical measurements depend either on some form of energy being applied to the living tissue or on some energy being applied as an incidental consequence of sensor operation. X-ray and ultrasonic imaging techniques and electromagnetic or Doppler ultrasonic blood flowmeters depend on externally applied energy interacting with living tissue.

Safe levels of these various types of energy are difficult to establish because many mechanisms of tissue damage are not well understood. A fetus is particularly vulnerable during the early stages of development. The heating of tissue is one effect that must be limited because even reversible physiological changes can affect measurements. Damage to tissue at the molecular level has been demonstrated in some instances at surprisingly low energy levels.

The operation of instruments in the medical environment imposes important additional constraints. Equipment must be reliable, easy to operate, and capable of withstanding physical abuse and exposure to corrosive chemicals. Electronic equipment must be designed to minimize electric-shock hazards.

The safety of patients and medical personnel must be considered in all phases of the design and testing of instruments.

Medical and Physiological parameters

No.	Parameter or Measur. Techniques	Definition	Measur. range	Freq. range Hz	Standard sensor or Method	Reference
1	Ballistocardiography (BCG)	It is an old, noninvasive technique used to record the movements of the body synchronous with the heartbeat due to left ventricular pump activity.	0–7 mg	dc – 40	Accelerometer and strain gage.	Zajiur, 2003
			0–100 µm	dc – 40	Displacement Linear Variable Differential Transformer LVDT	
2	Bladder pressure	Measurement of the bladder pressure is one component of an urodynamic study. Normally, the viscoelastic properties of the bladder allow it to store increasing volumes of urine with little change in bladder pressure (compliance) until capacity is reached. There are two interrelated components of bladder compliance, the passive of the connective-tissue elements of the bladder and the active properties of the smooth muscle in the bladder.	1–100 cm H_2O	dc – 10	Strain gage manometer	Levin and Horan, 1999
3	Blood flow	Blood flow can be measured by cannulating a blood vessel, but this has obvious limitations. Blood velocity can be measured with **Doppler flow meters.** Ultrasonic waves are sent into a vessel diagonally, and the waves reflected from the red and white blood cells are picked up by a downstream sensor.	1–300 ml/s	dc – 20	Flowmeter (electromagnetic or Ultrasound)	Barret, et al., 2010
4	Direct Blood Pressure, arterial		100–400 mm Hg	dc – 50	Strain gage manometer	
	Indirect Blood Pressure arterial		25–400 mm Hg	dc - 60	Cuff, auscultation	

Classification of Biomedical Instruments:

The study of biomedical instruments can be approached from at least four viewpoints. Biomedical measurement techniques can be grouped according to the quantity ***sensed***, such as pressure, flow, or temperature. One advantage of this classification is that it makes different methods for measuring any quantity easy to compare.

A second classification scheme uses the ***principle of transduction***, such as resistive, inductive, capacitive, ultrasonic, or electrochemical. Different applications of each principle can be used to strengthen understanding of each concept; also, new applications may be readily apparent.

Measurement techniques can be studied separately for each ***organ system***, such as the cardiovascular, pulmonary, nervous, and endocrine systems. This approach isolates all important measurements for specialists who need to know only about a specific area, but it results in a considerable overlap of quantities sensed and principles of transduction.

Finally, biomedical instruments can be classified according to the ***clinical medicine specialties,*** such as pediatrics, obstetrics, cardiology, or radiology. This approach is valuable for medical personnel who are interested in specialized instruments. Of course, certain measurements, such as blood pressure, are important to many different medical specialties.

INTERFERING AND MODIFYING INPUTS

Desired inputs are ***the measurands*** that the instrument is designed to isolate. ***Interfering inputs*** are quantities that inadvertently affect the instrument due to the principles used to acquire and process the desired inputs. If spatial or temporal isolation of the measurand is incomplete, the interfering input can even be the same quantity as the desired input.

A typical electrocardiographic recording system, shown in Figure 1, will serve to illustrate these concepts. The desired input is the electrocardiographic voltage v_{ecg} that appears between the two electrodes on the body surface. One interfering input is a 60 Hz noise voltage induced in the shaded loop by alternating environmental current (ac) magnetic fields.

The desired and the interfering voltages are in series, so both components appear at the input to the differential amplifier. Also, the difference between the capacitively coupled displacement currents flowing through each electrode and the body to ground causes an interfering voltage across Z_{body} between the two electrodes and two interfering voltages across Z_1 and Z_2, the electrode impedances.

COMPENSATION TECHNIQUES

1. Inherent Insensitivity: If all instrument components are inherently sensitive only to desired inputs, interfering and modifying inputs obviously have no effect.

2. Negative Feedback: When an adjusting input cannot be avoided, upgraded instrument performance needs a plan that makes the output less reliant on the transfer function.

3. Signal Filtering: a filter splits signals according to their frequencies. Most filters achieve this by reducing the part of the signal in one or more frequency bands.

4. Opposing Inputs: when interfering or modifying inputs cannot be filtered, extra interfering inputs can be used to terminate undesired output components.

Homework:

Q1: Describe the quasi-digital sensors.

Q2: List four medical and physiological parameters, and mention their definition, measuring range, frequency range, and standard sensor or method.

Q3: Describe using the following Instrumentation amplifier in ECG circuit AD620A. Note: follow the information in the datasheet