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DEPARTMENT: ELECT-ELECT

QUESTION ONE

In bioinstrumentation, after a biological signal has been detected with an appropriate sensor, it is amplified and filtered. Analog filter may be used to remove the noise hiding in biological signal or compensate for distortions caused by sensors. Amplification and filtering of biological signal may be necessary to meet the requirement of hardware specifications of signal conversion procedure. Continuous signal needs to be limited to a certain band of frequencies before signal can be digitized with an analog-to-digital converter, prior to storing in a digital computer.

Biological signals are often very small and typically contain some unwanted noise or interference. Such interference could determine the effect of obscuring relevant information that may be available in the measured signal. In order to extract the meaningful information from biological signals, equipments with high-precision low-noise are very necessary to minimize the effect of unwanted noise. Basic components of biomeasurement system are; sensors, analog processing circuit, A/D conversion, digital signal processing, output display, and data storage.

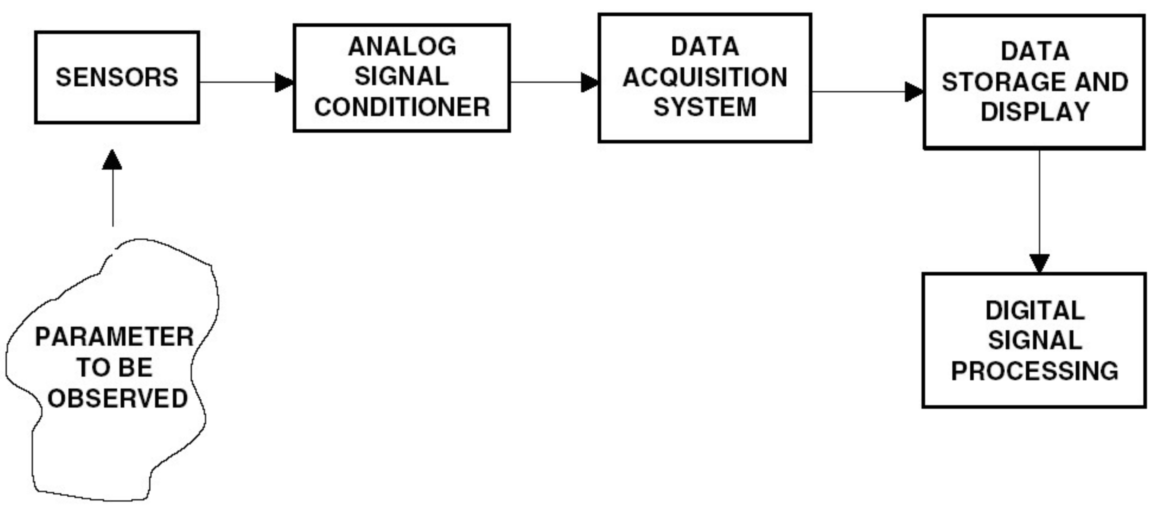


Fig 1.1 Biomedical signal acquisition process

From the figure above, sensors feel the biological signal that is being observed into an analog signal conditioner to adapt the requirement of data acquisition system. Here data acquisition system converts the analog signals into a calibrated digital signal that can be stored. Digital signal processing techniques are employed here to reduce the noise and extract additional information that can improve understanding of physiological meaning of original parameter.

The biomeasurement system is used to measure some biological signals such as quantity, property, or condition which are bioelectrical signal generated by muscles or the brain, or a chemical or mechanical signal that is converted into an electrical signal. It is shown below.

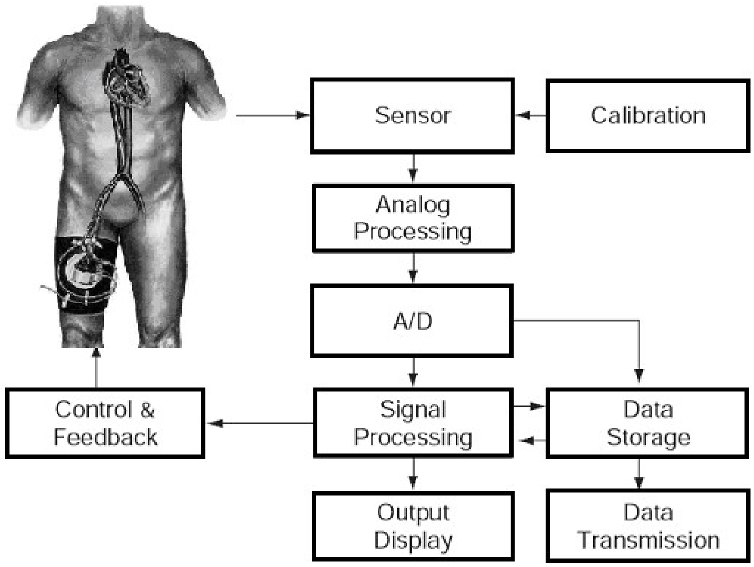


Fig 1.2 Bioinstrument system.

Two other components play important roles in bioinstrumentation system. The first is the calibration signal. A signal with known frequency and amplitude is applied to the bioinstrumentation system at sensor's input. The calibration device permits the system components to be adjusted so that it's known that the output and input have a certain linear relationship. Without such information, it's impossible to convert the output of an instrument system into a meaningful representation of the measurand.

The second is the control or feedback element, is not a part of all instrument systems. These parts include pacemakers and ventilators that could stimulate the heart and lungs. Some feedback devices collect physiological data and stimulate a response— a beat or breath—when needed or are part of biofeedback systems in which patients are made aware of a physiological instrument, such as blood pressure, and uses conscious control to change the physiological response.

QUESTION TWO

Functional Elements of a Measurement System

To understand a measuring instrument/system, it is important to have a systematic organization and analysis of measurement systems. The operation of a measuring instrument or a system could be described in a generalized manner in terms of functional elements. Each functional element is made up of a component or groups of components which perform required and definite steps in the measurement. The functional elements do not provide the intricate details of the physical aspects of a specific instrument or a system. These may be taken as basic elements, whose scope is determined by their functioning rather than their construction.

The main functional elements of a measurement system are:

i) **Primary sensing element:** which senses the quantity under measurement

ii) **Variable conversion element:** which modifies suitably the output of the primary sensing element.

iii) **Variable manipulation element:** The signal gets manipulated here preserving the original natre or form of it.

iv) **Signal conditioning element:** Further processes the incoming signal

v) **Data transmission element:** The transmission of data from one another is done by the data transmission element.

vi**) Data presentation element:** This is the display or read-out device that gives out the required information about the measurment.

Primary sensing element

The quantity under measurement makes its first contact with primary sensing element of a measurement system here, the primary sensing element transducer. This transducer converts measured into an analogous electrical signal.

Variable conversion element

The output of the primary sensing element is the electrical signal. It may be a voltage a frequency or some other electrical parameter. But this output is not suitable for this system. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form while retaining the original signal. Consider an example, suppose output is an analog signal form and the next of system accepts input signal only in digital form . Therefore we have to use analog to digital converter in this system. In many instruments variable conversion element is not required. Some instruments/measuring systems may require more than one element.

Variable manipulation element

Variable manipulation means a change in numerical value of the signal. The function of a variable manipulation element is to manipulate the signal presented to this element while preserving the original nature of the signal. For example, a voltage amplifier acts as a variable manipulation element. The amplifier accepts a small voltage signal as input and produces an output signal which is also voltage but of greater magnitude. The variable manipulation element could be either placed after the variable conversion element or it may precede the variable conversion element.

Signal conditioning element

The output signal of transducers contains information which is further processed by the system. Many transducers develop usually a voltage or some other kind of electrical signal and quite often the signal developed is of very low voltages, may be of the order of mV and some even V. This signal could be contaminated by unwanted signals like noise due to an extraneous source which may interfere with the original output signal. Another problem is that the signal could also be distorted by processing equipment itself. If the signal after being sensed contains unwanted contamination or distortion, there is a need to remove the interfering noise / sources before its transmission to next stage. Otherwise we may get highly distorted results which are far from its true value.

The solution to these problems is to prevent or remove the signal contamination or distortion. The operations performed on the signal, to remove the signal contamination or distortion, is called Signal Conditioning. The term signal conditioning includes many other functions in addition to variable conversion and variable manipulation. Many signal conditioning processes may be linear, such as, amplification, attenuation, integration, differentiation, addition and subtraction. Some may be non-linear processes, such as, modulation, filtering, clipping, etc. The signal conditioning processes are performed on the signal to bring it to the desired form for further transmission to next stage in the system. The element that performs this function in any instrument or instrumentation system is known as Signal Conditioning Element.

Data transmission element

There are several situations where the elements of an instrument are actually physically separated. In such situations it becomes necessary to transmit data from one element to another. The element that performs this function is called a Data Transmission Element. For example satellites or the air planes are physically separated from the control stations at earth. For guiding the movements of satellites or the air planes control stations send the radio by a complicated telemetry systems. The signal conditioning and transmission stage is commonly known as Intermediate Stage.

Data presentation element

The function of data presentation element is to convey the information about the quantity under measurement to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. The information conveyed must be in a convenient form. In case data is to be monitored, visual display devices are needed. These devices may be analogue or digital indicating instruments like ammeters, voltmeters, etc. In case the data is to be recorded, recorders like magnetic tapes, high speed camera and T.V. equipment; storage type C.R.T., printers, analogue and digital computers may be used. For control and analysis purpose computers and the control elements are used. The final stage in a measurement system is known as terminating stage.

Figure 2.1 below presents the block diagram of functional elements of a generalized measuring system / instrument. One must understand the difference between functional elements and the physical elements of measuring system. Functional element indicates only the function to be performed. Physical elements are the actual components or parts of the system. One physical element can perform more than one function. Similarly one function could be performed by more than one physical element. This is more suitably illustrated in the example of a measuring instrument described below.

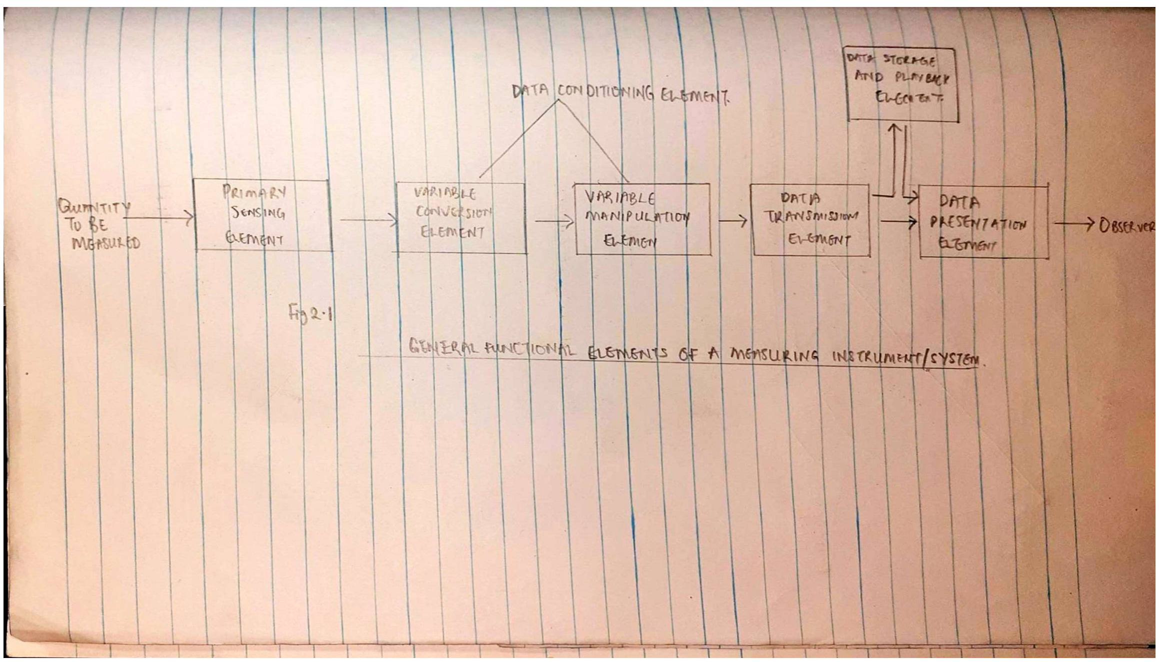


Fig 2.1 Functional Elements of a Bourdon Pressure Gauge

Examples

1. Functional elements of a Bourdon pressure guage

As an example of a measurement system, consider the simple Bourdon tube pressure gauge as shown in Fig. 2.2. This gauge offers a good example of a measurement system. In this case, the Bourdon tube acts as the primary sensing element and a variable conversion element. It senses the input quantity (pressure in this case). On account of te pressure the closed end of the Bourdon tube is displaced. Thus, the pressure is converted into a small displacement. The closed end of the Bourdon tube is connected through mechanical linkage to a sector-pinion gearing arrangement. The gearing arrangement amplifies the small displacement and makes the pointer to rotate through a large angle. The mechanical linkage thus acts as a data transmission element while the gearing arrangement acts as a data manipulation element. The dial scale on the gauge body plays the function of data presentation element and conveys the information about the quantity being measured. The information conveyed by this device is in analogue form.

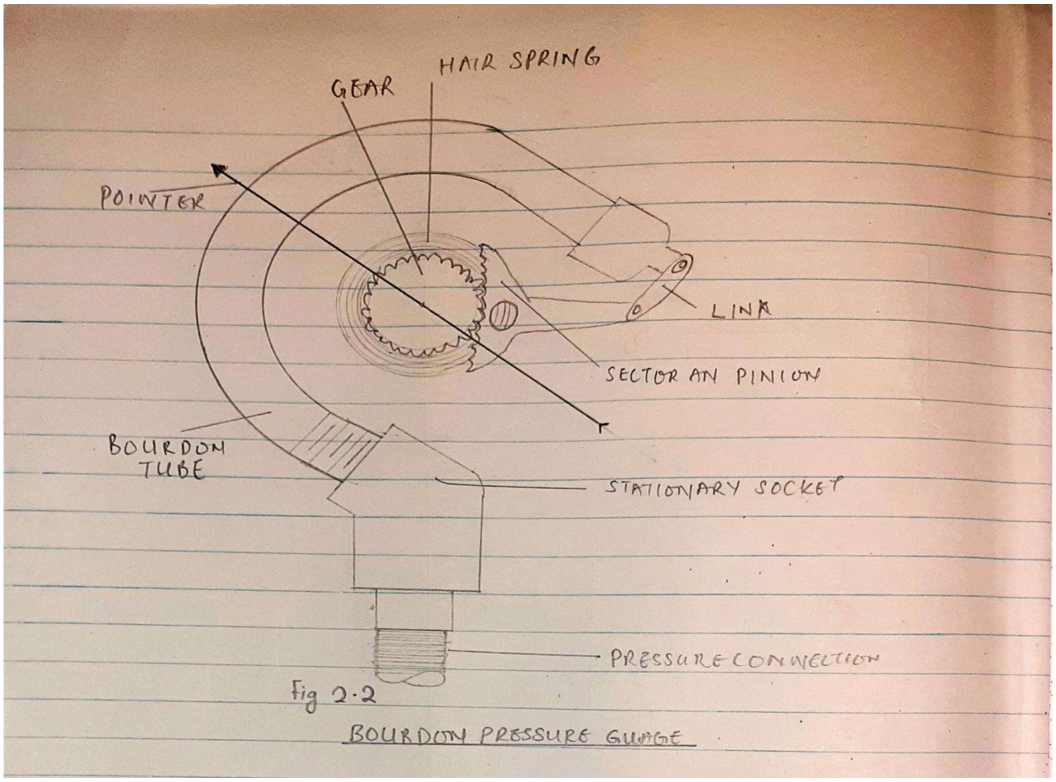


Fig 2.2 Bourdon Pressure Guage

2. Functional Elements of a Clinical Thermometer

As another example of a measurement system, let us consider the simple clinical thermometer shown in Fig. 2.3. In this case, the thermometer bulb containing mercury acts as the primary sensing element as well as a variable conversion element. It senses the input quantity, the temperature. On account of the increase in temperature the mercury in bulb expands and its volume is increased. The temperature signal is converted into volume displacement. As the mercury expands it move through the capillary tube in the thermometer stem, integrated to the bulb. The cross section area of the capillary being constant, the volume signal is thus converted into linear distance signal. The capillary thus has the role of signal manipulation and data transportation elements. The final data presentation stage consists of the scale on the thermometer stem, which is calibrated to give the indication of the temperature signal applied to the thermometer bulb. A restriction bend is provided in the clinical thermometers at the junction of the bulb and the capillary, which does not allow the back flow of mercury to the bulb once it has expanded to the capillary. Thus the restriction in the capillary acts as the data storage function of the instrument.

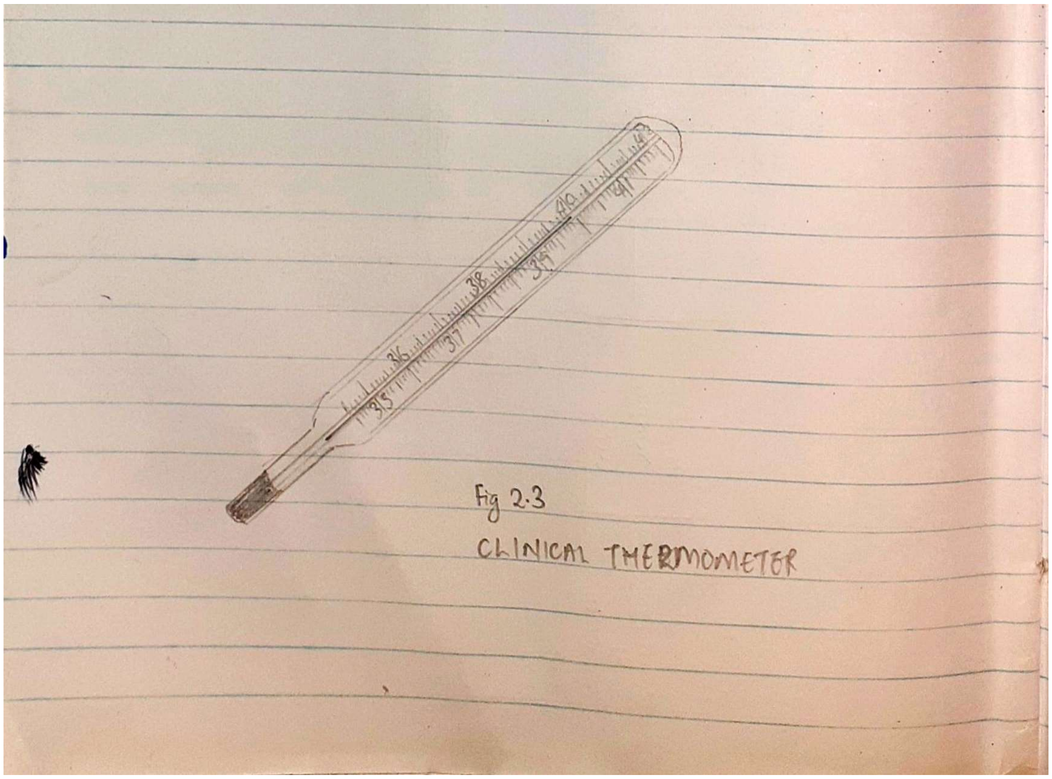


Fig 2.3 A Clinical thermometer

QUESTION THREE

1. Fetus heart sound sensor

Detecting fetus heart sound is very important in clinic application for doctor sometimes needs to grasp the present body status of fetus. PVDF piezoelectric thin film sensor is utilized to be fit for the measurement of fetus's heart sound as illustrated in figure 7. Its piezoelectric coefficient is the following:

d31=(15~30)×10−12C/Nd33=−(5~8)×10−12C/N

In this structure, silicon rubber converts the vertical motion of itself into the radial motion of PVDF piezoelectric thin film and then corresponding dynamic charge produced by PVDF thin film is proportional to the externally transient force. The voltage along thickness direction is output. Obviously, its work mode is d31 work mode. For both thin film and silicon rubber are very soft, they could well touch the skin of body belly. Then fetus heart sound is gained to judge fetus heart. Design requirement of PVDF heart sound sensor is as follows:

In the same piezoelectric thin film, one part is used as driving electrode; another is utilized as receiving the sound wave from heart sound.

Dynamic response characteristics on the surface of belly should be considered to well mate belly skin and sensor.

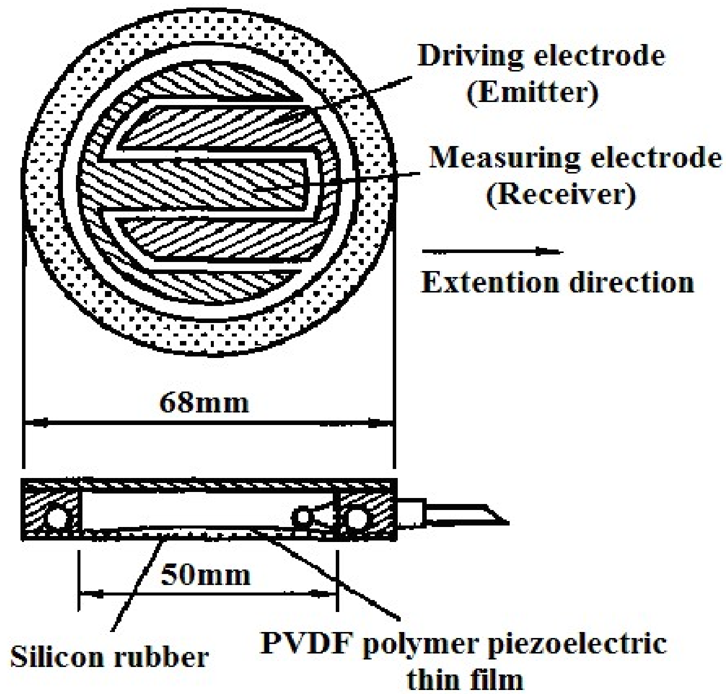
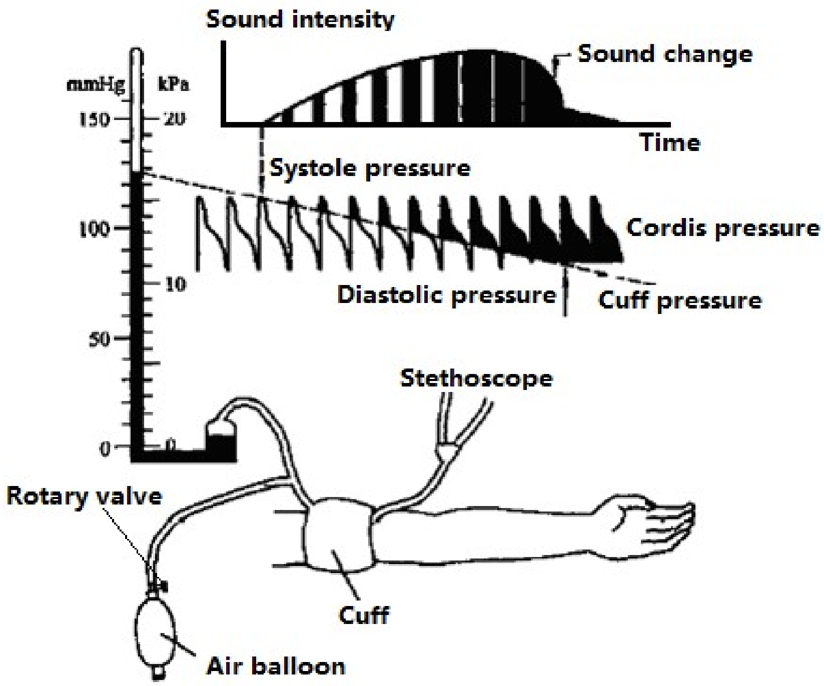


Fig 3.1 Sensing structure of PVDF piezoelectric acceleration sensor

2. Blood pressure sensor

If blood circulation is to be maintained in the body, tissues are to be perfused with oxygen. Then correct pressure measurement has to be applied in the vascular system. The usual blood pressure methods have: liquid coupling direct measurement, pipe-end sensing measurement, indirect blood pressure sensing measurement. Liquid coupling direct measurement means that the pipe filled with liquid is inserted into the measured part and that the pressure is measured by liquid coupling of pipe end position in the body, which is the simplest method. Pipe-end sensing measurement employs pipe-end sensor to measure blood pressure. Pipe-end sensor which can convert the pressure signal into electronic signal is placed on the measured part. And then the electronic signal measured is transmitted to the external wire. Such method could avoid the distortion of signal of blood pressure. Pipe-end sensing measurement has a lot of advantages, but such method needs to activate the skin and relative sensors have to been placed into the body. Hence indirect blood pressure measurement is noted by people and continuously explored. Blood-pressure meter is a classic example of indirect blood pressure measurement, which is shown in the figure below.


Sound intensity
Sound change
Time
mmHg
kPa
150
20
100
10
50
0
0
Systole pressure
Cordis pressure
Diastolic pressure
Cuff pressure
Stethoscope
Rotary valve
Cuff
Air balloon