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Department: Computer Engineering
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1. Describe briefly with examples sensors and Actuators for Biomedical Application.
- Many different kinds of sensors can be used in biomedical application. According to the sensing principle in biomedical application, biomedical sensors can be classified into physical sensors and chemical sensors. It's possible to categorize all sensors as being physical or chemical. In the case of physical sensors, quantities such as geometric, mechanical, thermal and hydraulic variables are measured. In biomedical applications these variables can include things such as muscle displacement, blood pressure, core body temperature, blood flow, cerebrospinal fluid pressure and bone growth velocity. The other type of physical sensor that finds many applications in biology and medicine is optical sensor. These sensors can utilize light to collect information and in the case of fiber optic sensors, light is the signal transmission medium as well. The second major classification of sensing device is chemical sensors. In this case sensors are concerned with the chemical quantities such as identifying the presence of chemical composite, detecting the concentration of various chemical species, and monitoring the chemical activities in the body for diagnostic and therapeutic application. Other types of physical chemical sensors such as the mass spectrometer utilize various physical methods to detect and quantify chemicals associated with biologic systems. The use of biologic reaction gives bioanalytic sensors high sensitivity and specificity in identifying and quantifying biochemical substances.

- Oxygen and Carbon dioxide Sensor for blood

Measurements of arterial blood gas (pO_2 and pCO_2) and pH are frequently performed by on critical patients in both the operating rooms and intensive care unit. They are selected and used by the physician to adjust mechanical ventilation or administer pharmacological agents.

- Heart sound sensor

The expansion and shrinkage of heart necessarily lead to the vibration of artery that is formed by blood turbulence in vein. The range of heart sound is from 20Hz to 200Hz. Low limit frequency of heart sound could reach about 4Hz and high frequency limit is greater than 1000 Hz.

- Blood flow sensors

If oxygen and nutrients are to reach tissues, the flow of blood must be maintained in body. Cardiac output flow is often measured as an index of cardiac performance, blood flow through arterial graft is used to ensure that a graft has been successfully inserted during surgery, or the blood flow in peripheral arteries and veins may be measured to assess vascular diseases.

- Respiration sensors

In biomedical research ^{or clinic} ~~for online~~ monitoring, respiration frequency of patient needs to be sometimes detected to record the physiological status. Thermistor is mounted to the front-end of binder. According to the change of thermistor value, the respiration frequency would be measured.

Actuators For Biomedical Applications

- Lab-on-a-chip (LOC): LOC is a class of miniaturized microfluidic devices configured in a single-chip form that is primarily designed for biological or chemical processing and analysis. These devices allow miniaturization and amalgamation of complex processes to be implemented on a small chip, which otherwise needs to be operated via repetitive laboratory tasks. Piezoelectric actuators have been one type of the actuators widely used as micropump elements in LOC to control the fluid flow with high accuracy.

- Implantable Drug Delivery Systems: Advances in MEMS and miniaturization technologies have enabled implantable biomedical devices specially designed to assist in the diagnosis and treatment of chronic or acute diseases. Micromachined drug delivery systems are among those emerging implantable devices. Many of these systems are comprised of micro reservoirs that store liquid-phase drugs and

microactuators that constitute a mechanism to eject the drugs out of the system and deliver them to the implanted sites.

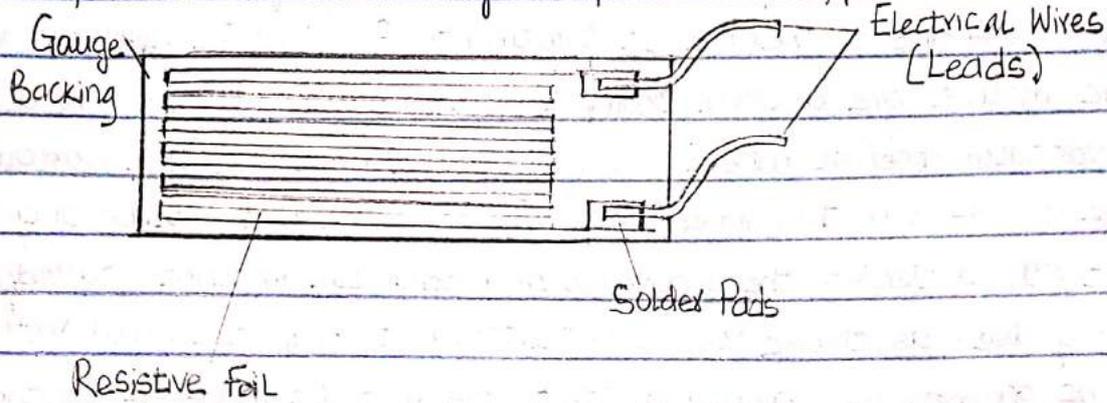
- **Cardiac Devices:** Many implantable devices are targeted at providing enhanced diagnoses and/or therapeutic treatments for specific diseases in vivo. Cardiac implants are a good example of them. Atherosclerosis is a type of cardiovascular disease where arteries become hardened and narrowed due to plaque build-up on their inner walls. In conjunction with balloon angioplasty to treat atherosclerosis, the endovascular mechanical implants called stents are commonly used as chronic vascular scaffolds to keep the blood vessel open. Most of commercially available stents are metallic, made of biocompatible alloys such as medical-grade stainless steel and Nitinol, to configure balloon expandable or self-expanding stents.

- **Surgical and Endoscopic Tools:** MEMS actuators offer promising opportunities in creating novel surgical devices as well. In particular, these actuators based on shape-memory materials, piezoelectric, and pneumatic principles and related fabrication processes are paving avenues to miniaturizing and improving the tools for surgical, interventional, and related procedures including catheter manipulators, endoscopes and imaging devices. Utilizing the features of nanometer range resolution and fast response, piezoelectric microactuators have been applied for delivering and scanning high-frequency laser pulses for microsurgery purposes. For example, Ferhanoglu et al. reported rapid removal of bulk tumors and bones using the 5mm diameter fiber device comprised of an air-core photonic bandgap fiber for delivery of high energy laser pulses, a piezoelectric tube actuator for fiber scanning, and two aspheric lenses for focusing the laser beam. To enhance the visualization of fine biopsy needles under ultrasound imaging, the needle-like catheter that equipped a miniaturized ultrasonic actuator was developed with a PZT layer sandwiched between two flexible electrodes using MEMS technology. Being attached to a catheter, the actuator radiated low-intensity ultrasound for detection of a biopsy needle tip under sonography. Pneumatic actuators shaped with soft and flexible elastomers are considered as one of the most suitable candidates for surgical device applications.

Describe with sketches and examples of the components of basic measuring instrument.

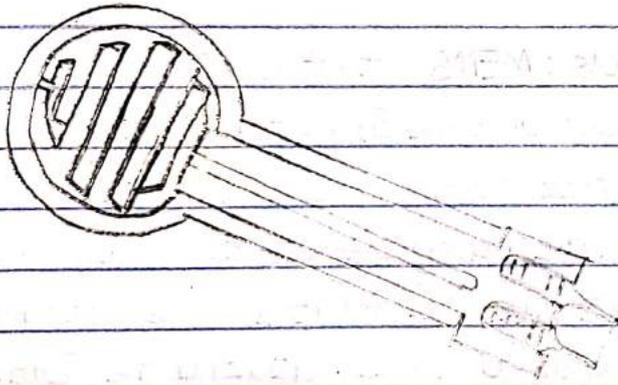
2. Strain gauges

Strain gauges consist of a very fine metallic foil etched in a grid pattern, which is bonded to a device and used to measure the strain, or amount of deformation of the device when weight or pressure is applied.



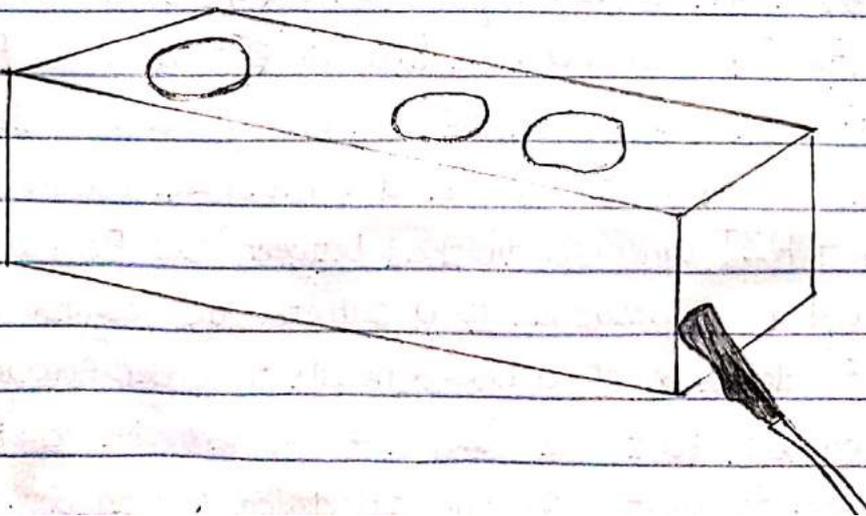
Force Sensors

The force sensors are sensors for mass production that use strain gauges.



Load Cells

Minebea manufactures load cells that use strain gauges to convert weight into electrical output.



3 Describe briefly case studies of two medical measurement instruments

MERCURY IN GLASS THERMOMETER

The mercury-in-glass or mercury thermometer was invented by physicist Daniel Gabriel Fahrenheit in Amsterdam (1714). It consists of a bulb containing mercury attached to a glass tube of narrow diameter; the volume of mercury in the tube is much less than the volume in the bulb. The volume of mercury changes slightly with temperature; the small change in volume drives the narrow mercury column a relatively long way up the tube. The space above the mercury may be filled with nitrogen gas or it may be at less than atmospheric pressure, a partial vacuum. In order to calibrate the thermometer the bulb is made to reach thermal equilibrium with a temperature standard such as an ice water mixture, and then with another standard such as water vapour, and the tube is divided into regular intervals between the fixed points. In principle, thermometers made of different material (e.g. coloured alcohol thermometers) might be expected to give different intermediate readings due to different expansion properties; in practice the substances used are chosen to have reasonably linear expansion characteristics as a function of thermodynamic temperature, and so give similar results. In the first decades of the 18th century in the Dutch Republic, Daniel Fahrenheit, made two revolutionary breakthroughs in the history of thermometry: He invented the mercury-in-glass thermometer (first widely used, accurate, practical thermometer) and Fahrenheit scale (first standardized temperature scale to be widely used). The application of mercury (1714) and Fahrenheit scale (1724) for liquid-in-glass thermometers ushered in a new era of accuracy and precision in thermometry, and is still to this day (as of 1966) regarded as one of the most accurate thermometers available. Mercury thermometers cover a wide temperature range from -37 to 356°C (-35 to 673°F); the instrument's upper temperature range may be extended through the introduction of an inert gas such as nitrogen. This introduction of an inert gas increases the pressure on the liquid mercury and therefore its boiling point is increased, this in combination with replacing the Pyrex glass with fused quartz allows the upper temperature range to be extended to 800°C (1470°F). Mercury cannot be used below the temperature at which it becomes solid, -38.83°C (-37.89°F).

SPHYGMOMANOMETER

A sphygmomanometer is a device that measures blood pressure. It is composed of an inflatable rubber cuff, which is wrapped around the arm. A measuring device indicates the cuff's pressure. A bulb inflates the cuff and a valve releases pressure. A stethoscope is used to listen to arterial blood flow sounds. As the heart beats, blood forced through the arteries cause a rise in pressure, called systolic pressure, followed by a decrease in pressure as the heart's ventricles prepare for another beat. This low pressure is called the diastolic pressure.

The sphygmomanometer cuff is inflated to well above expected systolic pressure. As the valve is opened, cuff pressure (slowly) decreases. When the cuff's pressure equals the arterial systolic pressure, blood begins to flow past the cuff creating blood flow turbulence and audible sounds. Using a stethoscope, these sounds are heard and the cuff's pressure is recorded. The blood flow sounds will continue until the cuff's pressure falls below the arterial diastolic pressure.

The pressure when the blood flow sounds stop indicates the diastolic pressure.

Systolic and diastolic pressures are commonly stated as systolic 'over' diastolic. For example, 120 over 80. Blood flow sounds are called Korotkoff sounds.

There are three types of sphygmomanometers. Digital sphygmomanometers are automated, providing blood pressure reading without needing someone to operate the cuff or listen to the blood flow sounds. However digital types are less accurate. Some healthcare providers use digital for screening but use manual sphygmomanometers to validate readings in some situations. Manual sphygmomanometers consist of aneroid (dial) and mercury (column) devices. Operating the aneroid and mercury devices is nearly the same, except that aneroid devices require periodic calibration.