Chapter 9
Biomedical Sensors

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ABSTRACT

This chapter addresses biomedical sensors, which are important factors for the quality of measurement of biological and physiological variables, and thus deserve close attention both with respect to the medical functions and the technical requirements. There are special demands for biomedical sensors, particularly for invasive sensors that must pass sterilization by temperature or radiation at much higher levels than the rest of the medical equipment. On the other hand, miniaturization, mechanical strength, electrical safety, and sterility are important elements of the sensor design process. The sensor determines the accessibility, spatial resolution, accuracy, sensitivity, selectivity, and response time of the measurement. In order to convert the parameter of interest into an electrical signal suited for medical use, a transducing element is necessary. Knowledge of the complete chain of transducer materials, their electrical properties, and integration with bio-amplifiers are therefore necessary to design high-quality biomedical sensors.

9.1. CHAPTER OBJECTIVES

This chapter enables the reader to:

- Describe the most common biomedical sensors and their clinical applications.
- Classify the different generic sensor types and explain advantages and disadvantages of each different type.
- Identify suitable amplifier circuits for each sensor type.
- Analyze biomedical sensor modes of operation and limitations.
- Identify and analyze sources of error for each clinical sensor application.
- Describe different sterilization methods and their suitability for different sensor types.

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9.2. INTRODUCTION

The use of biomedical sensors in clinical medicine has increased rapidly during the last decade and is now routinely used in modern patient care for monitoring of critical physiological parameters as well as for diagnostic procedures. A hospital admission in industrialized countries without connecting the patient to one or more biomedical sensors is almost unthinkable, and much of the clinical decision basis for each patient is acquired from biomedical sensors. This extensive introduction of increasingly advanced biomedical sensors in modern health care will probably continue for the years to come. One of the most dominant trends in modern specialized healthcare is the increasing pressure to lower health care cost and increased efficiency of patient treatment. As a result of this trend, the importance of biomedical sensors is expected to increase. Biomedical sensors are usually relatively inexpensive due to technologically efficient production methods, and can be used for a variety of monitoring and diagnostic procedures even outside hospitals.

9.3. A COMPREHENSIVE DEFINITION OF BIOMEDICAL SENSORS

The sensor concept is widely used in literature and everyday speech and, therefore, often not very well defined. In this chapter, we define the most important terms as unambiguous as possible but still within the generally accepted understanding of the concepts. In a generalized model, a physical variable of interest called the *measurand* is to be measured and recorded. An example of a well-known biomedical measurand is body temperature, which is directly recordable by a thermocouple (section 9.10). Very few physical processes are directly recordable, and a *mediator* is necessary to convert the measurand into a readable signal suitable for processing, presentation and recording.

Sensor is a mediator able to convert one or more measurands or physical variables into an equivalent signal variable of another type of quantity within a frame of a given unity (Pallàs-Areny & Webster, 2001, pp. 3-4). A sensor measures a selected parameter and comprises a transducing element converting the selected parameter into a signal; e.g., electric, light or mechanical pointer position.

Biosensor is a sensor applied on a biological material. Example: blood pressure sensor.

Transducer is in most cases a synonym to sensor. However, while a sensor comprises a sensing element and necessary signal processing elements in order to facilitate further post-processing of the measured quantity, a transducer is limited to the elements needed for the conversion process in the transducing element.

Transducing element is based upon a material like a piezoelectric crystal, piezoresistive semiconductor, steel wire, thermoelement, temperature sensitive resistor, pH-sensitive glass membrane, semiconductor radiation detector et cetera.

Biological sensor uses a biological transducing element. The biomaterial may be a part of living tissue; e.g., the electric field cell morphology biosensor (Giaever & Keese, 1993). It may also be dead tissue; e.g., as in a hair hygrometer.

Sensor system comprises the total signal path from the measurand to the observer and includes all sensing, conditioning and real-time processing elements in the path. As shown in Figure 1 there may be more than one transducing element, e.g. a pressure on a membrane converting the variable to a force which is then measured by the secondary element. It is preferable that biosensors do not ground the patient. Therefore, in many systems a galvanic separation must be inserted somewhere between the patient and the grounded instrumentation, Figure 1. The electronic circuitry to the left of the galvanic separation must use a power supply without reference to ground (floating). A biosensor may be sensitive to more than one parameter