BIOMEDICAL INSTRUMENTATION AND MEASUREMENTS

Leslie Cromwell
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SECOND EDITION

Biomedical Instrumentation and Measurements

Second Edition

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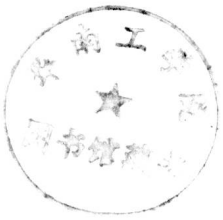

To our wives:

IRINA CROMWELL

CAROL WEIBELL

LIANNE PFEIFFER

Preface to the First Edition

As the world's population grows, the need for health care increases. In recent years progress in medical care has been rapid, especially in such fields as neurology and cardiology. A major reason for this progress has been the marriage of two important disciplines: medicine and engineering.

There are similarities between these two disciplines and there are differences, but there is no doubt that cooperation between them has produced excellent results. This fact can be well attested to by the man or woman who has received many more years of useful life because of the help of a prosthetic device, or from careful and meaningful monitoring during a critical illness.

The disciplines of medicine and engineering are both broad. They encompass people engaged in a wide spectrum of activities from the basic maintenance of either the body, or a piece of equipment, to research on the frontiers of knowledge in each field. There is one obvious common denominator: the need for instrumentation to make proper and accurate measurements of the parameters involved.

Personnel involved in the design, use, and maintenance of biomedical instrumentation come from either the life sciences or from engineering and technology, although most probably from the latter areas. Training in the life sciences includes physiology and anatomy, with little circuitry, electronics, or instrumentation. For the engineer or electronics technician the reverse is true, and anything but a meager knowledge of physiology is usually lacking on the biomedical side.

Unfortunately for those entering this new field, it is still very young and few reference books are available. This book has been written to help fill the gap. It has grown out of notes prepared by the various authors as reference material for educational courses. These courses have been presented at many levels in both colleges and hospitals. The participants have included engineers, technicians, doctors, dentists, nurses, psychologists, and many others covering a multitude of professions.

This book is primarily intended for the reader with a technical background in electronics or engineering, but with not much more than a casual familiarity with physiology. It is broad in its scope, however, covering a major portion of what is known as the field of biomedical instrumentation. There is depth where needed, but, in general, it is not intended to be too sophisticated. The authors believe in a down-to-earth approach. There are ample illustrations and references to easily accessible literature where more specialization is required. The presentation is such that persons in the life sciences with some knowledge of instrumentation should have little difficulty using it.

The introductory material is concerned with giving the reader a perspective of the field and a feeling for the subject matter. It also introduces the concept of the man-instrument system and the problems encountered in attempting to obtain measurements from a living body. An overall view of the physiological systems of the body is presented and then is later reinforced by more detailed explanations in appropriate parts of the text. The physiological material is presented in a language that should be readily understood by the technically trained person, even to the extent of using an engineering-type analysis. Medical terminology is introduced early, for one of the problems encountered in the field of biomedical instrumentation is communication between the doctor and the engineer or technician. Variables that are meaningful in describing the body system are discussed, together with the type of difficulties that may be anticipated.

It should also be noted that although reference works on physiology are included for those needing further study, enough fundamentals are presented within the context of this book to make it reasonably self-sufficient.

All measurements depend essentially on the detection, acquisition, display, and quantification of signals. The body itself provides a source of

many types of signals. Some of these types—the bioelectric potentials responsible for the electrocardiogram, the electroencephalogram, and the electromyogram—are discussed in Chapter 3. In later chapters the measurement of each of these forms of biopotentials is discussed. One chapter is devoted to electrodes—the transducers for the biopotential signals.

With regard to the major physiological systems of the body, each segment is considered as a unit but often relies on material presented in the earlier chapters. The physiology of each system is first discussed in general, followed by an analysis of those parameters that have clinical importance. The fundamental principles and methods of measurement are discussed, with descriptions of principles of equipment actually in use today. This is done in turn for the cardiovascular, respiratory, and nervous systems. There are certain physical measurements that do not belong to any specific system but could relate to any or all of them. These physical variables, including temperature, displacement, force, velocity and acceleration, are covered in Chapter 9.

One of the novel ideas developed in this book is the fact that, together with a discussion of the nervous system, behavioral measurements are covered as well as the interaction between psychology and physiology.

The latter chapters are devoted to special topics to give the reader a true overall view of the field. Such topics include the use of remote monitoring by radio techniques commonly known as biotelemetry; radiation techniques, including X rays and radioisotopes; the clinical laboratory; and the digital computer as it applies to the medical profession, since this is becoming a widely used tool.

The final chapter is one of the most important. Electrical safety in the hospital and clinic is of vital concern. The whole field becomes of no avail unless this topic is understood.

For a quick reference, a group of appendices are devoted to medical terminology, an alphabetical glossary, a summary of physiological measurements, and some typical values.

The book has been prepared for a multiplicity of needs. The level is such that it could be used by those taking bioinstrumentation in a community college program, but the scope is such that it can also serve as a text for an introductory course for biomedical engineering students. It should also prove useful as a reference for medical and paramedical personnel with some knowledge of instruments who need to know more.

The background material was developed by the authors in courses presented at California State University, Los Angeles, and at various centers and hospitals of the United States Veterans Administration.

In a work of this nature, it is essential to illustrate commercial systems in common use. In many examples there are many manufacturers who produce similar equipment, and it is difficult to decide which to use as illus-

trative material. All companies have been most cooperative, and we apologize for the fact that it is not possible always to illustrate alternate examples. The authors wish to thank all the companies that were willing to supply illustrative material, as well as the authors of other textbooks for some borrowed descriptions and drawings. All of these are acknowledged in the text at appropriate places.

The authors wish to thank Mrs. Irina Cromwell, Mrs. Elissa J. Schrader, and Mrs. Erna Wellenstein for their assistance in typing the manuscript; Mr. Edward Francis, Miss Penelope Linskey, and the Prentice-Hall Company for their help, encouragement, and cooperation; and Mr. Joseph A. Labok, Jr., for his efforts in encouraging us to write this book.

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Preface to the Second Edition

It is extremely gratifying to write a book in a relatively new field and achieve the wide acceptance enjoyed by the first edition of Biomedical Instrumentation and Measurements. Many major Biomedical Engineering and BMET programs have adopted the book over the last six years both in the U.S.A. and abroad. The reviews by our professional colleagues have also has been most encouraging and the remarks we have had from them and from students with respect to the "readability" have been a stimulant to the authors.

However, this field is dynamic and has progressed tremendously since the book was written. When the authors and publishers decided that a second edition should be prepared much soul searching was necessary to decide on what changes should be made to improve the work. Obviously everything had to be updated. Fortunately the original edition was written in "building block" style so that this could be achieved with relative ease. Also there were the constructive criticisms of our colleagues around the world to consider.

Perhaps the three major impacts on biomedical engineering in recent years are the tremendous expansion of non-invasive techniques, the sophistication built up in special care units and, along with other fields, the greater use of computers and the advent of microprocessors.

Taking all these facts together, the authors re-studied the book and the field and decided on the direction for the new edition. With respect to criticism, it was obvious, even after early adoptions, that the concept and principles of transducers should be presented earlier in the work. The original Chapters 1 and 2 were combined into a new introductory chapter and a new Chapter 2 was written on basic transducers, including some material drawn from the old Chapter 9. Chapter 9 was transformed into a new chapter on non-invasive techniques with the major emphasis on ultrasonics, a field that has developed greatly in recent years. However, some non-invasive techniques not covered in Chapter 9 are more appropriately included in other chapters.

Most of the material on physiology and basic principles has not been changed much, but the illustrative chapters contain many changes. Cardiovascular techniques have progressed considerably as reflected in the changes in Chapter 6. Because intensive care equipment and computers have also changed, Chapters 7 and 15 were virtually re-written. New topics such as echocardiography and computerized axial tomography have been added. Over two thirds of the illustrative photographs are new to reflect the many changes in the field.

This book now includes SI (Systeme Internationale) metric units, although other measurement units have been retained for comparison. Parentheses have been used where two sets of units are mentioned. However, it should be pointed out that the transition to SI metric units in the health care field is far from complete. Whereas some changes, such as linear measurements in centimeters, are now widely accepted others are not. Kilopascals is rarely used as a measurement for blood pressure, mmHg still being preferred. (1 mmHg is equal to 0.133 kilopascals.)

The authors again wish to thank the many manufacturers for their help and photographs, and the hospitals and physicians for their cooperation. These are individually acknowledged in the text. The authors also wish to thank Mrs. Irina Cromwell for typing and assembling the manuscript and Mrs. Elissa Schrader and Mrs. Erna Wellenstein for helping again in many ways in the preparation of this book. We are also indebted to California State University, Los Angeles, and the U.S. Veterans Administration for encouragement and use of facilities.

Los Angeles, California

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