Introduction to

INSTRUMENTATION IN SPEECH AND HEARING

Edward Cudahy

INTRODUCTION TO INSTRUMENTATION IN SPEECH AND HEARING

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PREFACE

This book is intended to serve as a primary textbook for an introductory course in instrumentation in speech and hearing. The focus in this book is application. Although some theoretical background is given for each instrument, most of the book is devoted to describing the functions and applications of various instruments. Quiklabs at the end of each chapter provide an opportunity to acquire experience by applying the information gained from each chapter. Throughout the book, "hands-on" experience is emphasized as the way to learn about instrumentation.

The book is divided into two parts. The first part consists of an introduction to the fundamentals of electronics and test instrumentation. The second part describes instrumentation specifically for speech and hearing, including common clinical instrumentation and instrumentation that is presently used mostly in research but is likely to be used in the clinic of the future. The division is between basic information and instrumentation used to calibrate and examine other instrumentation, which is typically used by a technician servicing other instrumentation, and the instrumentation used in the clinic. This book is designed to encourage clinicians to use test instrumentation (as described in the initial portion of the text) in an effort to be time and cost efficient. In addition, this text will assist all users of instrumentation to become more comfortable and more competent with their equipment. The book begins with a basic introduction to electronics. This is followed with a chapter describing basic test instrumentation. The basic information about electronics covered in chapters 1 and 2 serves as an introduction to the world of electronics, and chapter 3 gives the tools to examine this world. Clinicians can then apply this knowledge to the instrumentation with which they are more familiar and better understand the instrumentation that they use every day. The instrumentation commonly encountered in the clinic is covered in chapters 4–7. The last three chapters challenge the students to expand their knowledge beyond current clinic instrumentation and into the future. Chapter 7 covers both clinical and research instrumentation that measure physiological parameters of speech or hearing behavior. The next chapter is devoted to the principles and use of instrumentation for signal acquisition and analysis. While the concepts discussed in this chapter are applicable to virtually all of the instrumentation covered in this book, more advanced theoretical material is covered in this chapter; therefore this chapter might be of greater interest to more advanced students or classes. The final chapter covers computer and computer-related instrumentation in the field of speech and hearing. This chapter not only covers how to use the computer as a test or diagnostic instrument but also covers some of the other applications such as word processing and record keeping. A balanced view is attempted between the limitless possibilities offered by computers and the real-world concerns of applying the computer to the problems of the clinic and laboratory.

The book is developed in accordance with the successful procedures that I have used in my instrumentation course. The target audience is graduate or advanced undergraduate students, who routinely take such a course. Instrumentation is described in terms of the context in which it is most commonly used, and hints for the use of instrumentation are frequently given. Examples of research instrumentation that may be used in the clinic are presented, especially in the physiological instrumentation chapter.

In summary, this book is intended to be used as a teaching text and also as a reference on common clinical and research instrumentation in speech and hearing. An attempt is made to encourage familiarity with instruments in order to enhance the skills and efficiency of the clinician. The book also attempts to look to the future with the chapter on computers, which seeks to encourage clinicians to take advantage of these excellent general-purpose tools. This chapter also provides a knowledge base to those unfamiliar with computers, so that they may use the strategies given in the book to more adequately make decisions with regard to computer purchase and utilization. This book focuses not only on teaching about instrumentation but also on making the reader more comfortable in that world and on encouraging applications that he or she may not have thought of before.

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SECTION I

CHAPTER

1

Fundamentals of Electronics

You are about to be introduced to the marvelous and fascinating world of electronics. Electricity is so pervasive in our lives that we think little about how it is used, where it comes from, or even how all the gadgets that we use every day operate. Many of us know very little about how an automobile or digital alarm clock uses electricity. We may even think of electricity as having an almost magical quality. After working through this chapter, you may feel that some of the glitter is gone, but your initial sense of awe will be replaced with sufficient understanding of electronics to appreciate how some of these devices work. In addition, increased confidence regarding your use of electronic instrumentation should also be achieved. The Quiklabs at the end of the second chapter will provide opportunities to apply the knowledge gained from this chapter and to practice new skills.

This introduction to electronics is needed to insure that a few basic facts are learned before using instrumentation to make electronic measurements. These facts will help you to understand the quantities measured and will facilitate interpretation of measurement results. Trying to use instrumentation intelligently without understanding fundamental principles of electronics is akin to trying to build a house without a foundation. Lacking this supporting structure, the "house" will eventually sag and gaps will appear in the walls of knowledge surrounding you. Likewise, without some background information regarding electronics a person stands on pretty shaky ground when trying to use electronic instrumentation; worse yet, the maximum advantages provided by electronic technology will not be available. Remember that all measurements made with electronic instrumentation operate in some way on the basis of the fundamental principles that will be discussed in this chapter.

This introduction to electronics fundamentals begins with a description of basic electrical quantities (volts, amperes, ohms, and watts) and their properties. Next, electrical components that modify and control electricity are discussed, as well as some ways of describing instrumentation setups and electrical circuits. Then, the most common part of all instrumentation, the power supply, is examined. Finally, the behavior of direct current (DC) circuits and alternating current (AC) circuits is explained. Obviously not all aspects of electronics can be included in two chapters, nor will all of the indicated topics be considered in complete detail. To do so would require a number of volumes. Rather, the intent here is to provide the reader with some of the basics that will be useful in understanding the measurements and instrumentation covered in later chapters.

What is Electricity?

Electricity is the flow of electrons, which are small atomic particles. Electrons represent energy, and it is the energy in electricity that permits its multitude of uses. Another powerful aspect of electricity is the malleability of its energy. Electricity's pervasiveness in our daily lives illustrates the many different ways in which this power source can be altered and manipulated. Electricity can flow through almost any material, but the material's nature has an impact on the behavior of the electron flow or electrical current. This interaction of electricity and materials is critical to the operation of many current electronic devices such as transistors and integrated circuits.

Ohm's Law

A fundamental rule in electronics is Ohm's law. Ohm's law is the rule that ultimately governs the behavior of electricity, and like all good fundamental rules, it is very simple. Ohm's law (Equation 1) states that the electromotive force (E) equals the current (I) times the resistance (R). A more common name for electromotive force is *voltage*. Each of these fundamental attributes of electricity will be described along with some real-world representations.

$$E = I \times R \tag{1}$$

Electromotive Force

Lightning is a good example of electromotive force. No one denies that there is considerable force in a lightning bolt. If we fix a visual image of a lightning bolt in our minds, we note that the force travels a distance. Although the amount of distance is not critical, the difference between land and sky or low and high is important. During a storm, the sky and the land build up different kinds of electromotive force, called "positive" and "negative," which are attracted to each other.

Nature abhors an imbalance and solves the problem by using lightning to "equalize" the differences between the "negative" land and the "positive" sky. The force, in this case lightning, travels between the two points, or between land and sky. The greater the imbalance, the greater the force that must travel between the two points. The imbalance is quantified as volts, which is the difference in electromotive potential force between two points. An equivalent way to state the same thing is that voltage refers to the passage of electrons between two points of opposite polarity. Fortunately, most electrical differences do not (usually) generate lightning but behave in a much more sedate manner. These differences in electromotive force can be measured with a voltmeter, which is a measurement device discussed in the next chapter.

In general, the terms *electromotive force* and *volts* can be used interchangeably. In this book the electromotive force (EMF) will be used to describe the fundamental phenomenon that we measure as voltage potential and *voltage* will be used to describe the measurement of EMF. This is analogous to the fundamental phenomenon of height, which we measure in terms of feet and inches (or meters and centimeters).

Current

When lightning strikes, the force must get from land to sky in order to equalize the electrical differences. Electricity has been described previously as "the flow of electrons." The electrons carry the force from place to place. Current (I), the second quantity in Ohm's law, is the measure of this *flow* of electrons through a conducting point and is quantified as amperes. To give some idea of the number of electrons required to carry electrical current, 1 ampere equals 1 coulomb/s. Since 1 coulomb equals 6.28×10^{18} electrons (that is, 6,280,000,000,000,000,000 electrons), this means 6.28×10^{18} electrons/s.

One very interesting and important feature of current is the direction of its flow. Electrical potentials can be either positive or negative. Current flows from negative to positive. This occurs because electrons carry a negative potential and in the world of electricity opposites attract. Thus electrons flow toward positive potentials. This produces the interesting fact that since land is negative and the sky is positive, lightning actually goes upward, not downward, as our visual image tells us. It also means that the current flow in an electrical circuit will be from the negative portions of the circuit toward the positive portions of the circuit. This can be very important and must be kept in mind when examining or testing circuits because electricity flowing in the wrong direction at the wrong time can have disastrous results.

The statement that current can flow in only one direction represents a simplification. When electrons flow in one direction only, that is, the current flow is in one direction only, the current is referred to as direct