TELEMETRY COMPUTER SYSTEMS

AN INTRODUCTION

By O. J. Strock

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INSTRUMENT SOCIETY OF AMERICA

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PREFACE

When I first became involved in telemetry work in 1957, it was difficult to find written material on this technology that was applications oriented. New engineers and technicians searched eagerly for anything that would help them to set up subcarrier pre-emphasis or to measure peak-to-peak transmitter deviation on an FM/FM system.

Five years later, pulse-code modulation (PCM) was in widespread use, and again the lack of simply written, well-illustrated tutorial material was frustrating. When in 1967 I wrote the first magazine article on the use of a minicomputer in a real-time telemetry system, it was well received, not because of the quality of the article but because no other material was available on the subject.

My present employer, Fairchild Weston Systems, Inc., then known as "EMR Telemetry," began to publish a small tutorial document called the "Telemeter" in the mid-1960s; each issue of this document was requested for several years after its publication. This indicated to me that telemetry technology is poorly documented, and that users of telemetry-computer systems need a complete, not-too-technical book on the subject.

This book was prepared as the textbook for two-day classes that I have presented at more than a dozen locations in North America and Asia. The enthusiasm with which these classes are received by "new" engineers, technicians, and computer programmers, as well as by the "old timers," encouraged the Instrument Society of America and me to offer the book in the present form.

In preparing this book it was necessary to reference equipment of specific identity in many cases in order to illustrate given items of technology. The Instrument Society of America did not participate in selection of equipment types for these illustrations, and of course the use of such references does not constitute endorsement of those products. No representation is made as to the availability or suitability of any specific equipment for telemetry data handling or other purposes.

Since the state of the art in telemetry and computer equipment is moving forward rapidly, this book must be supplemented periodically,

and must be superseded by an updated version after a few years. It is our intention to provide new information as often as appropriate. In this connection, I will welcome suggestions from readers at the address below.

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ACKNOWLEDGMENTS

In any rapidly evolving area of technology such as telemetry-computer systems, it would not be possible to assimilate the material for a book like this without help from many associates. Such is the case with this book. In my more than 25 years of experience with telemetry, scores of people have patiently answered my questions, related their observations and knowledge to me freely, and given me clippings and copies of interesting documents. It is of such information that a book is made, and I appreciate the opportunity to share with others as it has been shared with me.

Since half of my experience has been with "EMR Telemetry" (a Schlumberger company known by various organizational names), it is natural that a greater acknowledgment is due to associates in this company. I appreciate especially the help from my fellow applications engineers (Barry Barton, Art Kelley, Wiley Dunn, and Gary Schumacher), the staff scientist (Bill Waggener), and the Systems staff engineer (Graham Hildebrand).

The draft copy of this book was used in 1981 and 1982 as the textbook for a class I taught at more than a dozen locations in three countries. The students in these classes helped immeasurably also, by asking questions on subjects that were unclear and by confirming the suitability of the material. This version reflects the inputs of many of those students.

Much-needed reference material helped me in the compilation of certain paragraphs, especially the following:

1. Miscellaneous: IRIG Document 106-80.
2. Section 2.3: internal documents at EMR, prepared by Kent Morgan.
3. Section 3.3 and 3.4: technical literature from Microdyne, Inc.
4. Section 4.5: internal documents and discussions at EMR with Bill Kessler.
5. Sections 5.1–5.3: tutorial material prepared at EMR by Bill Waggener.
6. Section 5.8: reference material from Datum, Inc.

7. Section 6.1: technical material from Graham Hildebrand at EMR.

8. Section 6.2: magazine article by P. Alexander, "Array Processor Design Concepts," *Computer Design,* December 1981.

9. Section 7.1 through 7.3 and 8.2: technical literature from the Digital Equipment Corporation (DEC).

10. Section 7.8.2: Magazine article by D. Brickner, "Military Multiplex Standard," *Electronic Design,* December 1979.

11. Appendices B, C, and D as credited (Art Kelley, Holland Bell, and Gary Schumacher).

Finally, but not least, I acknowledge the encouragement and patience of my wife, Maxine, without whose cooperation the draft could not have been put together, the word-processing department at EMR (led by Kathy Boley) who typed the draft and final versions, the illustrations department at EMR (led by Jim Horvath) who supplied readable drawings, and Frederic S. Cushing, at ISA headquarters, who gave much assistance in the publishing process of the book. The list must stop here or go on indefinitely! Thanks, all!

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Outline

Because many telemetry users have asked for it, this volume offers an abbreviated technical course that is keyed to the needs of the person not necessarily involved in the day-to-day operation or maintenance of telemetry stations, but whose job interests and responsibilities require a new look at telemetry-computer technology.

The word "telemetry" implies measurements that are made from a distance. In most uses of telemetry, such is the case—aircraft, spacecraft, rocket, automobile, or other vehicular testing. For the purposes of understanding the fuller application of telemetry/computer system technology, however, the general definition should be expanded to include "any grouping of data measurements in a format that can be transmitted or stored on a single medium, received or retrieved from that medium, and separated into the original measurement components for observation." This definition, therefore, will include the entire technique of data multiplexing (mixing) and demultiplexing, as in multichannel-per-track tape recording, for example.

Telemetry and computer equipment designs change drastically in just a few years. Many techniques that were state-of-the-art ten years ago are now marginal at best. System designs are being improved as data-handling requirements become more demanding. Better, faster computers and more sophisticated software are available. Now, one can spend a couple of days looking at these developments, and becoming more knowledgeable in this ever-changing technology, without needing to sift through the meager supply of literature and dig out the pertinent facts—a time-consuming if not totally impossible task.

This chapter introduces readers to telemetry/computer systems, and familiarizes them with Inter-Range Instrumentation Group (IRIG) standards. Chapters 2 through 6 describe pulse code modulation (PCM) telemetry components, from transducers all the way through a transmitter and receiver link, including the telemetry equipment that prepares data for ob-

servation and computer entry. In particular, data compression and preprocessing equipment and techniques are described. In Chapter 7, the entire computer subsystem is discussed. Various types of peripherals are examined, as are bus structures and other means of communication. Chapter 8 looks first at the general function of software, then at computer software, and then at a unique telemetry software system.

The several appendices elaborate on specific elements of telemetry/computer technology. Appendices A through E describe specific applications of telemetry and Appendix F discusses some of the economic aspects of purchase and operation of a telemetry/computer system. They are followed by a glossary of terms as well as subject index with reference to specific paragraphs in the book.

1.2 System Configuration

While every telemetry system is configured to meet the unique needs of a specific customer, the overall block diagram of any system has certain elements in common with that of any other system. This configuration commonality is shown in Figure 1.2-1.

Electrical data originate at the sensors or transducers, each of which converts some physical condition (such as temperature, pressure, or acceleration) into a proportional electrical voltage. Typical sensor types are thermocouples, resistance-temperature devices, bridges, and potentiometers.

A typical system includes several types of signal conditioners, each of which is used to convert the output of a specific type transducer to data with a range of 5 to 10 volts. One extreme of voltage corresponds to the lowest temperature, pressure, or other specific condition expected at the measurement point; the other extreme corresponds to the highest measurement expected.

Obviously, if a transducer has a self-contained signal conditioner with an output range adjustable to 5 to 10 volts, or if the measurement is already in that range without signal conditioning, the signal conditioner can be bypassed for that measurement.

The multiplexer's task is to combine several measurements into a single output stream so that they can be transmitted over a single radio channel, coaxial cable, or telephone line, and/or they can be recorded on a single track of a tape recorder. The PCM multiplexer outputs measurements as a serial bit stream; any channel can be identified later by its relative location in the stream.

The next link in a system is the transmission-reception medium (radio, coaxial cable, or telephone) and/or magnetic tape recorder. Voice

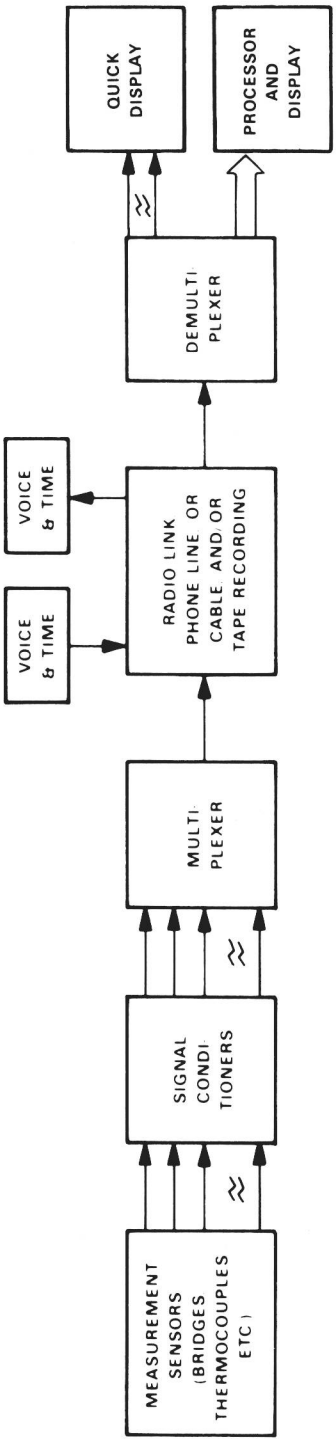

FIGURE 1.2-1 SYSTEM CONFIGURATION.