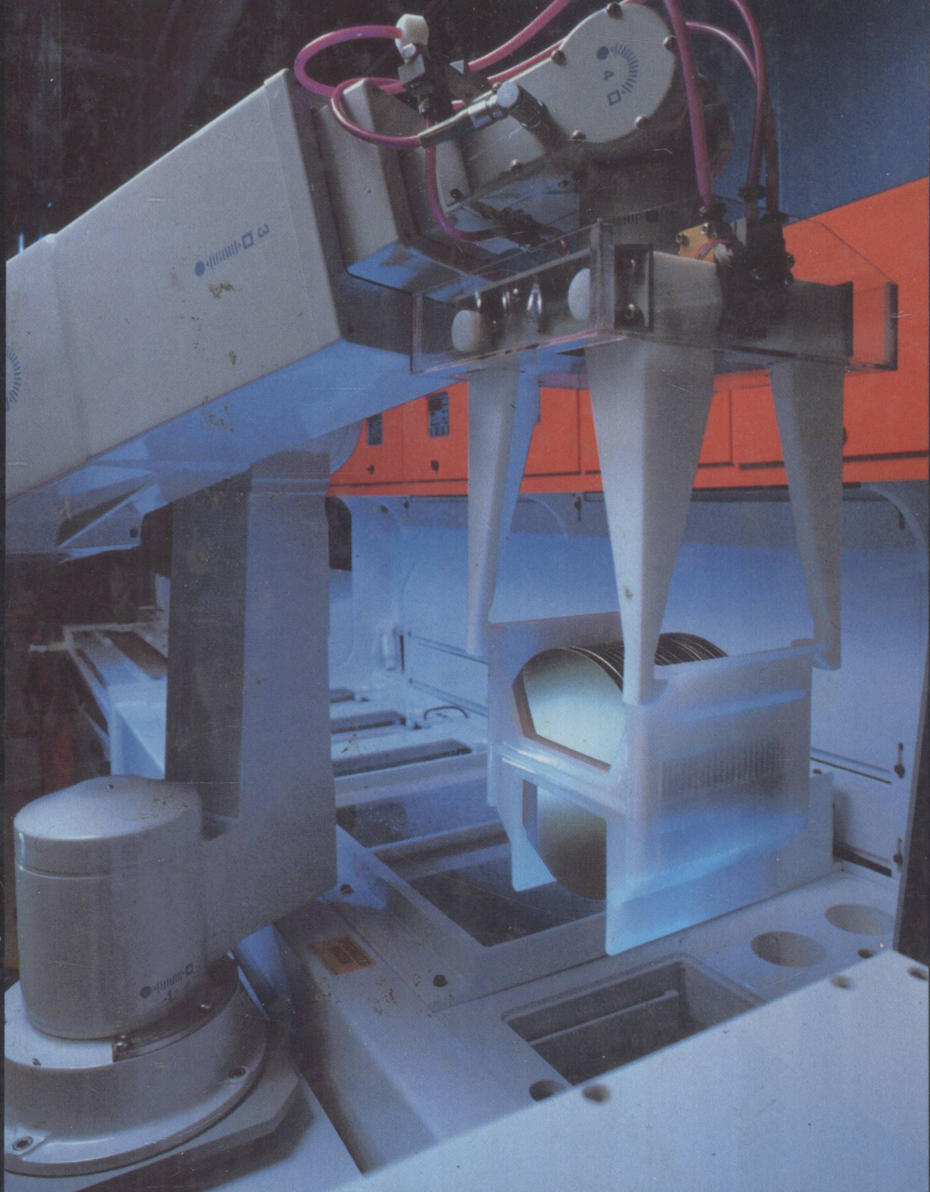
Industrial Electronics

4th Edition



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Industrial Electronics

Edition

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To our wives, Marg and Joyce

She is far more precious than jewels—Proverbs 31:10

Preface

Few areas of electronics have changed as much as that of industrial electronics. Faced with pressures from manufacturers overseas, managers in industry have used the latest developments in electronics to make their businesses more competitive. The growth in this area places an increasing demand on instructors to prepare students to work in the industrial electronics area. Most managers and instructors would agree that a thorough knowledge of electrical theory is not enough to be successful in today's industrial environments. Therefore, the fourth edition of *Industrial Electronics* covers not only the theory but also the applications in industrial systems necessary to survive as a technician in industry today.

FEATURES

- All the chapters present in the third edition have been retained in this fourth edition. A survey of users of the text feel that the coverage in most areas is adequate. A chapter covering *robotics* and one covering *optoelectronic devices* (lasers and light-emitting diodes) have been added. These two areas are seldom covered in other courses. On the recommendation of several users, an appendix on Operational Amplifiers has been added for reference.
- *Bibliographies* are included at the end of the book for each chapter. These references may be used as supplemental reading or study assignments for topics that are to be covered in depth.
- *Data sheets* have also been included at the back of the book for reference. They present detailed information about some of the IC chips used in the text. We hope that students will use this information to gain greater understanding of the IC chips and circuits we have used as examples. These same IC chips can also be used in student design projects, and the data sheets should help.
- A book of *laboratory experiments* is available as an accompaniment to the fourth edition. We have tried to include experiments in the lab manual that will reinforce the concepts taught in the text material. Every effort has been made to use inexpensive, generic components and circuits for experiments. In many cases, equipment already on hand can be adapted for use in these experiments. The laboratory manual is available as a separate publication and is keyed to reading assignments in the text.
- An ancillary *instructor's guide* is available without charge from the publisher for the convenience of instructors who adopt this book for classroom use. The instructor's guide will include the solutions to problems at the end of the chapters, as well as solutions to the laboratory experiments.

GOALS

The primary goal of the fourth edition of *Industrial Electronics* is the same as all other editions: to provide the student with an understanding of the basic components and systems used in industrial electronics in an interesting and easy-to-understand style. We feel that students need a course that introduces a systems approach to many of the devices they have studied earlier in their coursework. They also need a text that covers devices they may not have been exposed to in other courses. The explosion of knowledge in the electronics field—especially in the area of digital electronics and microprocessors—has caused many electronics programs to decrease or eliminate coverage of many devices that are important in industrial electronics.

Success in any facet of electronics depends on a knowledge of fundamentals. This text presents the basic facts, concepts, and principles of industrial electronics. Since an industrial electronics course tries to prepare students for entry into the workplace, any text should reflect those changes that are occurring in industry. In this fourth edition, we have made every effort to bring this text up-to-date to reflect what industry is demanding of our graduates and what instructors are now teaching and should be teaching in their courses.

- *The text avoids design questions.* Instead, it focuses on the underlying concepts and the operation of electronic devices, circuits, and systems. We feel that if concepts are understood, designing circuits, in most cases, is not a problem. We definitely do not subscribe to the notion that the best way to understand electronic circuits is to design them.
- *The text is comprehensive.* Experience has shown that a course in industrial electronics requires the coverage of a large number of topics. But how can these topics be covered in one course? One solution is to use several textbooks for the course. Another is to supplement one text extensively with instructor-prepared materials. A third approach is to modify the course and teach only those topics covered in the textbook. However, we feel that all of these alternatives are unacceptable. Thus, we have purposely written a comprehensive text that includes most of the required topics.
- *The text presentation is flexible.* We have written all chapters so that certain topics can be easily omitted. Although we cover most of the topics in the book in a one-semester course, some of the topics can be treated in other courses. Thus, the material in this book could easily be expanded to two semesters or two quarters, depending on the depth of treatment for each topic.
- *The text presentation is not overly mathematical.* We expect students to have a mathematics background no higher than algebra and trigonometry, and we have avoided any higher level of mathematics in our presentation. We realize, however, that mathematics is a concise way of representing concepts. Thus, we have included it where we feel that an adequate grasp of the concept demands a mathematical treatment.

LEVEL

This book is intended for use in electronics programs offered in two- or four-year colleges. All electronics students at the College of Technical Careers at Southern Illinois University, Carbondale, are required to take an industrial electronics course. We feel that every graduate of a two-year or four-year electronics program should have a basic understanding of both digital and analog circuitry. Many of our graduates report that their preparation in analog circuits and systems has been invaluable. They typically find themselves acting as liaisons between analog applications and people who have a predominantly digital background.

We also expect students to have some background in basic digital gates and logic gained from an introductory course in digital electronics earlier in their electronics education. It may also be helpful, but not essential, for the student to have completed a technical physics course.

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James T. Humphries
Leslie P. Sheets

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Introduction

Industrial electronics can be defined as the control of industrial machinery and processes through the use of electronic circuits and systems. Each of the topics in this text has been carefully chosen to help you, the future technician, survive in such an environment. We feel that knowledge gained by studying these topics will make you better prepared for entry-level employment as an electronics technician.

Although many topics have been included in this text, there are many additional topics you will need to know to function successfully in industry. As a starting point, we assume that your previous electronics courses have given you a firm grounding in alternating and direct current theory, the functions of electrical and electronic components, and mathematics through algebra and trigonometry.

The topics in this text are built around a very general process control system since we believe the electronics technician should be a generalist. Furthermore, it is not possible to cover in one text all the circuits and systems you are likely to encounter in industry. The range of industrial applications is simply too broad. Therefore, we have concentrated on some basic circuit and component concepts with appropriate examples. Once you have mastered the basic circuit and component functions, you will be ready to put these parts together into a functional system. That is, your knowledge of the functions of subparts and subsystems will help you understand how the overall system functions.

An example of a very basic process control system is illustrated in Figure I.1. Each block in the

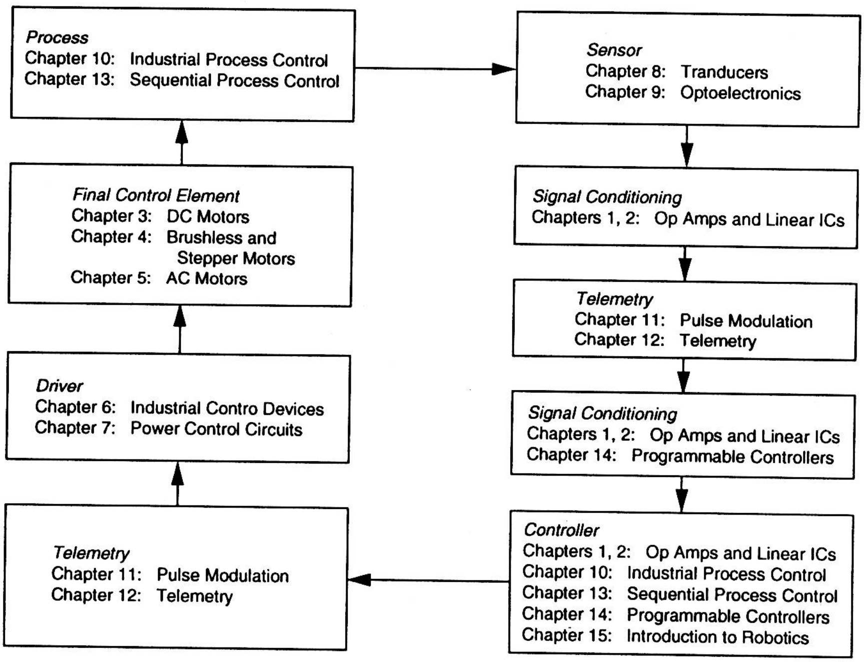

FIGURE I.1 General Process Control System diagram represents a division of the elements within a process control system. Note that it is sometimes difficult to separate physically one block or topic from another in a real system. And, of course, not all blocks will be used in every control system; however, all are likely to be encountered in industry.

Each block in Figure I.1 contains the associated chapter in which that topic is discussed. The chapters by themselves may seem disconnected from one another, but they obviously are related when you consider the complete system.

The process in Figure I.2 is a hypothetical example. It shows a conveyor belt and a motor driver that must keep a constant speed on the belt regardless of the load. This example is related to the system of Figure I.1 in the following manner: The process in Figure I.1 is the transportation of the load from one point to another at a constant speed. As the load on the belt changes, some type of speed sensor is used to detect changes in speed and convert this change into an electric output. If the controlling system is some distance from the belt, a communications circuit can be used to transport the information from the sensor to the controller.

Before the controller can operate on this sensor output, it may require conditioning of some type to get the electric signal in the correct range or form. The controller can then make a decision, on the basis of the results of the incoming data, as to whether the belt should have more or less power than it had previously or the same power. This decision is then transmitted by telemetry back to the belt drive circuitry, which will apply the appropriate amount of power, depending on the results of the controller's decision. The final control element, the motor, will then be provided with the appropriate power necessary to keep the belt operating at a constant speed. This simple process illustrates the concept of process control and the basis for the inclusion of the topics in this text.

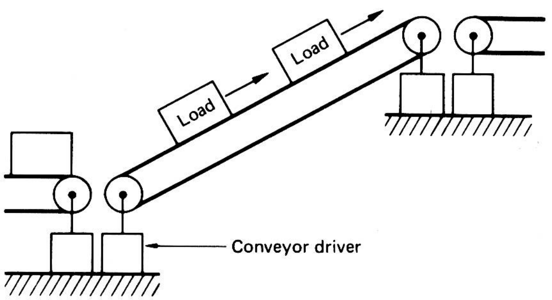

FIGURE I.2 Conveyor Belt System Used to Illustrate a Simple Process and Its Control

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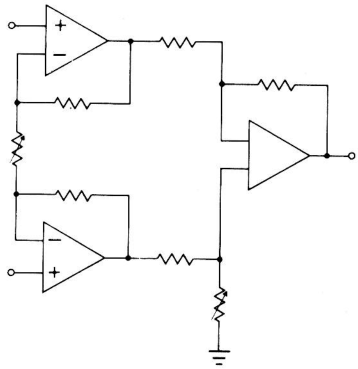
CHAPTER 1

Operational Amplifiers for Industrial Applications



OBJECTIVES

On completion of this chapter, you should be able to:

- Describe the operation of an instrumentation amplifier.
- Calculate the output voltage and gain, given an instrumentation amplifier circuit and an input voltage.
- Calculate the output voltage of a logarithmic amplifier with a given input voltage.
- Explain the operation and calculate the output frequency of a Wien-bridge oscillator.
- Compare the current-differencing amplifier (CDA) to the op amp.
- Calculate the output voltages and gains of the noninverting and inverting CDAs.
- Calculate the trigger voltages and currents of both inverting and noninverting CDA comparators with and without hysteresis.
- Explain the operation and applications of the CDA window comparator.
- Describe the operation of the operational transconductance amplifier (OTA) and draw its schematic symbol.
- Describe an application for the op amp current-to-voltage converter.
- List the general procedures for troubleshooting op amps.