Numerical Control and Computer-Aided Manufacturing

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To

Barbara P., Mathew, and Michael
Barbara W., Lorraine, and Stephen

Preface

The manufacturing process has undergone significant change during the past 20 years. The major contribution to this change has been programmable automation, made possible by machines that can be automatically controlled to perform a variety of tasks.

From humble beginnings in the late 1940s, numerical control has progressed to the forefront of automated machine development. In little more than two decades, numerical control has evolved from simple automatic positioning machines, controlled by instructions on perforated tape, to sophisticated machine systems integrated within a computer controlled manufacturing network.

An understanding of the numerical control process requires information from many engineering disciplines. This book presents a treatment of numerical control that bridges the gap between the hardware and software elements that enable the system to function. Numerical control is traced from its foundation in control theory, through the development of the hardware components of the system, into the use of computer based elements of modern programmable, automated devices.

The initial chapters of this book present a conceptual view of a conventional numerical control device. The fundamental concepts of automatic control theory are introduced to familiarize the student with basic mathematical methods and terminology. The elements of a numerical control system are next presented as interrelated components of an overall information network. The machine control unit and system elements that perform digital control, actuation, and monitoring are considered. Finally, special considerations for the design of numerically controlled machines are discussed.

In subsequent chapters the emphasis shifts from hardware to the interface between the machine control system and the coded data that drives the machine. A discussion of numerical control input and output concentrates on the nature of the data that provides the man-machine interface.

The methods that are used to generate coded instructions for input to a programmable controller vary greatly in their level of complexity. Simple manual procedures and sophisticated computer techniques are presented to illustrate the various modes of part programming. Special mathematical techniques, fostered by the expanding application of numerical control for the manufacture of complex components, are examined in a separate chapter.

The concluding chapters deal with numerical control optimization methods and computer-aided manufacturing. Adaptive control provides a second information path that optimizes numerical control operation by evaluation and modification of process parameters. Computer managed numerical control systems form the foundation for the latest step in the evolution of the manufacturing process—the computer based manufacturing system.

This book has been developed as a teaching tool for a subject that touches on many diverse engineering disciplines. The chapters have been arranged so that the physical elements of the numerical control system are explained before software and advanced systems are considered. Example problems are used to illustrate important concepts, and references are listed at the end of each Chapter to guide further investigation of various topics. Chapters Two to Nine contain problems for the student to solve.

Numerical Control and Computer-Aided Manufacturing is a suitable text for a one-semester course in mechanical, industrial, or manufacturing engineering at the undergraduate level. It may also be used to complement existing material in courses dealing with manufacturing processes developed for engineering technology programs. It provides a comprehensive framework for a graduate level course in programmable automation.

We acknowledge the many authors who have contributed to the numerical control literature during the past two decades. Their work and the publications, specifications, and manuals provided by numerical control manufacturers have had an important influence on the subject matter and methods of our presentation. We also thank the many contributors in industry who have provided state-of-the-art information and photographs.

Finally, we thank Barbara Williams for typing and Barbara Pressman for checking the manuscript. Both are thanked for their patience, understanding, and encouragement.

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Chapter One

Introduction to Numerical Control

Man has been described as a tool using animal. Among the characteristics that distinguish him from other species is an ability to fashion complex devices that magnify or extend his own capabilities. These devices which we call machines have governed the rate of man's material progress throughout history. The evolution of the machine can be attributed to its inherent *propagating power.* Existing tools make possible the manufacture of more advanced tools which in turn serve to accelerate the evolutionary process.

1.1 Man and the Machine

The first machine tools are believed to have been developed more than 2500 years ago. These early rotary devices allowed the artisan to produce intricate circular forms from wood and other hard materials. Although the early machines extended man's ability to produce relatively complex shapes, it was not until the fourteenth century that the first elementary precision machines were developed. The mechanical weight driven clock, proposed by Giovanni DeDondi (1318–1389), became the impetus for the development of the first true machine tools, such as the screw cutting lathe. The advent of the industrial revolution greatly accelerated the evolution of the machine tool, and the development of the steam engine by James Watt in the latter half of the eighteenth century precipitated requirements for new devices and precision in metal cutting tools.

In 1798 Eli Whitney signed a contract with the U.S. Government to produce 12,000 muskets and promised that the parts of each musket would be interchangeable. The commitment required manufacturing control which had never before been attempted. Whitney and his associates designed water powered machinery to perform the forging, boring, grinding, polishing, and rolling operations at his mill in New Haven, Connecticut. Although Whitney