Automatic Control System Technology

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Automatic Control System Technology

To the new generation of students
who will make the world an even better place in which to live.

Preface

Automatic Control Systems is one of the most exciting areas of study in electrical technology. It encompasses nearly all of the basic concepts learned in electrical and communication theory.

It is the complete logical development and analysis of dynamic systems. A slightly different approach is presented than what is normally used in control system analysis. It is based on the expansions of commonly known electronic and electrical phenomena such as resonance and damping, and relies heavily on a good understanding of the time constant. The electrical circuit elements are replaced later with their mechanical counterparts or equivalents, and the solution of electro-mechanical system performance is then completed.

This text does not follow the usual procedure for learning control system theory. I have found that the student of electrical technology can interpret the fundamental behavior of automatic control systems more easily when approached with electrical

symbols and concepts, than when it is introduced with the usual spring-mass system with its newtons, meters and kilograms.

The step by step development of simple closed-loop systems is included in this text. It permits the student to see the integration of the subsystems (or blocks) into a complete closed-loop system and establishes the criteria for determining the stability or instability, frequency response, and gain characteristics of the overall system.

This course is geared to the college student in electrical technology who has a working knowledge of complex algebra and trigonometry—an introduction to calculus is most desirable but not absolutely necessary. The use of an electronic calculator is encouraged. Numerous transformations from rectangular to polar coordinates are required; both the natural logarithms for solutions of the exponential function e^{-x} and logarithms to the base 10 for conversion to decibels are called for. Of course, the trigonometric functions are needed to establish various phase angles which are very important in the study of any closed-loop system. A few approximations and generalizations are used to help clarify some of the more complex mathematical relationships. This is done with very little error to the final system solutions.

Laplace transformations, in their simplest form, (the use of the s operator to obtain solutions of complex networks which are in terms of $j\omega$) are used as a tool, in much the same way we use logarithms to simplify the solution of multiple stage amplifiers for the overall gain and frequency response characteristics. The interrelationship between electrical and mechanical oscillatory systems is made quite clear by the use of these Laplace transforms. The transition from electrical system behavior to mechanical system behavior becomes simply a matter of interchanging complimentary components. For example, the "inductance" is replaced by a "mass", the "capacitor" by a "spring constant" and the "resistor" by a "damping device".

This text provides for a basic working knowledge of Automatic Control Systems. At the same time, it bridges the gap that usually exists in relating the similarities between electrical and mechanical system phenomena.

In this process, the importance of resonance in its many forms is emphasized. On the whole, students obtain a final review of

nearly all the basic concepts to which they have been exposed, integrated into an electro-mechanical model called an Automatic Control System.

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Contents

1

Basic Control System Concepts

1-1 INTRODUCTION

Throughout history, there have been human beings who desired to do work much beyond the limits of their meager physical capabilities. Animals helped them move large masses, the lever gave them a mechanical advantage, the wheel provided mobility, and later the motor, with its rotating shaft, was capable of performing very large blocks of work in a relatively short time. As motors became more powerful and refined, better systems were needed to control them and so emerged the field of *automatic control systems*.

Today, the field of automatic control systems encompasses nearly every facet of our society. In manufacturing, it appears in automated production and process control operations; in the food industry, it is used to automatically blend and package food; the military applications are numerous and extend from the aiming of guns to control of radar systems to automatic guidance of missile