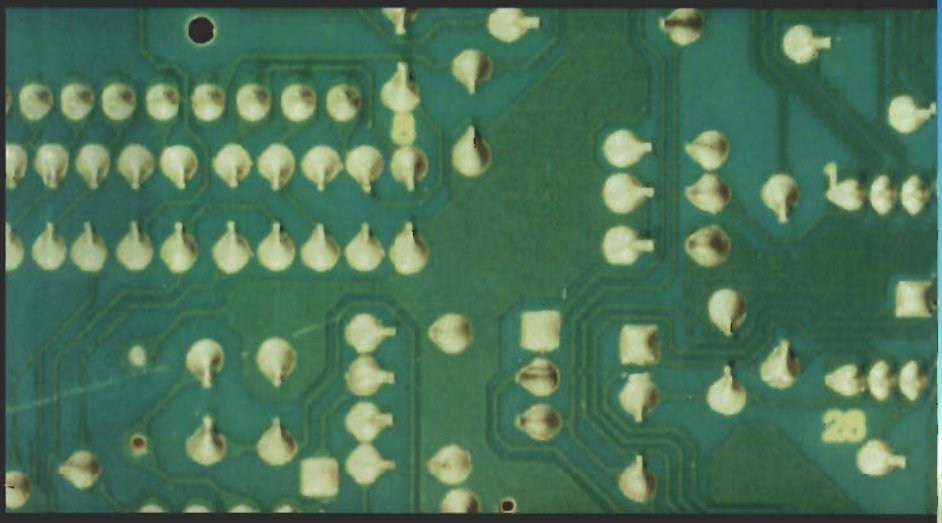
Power Electronics Handbook

THIRD EDITION



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Preface

There have been many developments in the field of power electronics since the publication of the second edition, almost five years ago. Devices have become bigger and better – bigger silicon die, and current and voltage ratings. However, semiconductor devices have also become smaller and better, integrated circuit devices, that is. And the marriage of low power integrated circuit tecnology and high power semiconductors has resulted in benefit to both fields.

The third edition of the *Power Electronics Handbook* reflects these changes. Although the basic design chapters have been largely unchanged, those on power and control components have been updated with the addition of sections on power devices such as the IGBT, and on the integration of low and high power devices, such as in smart power components The section on EMC has also been updated to include recent standards. A new section on the application of power components within automobiles has been added, since the use of power devices in this area has increased considerably.

The first chapter describes the processes used in the manufacture of power semiconductors and the construction and characteristics of the power semiconductors currently available. Chapters 2 to 5 cover devices which are used in conjunction with power semiconductors. Chapter 2 introduces the methods and components for removing heat generated within the power semiconductor, a vital requirement for effective operation. Chapter 3 describes low power devices, including those classified as smart power, which are used to control the operation of power semiconductors. Chapter 4 introduces the techniques and components necessary to minimise radio frequency interference generated by power electronic circuits; with the tightening of European and world regulations, this is clearly an important consideration. Chapter 5 describes components and circuits used to protect power components from malfunction, such as caused by overcurrent and overvoltage.

Chapters 6 to 13 provide detailed information on the arrangements and design of the various types of power semiconductor circuits. Because there are a large number of different types of such circuits, this whole field is first surveyed in Chapter 6, to give the student a unified picture.

Chapter 7 describes the most basic type of power circuit, that used for simple static switching. This is taken further in Chapter 8 to controlling the value of the a.c. line voltage. Chapter 9 extends the voltage control concept

to include rectification, so taht the a.c. is controlled to give a variable d.c. voltage.

Although similar in concept to a.c. line control and rectification, the next chapter describes a completely different application, the use of power electronics to vary the frequency of an a.c. supply without first going through d.c. These are also referred to as cycloconverters.

Chapters 11, 12 and 13 are related, since in these the power semiconductors switches operate from a d.c. supply and need to be forced commutated. Chapter 11 classifies the various commutation systems which are popularly used, and Chapters 12 and 13 describe two prime application areas, those of voltage control and of frequency changing.

Finally Chapter 14 describes some of the most common applications of power semiconductor components and circuits, introduced in earlier chapters of the book. This includes power supplies, electrical machine control, heating and lighting, and automobile control applications.

I started my career as a power electronic engineer at just about the time that the first thyristors were becoming commercially available. From then on I have continued to learn daily, as new developments have been made and new material published. I am grateful to the many authors who have enriched the technical press with their writings and so made this possible. To them, and to the many other power electronic engineers, who have worked to extend our knowledge in this valuable area, this book is gratefully dedicated.

Fraidoon Mazda
Bishop's Stortford
September 1997

Part 1

Components

Chapter 1

Power semiconductor devices

1.1 Introduction

1.1.1 Historical development

The field of power electronics is not new. The post- and pre-war periods, from about 1930 to 1950, saw extensive application of power electronics, based primarily on the mercury arc rectifier and the gas-filled tube.

It was in December 1939 that William Shockley first noted the principle of a semiconductor which could be used for controlling electrical power. However, it was not until 23 December 1947, the official date for the invention of the transistor, that a simple point contact transistor was demonstrated by William Shockley, John Bardeen and Walter Brattain, to the executives of Bell Laboratories. It was at this point that semiconductor electronic technology was born.

Two other dates are important when tracking the development of power semiconductors. The integrated circuit was invented by Jack Kelby of Texas Instruments in 1958. Integrated circuits, especially microprocessors, are now used extensively to control power semiconductor devices. Finally, the thyristor, the workhorse of the power semiconductor field, was announced by General Electric in 1957. It was originally called the silicon-controlled rectifier (SCR), to differentiate it from the common silicon rectifier, and it was some time later that the name was changed to thyristor.

1.1.2 Applications

Power semiconductors are used in wide-ranging applications. The following gives only a representative sample.

(i) Industrial applications consist primarily of two areas, motor control and power supplies. The motors which are controlled vary from the very large, as used in steel mills, to the relatively smaller ones, such as in machine tools. Power supplies too come in many shapes and sizes, such as for battery charging, induction heating, electroplating and welding.

(ii) Consumer applications cover many different areas in the home, such as audio amplifiers; heat controls; light dimmers; motor control for food mixers and hand power tools; and security systems.