MANUAL FOR INTEGRATED CIRCUIT USERS

John D. Lenk

MANUAL FOR INTEGRATED CIRCUIT USERS

John D. Lenk

Consulting Technical Writer

Reston Publishing Company, Inc.

A Prentice-Hall Company

Reston, Virginia

© 1973 by
Reston Publishing Company, Inc., A Prentice-Hall Company
P.O. Box 547
Reston, Virginia 22090

All rights reserved. No part of this book may be reproduced in any way, or by any means, without permission in writing from the publisher.

10 9 8 7 6 5 4

ISBN: 0-87909-482-6

Library of Congress Catalog Card Number: 72-96757
Printed in the United States of America.

PREFACE

As the title implies, this handbook is written for integrated circuit (IC) *users*, rather than for designers of integrated circuits. The book is, therefore, written on the basis of using existing, commercial integrated circuits to solve design and application problems. Typical users include design specialists who want to integrate electronic units and systems, or technicians who must service equipment containing ICs. Other groups that can make good use of this approach to integrated circuits are the experimenters and hobbyists.

There are two very common, although not necessarily accurate, concepts concerning ICs. First, it is assumed that the basic approach to IC design involves stating design parameters and requirements for a particular circuit to an IC manufacturer, and then having them fabricate an IC to meet these exact requirements. While this approach is satisfactory for some highly specialized circuits, and particularly where cost is no factor (such as the aerospace industry where the government is footing the bill), the approach may generally be wasteful and often unnecessary. On the other hand, it is often assumed that existing commercial ICs are limited in application; that such ICs are designed with only one or two uses in view.

There is a middle ground. Except for certain very special circuits, there are a number of commercial ICs that can be adapted to meet most circuit requirements. Also, new IC modules are being developed by various manufacturers. Likewise, although most off-the-shelf ICs are manufactured with certain specific uses in mind, these ICs are certainly not limited to only those uses.

Thus, the approach found in this handbook serves a two-fold purpose: (1) to acquaint the readers with ICs, in general, so that the users can select commercial units to meet their particular circuit requirements, and (2) to show readers the many other uses for existing ICs, not found on the manufacturer's data sheet.

This handbook assumes that the reader is already familiar with basic electronics, including solid-state, but has little or no knowledge of ICs. For this reason, Chapter 1 provides an introduction to ICs. Such topics as the how and why of IC fabrication techniques, a comparison of IC to discrete component circuits, a description of the basic physical types, and circuit types, found in commercial ICs, as well as some basic design considerations are covered.

With basics out of the way, Chapter 2 discusses practical considerations for ICs. No matter what IC is used, it must be mounted (both in breadboard form for design, and in final production form), leads must be soldered and unsoldered, power must be applied, and heat sinks may be required. These subjects are described in detail.

As the reader will soon find out, there are two basic IC types: linear and digital. Linear ICs are discussed in Chapters 3 through 5. Digital ICs are covered in Chapter 6. Considerable emphasis is placed on interpreting manufacturer's datasheets. For example, in Chapter 3, a typical IC datasheet is analyzed, characteristic by characteristic.

Often, experimenters must work with ICs on which complete data is not available. Under these circumstances, it is necessary to test the IC under simulated operating conditions. For this reason, detailed test data is included in Chapter 7.

With any IC, it is possible to apply certain approximations or rules-of-thumb for the selection of external component values. These rules can then be stated in basic equations, requiring only simple arithmetic for the solutions. This book starts with rules-of-thumb for the selection of external components on a trial-value basis, assuming a specified goal and a given set of conditions. The handbook concentrates on simple, practical approaches to IC use, not on IC analysis. Theory is kept to a minimum.

The values of external components used with ICs depend upon IC characteristics, available power sources, the desired performance (voltage amplification, stability, etc.) and existing circuit conditions (input, output impedances, input signal amplitude, etc.) The IC characteristics are to be found in the manufacturer's data. The overall circuit characteristics can then be determined, based on a reasonable expectation of the IC characteristics. Often, the final circuit is a result of many tradeoffs between desired performance and available characteristics. This handbook discusses the problem of tradeoffs from a simplified, practical standpoint.

Since the book does not require advanced math or theoretical study, it is ideal for the experimenter. On the other hand, the book is suited to schools where the basic teaching approach is circuit analysis, and a great desire exists for practical design.

试读结束，需要全本PDF请购买 www.ertongbook.com

The author has received much help from many organizations and individuals prominent in the field of integrated circuits. He wishes to thank them all.

The author also wishes to express his appreciation to Mr. Joseph A. Labok of Los Angeles Valley College for his help and encouragement.

John D. Lenk

CONTENTS

1. INTRODUCTION TO INTEGRATED CIRCUITS

Typically, an *integrated circuit*, or *IC*, consists of transistors, resistors, and diodes etched into a semiconductor material. The material is usually silicon, and is finally sold or used in the form of a "chip." Since all of the components are fabricated on the same chip, construction of an IC is called "monolithic." All of the devices are interconnected (by techniques similar to those used in printed circuit boards) to perform a definite function or operation. Thus, the IC concept is one of a complete (or nearly complete) circuit, rather than a group of related semiconductor devices.

To make the IC package an operable unit, it must be connected to a power source, an input, and an output. In most cases, the output must also be connected to external components such as capacitors and coils, since it is not practical to combine these relatively large parts on the very tiny semiconductor chip.

1-1. PACKAGING INTEGRATED CIRCUITS

In theory, an integrated circuit semiconductor chip could be connected directly to the power source, input, etc. However, this is not practical because of the very small size of the chip. IC chips are almost always microminiature. Instead of direct connection, the chip is mounted in a suitable container and connected to the external circuit through leads on the container.

There are three basic IC packages: the *transistor package*, the *flat-pack*, and the *dual-in-line package*. Some typical examples of these are shown in Fig. 1-1.

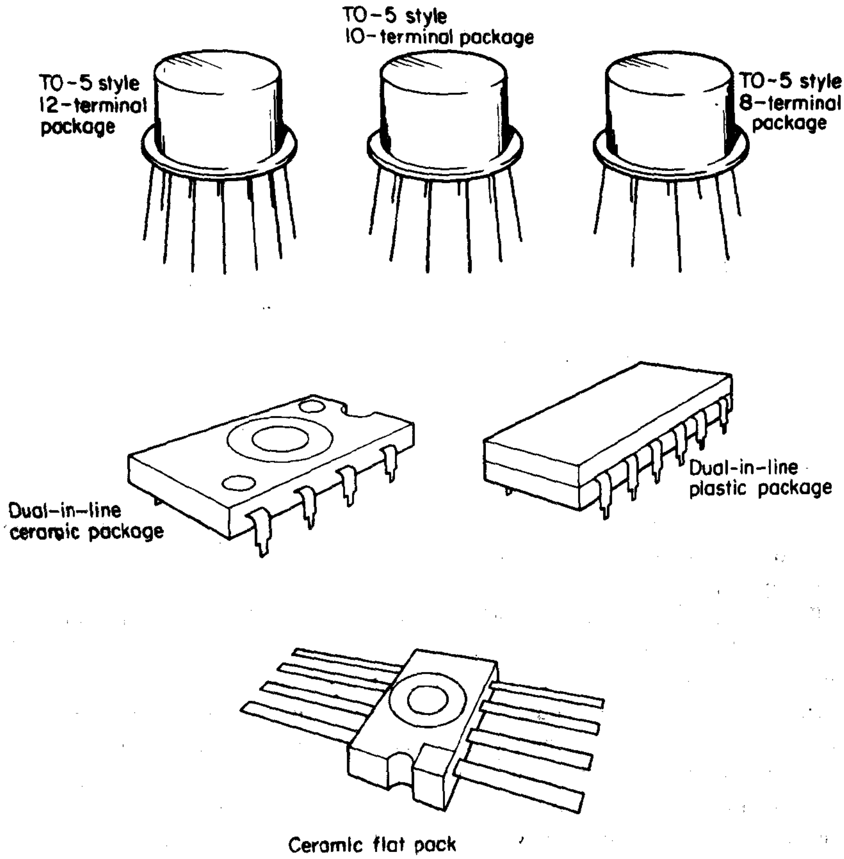


FIG. 1-1. Typical IC packages.

In the transistor package, the chip is mounted inside a transistor case such as a TO-5 case. Instead of the usual three leads found on a transistor case (emitter, collector, and base), there are 8, 10, 12, or more leads to accommodate the various power source and input/output connections required in a complete circuit.

In the flat-pack, the chip is encapsulated in a rectangular case with terminal leads extending through the sides and ends.

In the dual-in-line package (*DIP*), the chip is encapsulated in a rectangular case longer than the flat-pack. In general, the DIP has replaced the flat-pack for most applications.

Although there has been some attempt at standardization for IC terminal connections, the various manufacturers still use their own systems. It is

试读结束，需要全本PDF请购买 www.ertongbook.com

therefore necessary to consult the data sheet for the particular IC when making connections from an external circuit.

1-2. INTERNAL CONSTRUCTION OF INTEGRATED CIRCUITS

There are many methods for fabrication of the semiconductor chip of an IC, and new methods are being developed constantly. Because of the many methods and because we are primarily interested in using existing IC units we will not discuss all of the methods. Instead, we will describe one popular technique that is similar to the method used for fabrication of *silicon planar transistors*.

As shown in Fig. 1-2, the starting material for a planar transistor is a uniform single crystal of *N*-type silicon. (*P*-type silicon could also have been used for the starting material.)

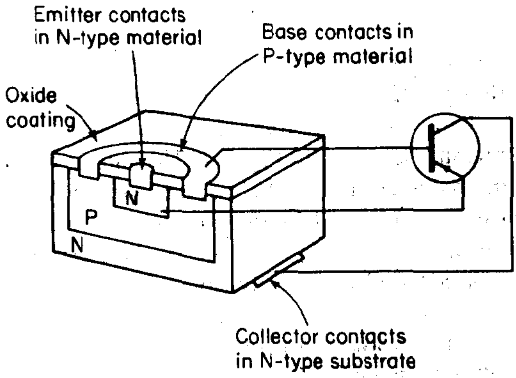
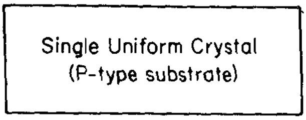


FIG. 1-2. Basic planar transistor.

The collector of the planar transistor is formed by the *wafer* (or *substrate*) of *N*-type silicon, which has been *passivated* (coated) with an oxide layer. A circular trench is etched out of the oxide. The trench is filled with a *P*-type crystal by a diffusion process requiring precise time and temperature control. The *P*-type material forms the transistor base element. Another disc-shaped area is etched at the center and filled (by diffusion) with an *N*-type crystal, which forms the transistor emitter. The result is an *NPN* transistor. Metalized contacts are attached to the three elements. The oxide layer prevents shorts between the metalized contacts and protects the emitter-base and collector-base from contamination.

A single transistor is shown in Fig. 1-2. The same basic process is used to fabricate many electrically-isolated transistors on a single silicon substrate. The first step is to diffuse two (or more) regions of similar crystal-line material into a substrate of dissimilar material, as shown in Fig. 1-3. Here, two *N*-



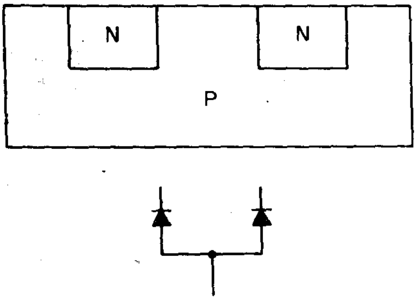


FIG. 1-3. Diffusion of N-type areas into P-type substrate to produce two diodes with common anodes and isolated cathodes.

type regions are diffused into a P-type substrate. Without further processing, this would result in two diodes with common anodes, but isolated cathodes.

Transistors are formed by diffusion of additional N-type and P-type regions, as shown in Fig. 1-4. The silicon wafer is then coated with an insulating oxide layer, and the oxide is opened (etched) selectively to permit metalized contacts and interconnections between elements (and between transistors), as required. With the contact arrangement shown in Fig. 1-5, two separate and electrically-isolated NPN transistors are formed in a P-type substrate.

When resistors are required in the integrated circuit, the N-type emitter diffusion is omitted, and two contacts are made to a P-type region (formed concurrently with the transistor base diffusion), as shown in Fig. 1-6. Here, an NPN transistor with a resistance connected to the emitter is integrated in a P-type substrate.

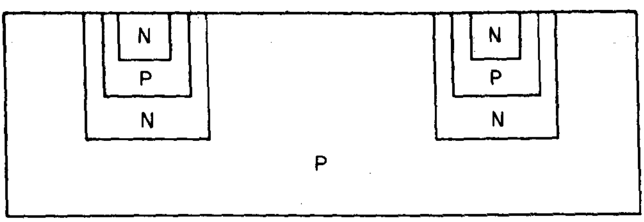


FIG. 1-4. Diffusion of P-type and N-type materials into a P-type substrate to form two transistors.

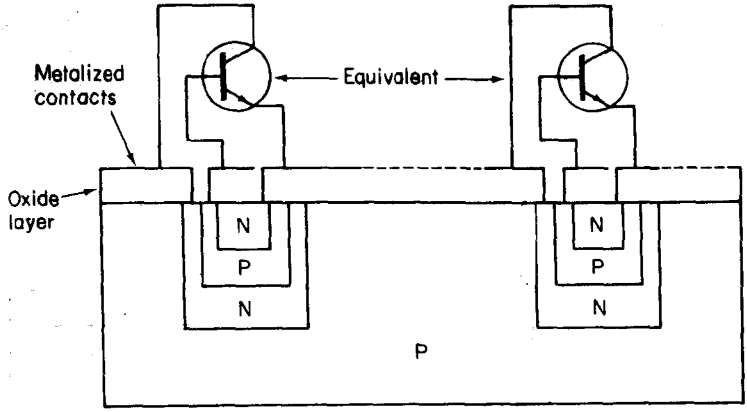


FIG. 1-5. Addition of metalized contacts to transistor elements formed in P-type semiconductor chip.

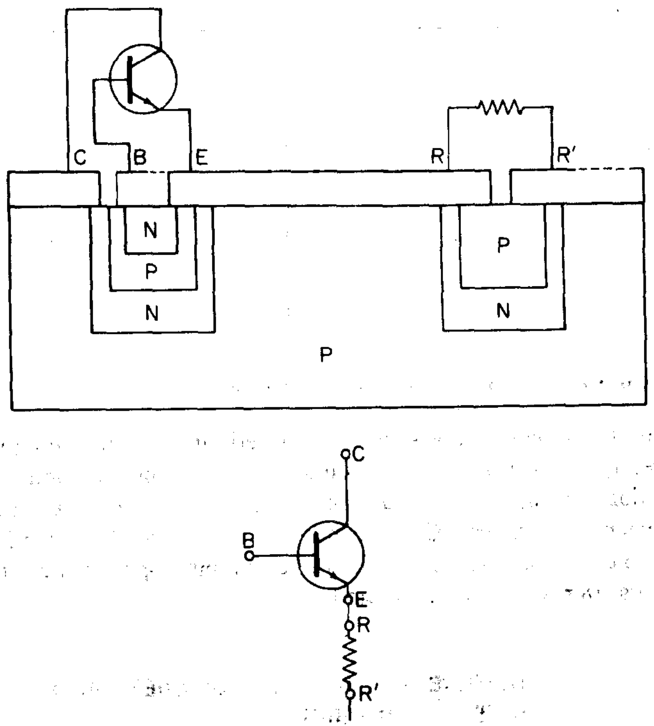


FIG. 1-6. Connection of contacts to P-type region to form integrated transistor and resistor.

When capacitors are required in the integrated circuit, the oxide itself is used as a dielectric, as shown in Fig. 1-7. Here, an *NPN* transistor with a capacitance connected to the emitter is integrated in a *P*-type substrate.

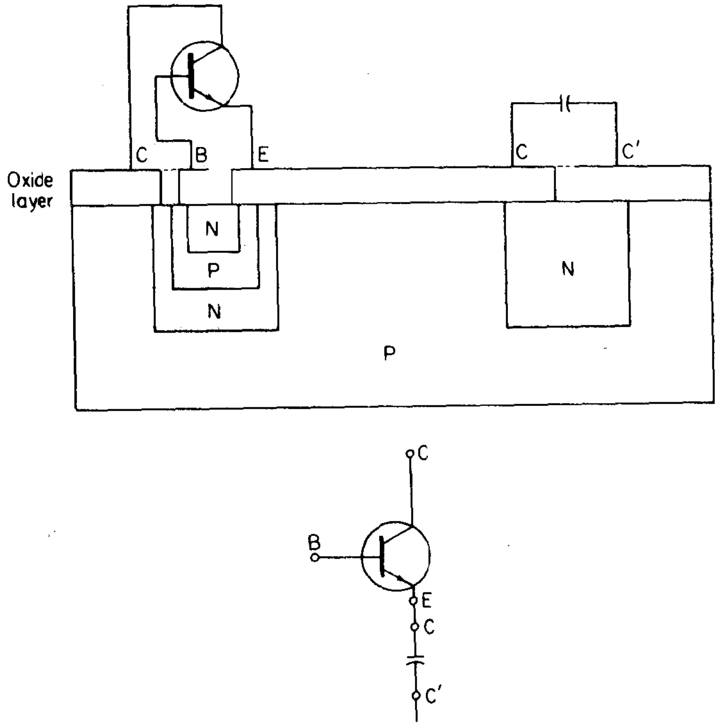


FIG. 1-7. Use of oxide as a dielectric to form integrated capacitor.

Figure 1-8 shows a very simple integrated circuit with a combination of the three types of elements on a single chip. It is not uncommon to have several dozen components on a single chip. Figure 1-9 shows the physical arrangement of a typical IC semiconductor chip. The IC shown in Fig. 1-9 is a complete voltage regulator circuit containing approximately two dozen transistors, 18 resistors, and ten diodes.

1-3. DIFFERENCES BETWEEN DISCRETE AND INTEGRATED CIRCUITS

Although the basic circuits used in ICs are similar to those of discrete transistors, there are certain differences. For example, inductances (coils) are never found as part of an IC. It is impossible to form a useful inductance on a material that contains transistors and resistors. Likewise,

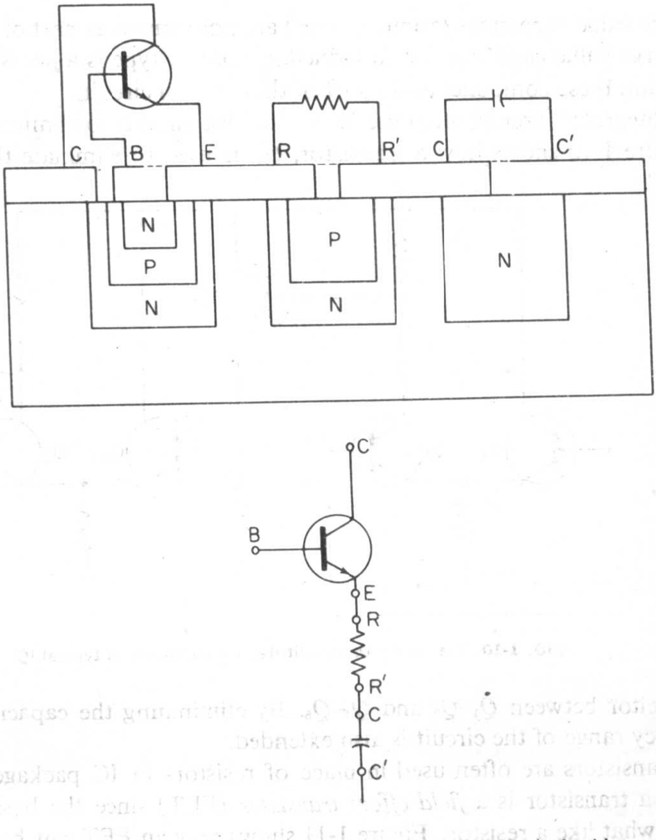


FIG. 1-8. Simple IC with three basic elements on a single chip.

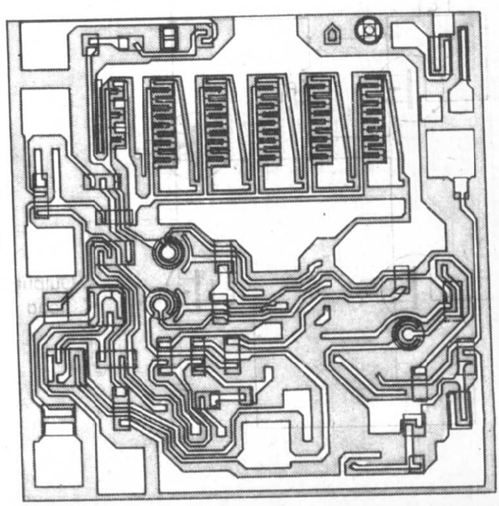


FIG. 1-9. Physical arrangement of typical IC semiconductor chip.

large value capacitors (about 100 pF) are not formed as part of an IC. When a large value capacitor, or an inductance of any type is a necessary part of a circuit, these components are part of the external circuit.

Integrated circuits often use direct-coupled circuits to eliminate capacitors. Figure 1-10 shows how a transistor, Q_3, is used to eliminate the need for a

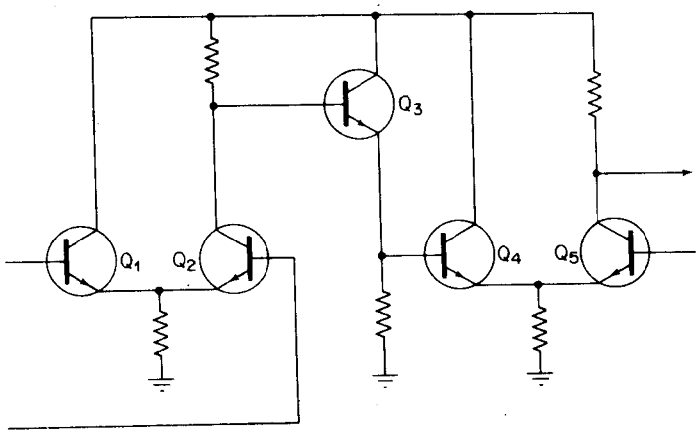


FIG. 1-10. Transistor Q_3 substitutes for capacitor in typical IC.

capacitor between Q_1–Q_2 and Q_4–Q_5. By eliminating the capacitor, the frequency range of the circuit is also extended.

Transistors are often used in place of resistors in IC packages. Usually, such a transistor is a *field effect transistor* (FET) since the basic FET acts somewhat like a resistor. Figure 1-11 shows how an FET can be substituted

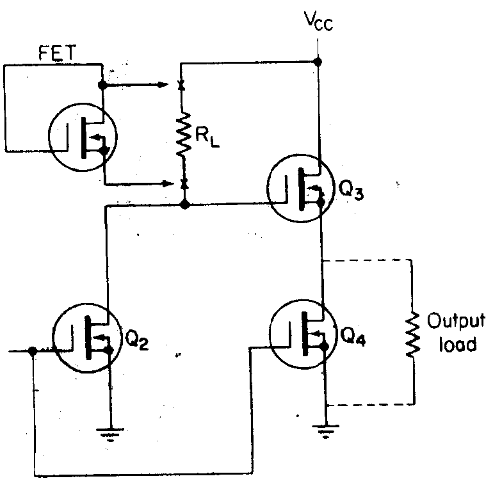


FIG. 1-11. How a FET can be substituted for a resistor in an IC.

试读结束，需要全本PDF请购买 www.ertongbook.com