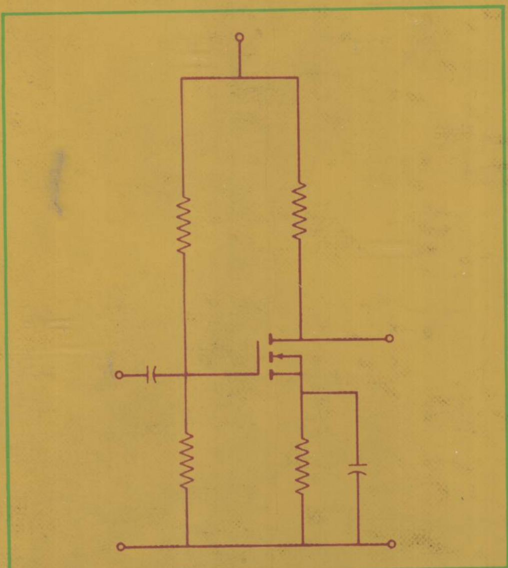
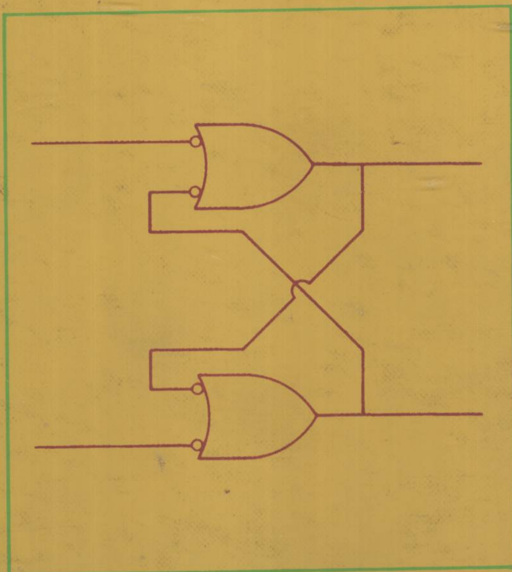
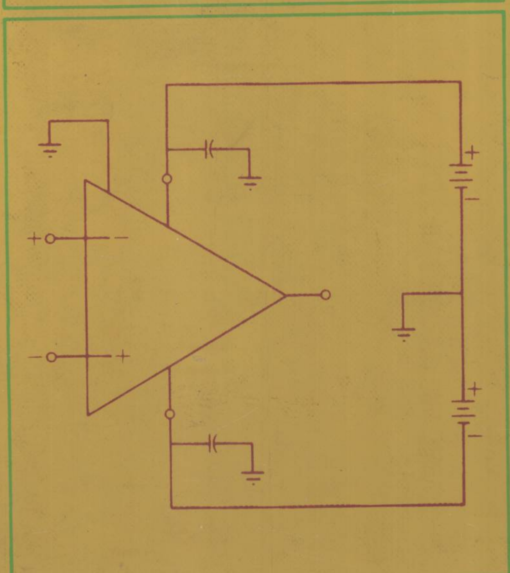
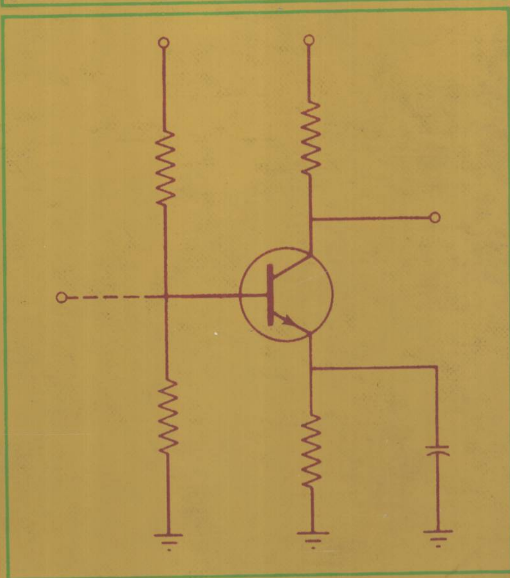
MARLIN P. RISTENBATT

SEMICONDUCTOR CIRCUITS

Linear and Digital

TN792
R2

7960986

MARLIN P. RISTENBATT

Research Engineer
University of Michigan

SEMICONDUCTOR CIRCUITS: Linear and Digital

E7960986

Prentice-Hall, Inc.
Englewood Cliffs, New Jersey

Library of Congress Cataloging in Publication Data

RISTENBATT, MARLIN P.
Semiconductor circuits.

1. Transistor circuits. 2. Digital electronics.
3. Integrated circuits. I. Title.
TK7871.9.R57 621.3815'3'042 74-19006
ISBN 0-13-806158-0

Formerly published under title TRANSISTOR PHYSICS AND CIRCUITS, 2nd ed.

© 1975 by Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

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

10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

PRENTICE-HALL INTERNATIONAL, INC., *London*
PRENTICE-HALL OF AUSTRALIA, PTY. LTD., *Sydney*
PRENTICE-HALL OF CANADA, LTD., *Toronto*
PRENTICE-HALL OF INDIA PRIVATE LIMITED, *New Delhi*
PRENTICE-HALL OF JAPAN, INC., *Tokyo*

SEMICONDUCTOR CIRCUITS: Linear and Digital

PREFACE

This third edition is thoroughly revised to account for the vastly increased importance of digital circuits, increased use of integrated circuit implementation of both linear and digital circuits, and the importance of MOS field-effect transistors. The objective has been retained: to provide a systematic description of the basic electronic devices and their circuit properties. Whereas prior editions emphasized discrete circuits, this edition reduces the discrete material and includes the description and application of linear and digital integrated circuits. Operational amplifiers are emphasized in the linear integrated circuit material. The digital material describes logic gates and memory elements (flip-flops).

The importance of semiconductors, applied either in discrete form or in large integrated circuits, cannot be exaggerated. Semiconductor devices have almost completely replaced the vacuum tube (except in certain specialized applications) and have spawned new generations of computers and control equipment. The "smartness" and sophistication of all of man's products continues to increase due to the increasing cost-effectiveness of integrated-circuit implementation of semiconductor circuits.

This book treats the keystone issues which underlie any activity with electronic circuits. The material is built step-by-step so as to afford easier learning of somewhat difficult material. Adequate explanation accompanies each step, so that the reader can easily grasp and remember the rationale in each area. This systematic treatment of keystone issues has been found to facilitate easier learning and retention of the electronic principles. Hence the principles treated here remain valid and valuable even as the transistor or

试读结束：需要全本请在线购买： www.ertongbook.com

integrated circuit itself is changed and improved, so that the material here should be valuable to the reader for many years. With this treatment, the reader comes to understand the reason for the particular analysis method in the given area, and lays the groundwork for further specialized knowledge. Treatment of this basic material is most sensible, it is felt, for either the classroom or self-study situation. This book contains that material which should logically be mastered before using handbooks, manufacturers' application notes, and specification sheets.

The level of the material here is that commonly associated with electronic technology. A prior course in basic electricity is assumed; an Appendix review is provided for those who can profit from it. The mathematics used for describing the performance of semiconductor circuits emphasizes algebra; a prior calculus course is not required.

The transistor and integrated circuit models employ parameters which are given universally by the manufacturer. Thus *h*-parameters are used for the bipolar transistor small-signal equivalent circuit, while *y*-parameters are used for the field-effect transistors. Throughout this book an effort is made to describe the rationale behind all of the major device parameters, for both discrete and integrated units.

This book is intended to be applicable wherever electronic technology is required. It should serve directly as a source of electronic principles for technicians and engineering students who will continue into instrumentation and circuit design. The level and (nondetailed) application-oriented material here should make this book a candidate for a wide range of electronic technology courses or programs including adult courses. Relative emphasis should be placed on that material deemed most important for the particular instructional goals. Often manufacturers' application notes would provide useful supplements to the basic material here.

Chapters 2 and 3 develop an explanation of the physical operation of bipolar and (MOS) field-effect transistors from first principles. Semiconductors are first explained and then applied to the transistors. Chapter 4 develops the graphical description and the *ac* equivalent circuit of the bipolar and MOS transistor.

Chapter 5 describes the *dc* bias circuits and equations for a transistor stage, and Chapter 6 develops the important terminal properties of small-signal bipolar and MOS amplifiers. Power amplifier aspects and circuits are described in Chapter 7.

The frequency response and feedback chapters both describe important discrete aspects, and prepare for applications of the integrated circuit operational amplifiers. Chapter 10 (new with this edition) describes linear integrated circuits, emphasizing the operational amplifier and its application. Noise considerations (Chapter 11) complete the coverage of linear transistors and integrated circuits.

Chapters 13 and 14, also new with this edition, describe digital discrete and integrated circuits. Chapter 13 describes the basic transistor switch and logic principles, along with the major bipolar logic (TTL) and the MOS logic implementations. The TTL and the MOS are the major alternatives for digital circuits. Chapter 14 describes the various bipolar and MOS flip-flops, and their application in digital circuits. It is felt that this is the proper fundamental material for the constantly improving bipolar and MOS digital integrated circuits.

Three Appendixes are provided for convenience and flexability. Appendix A briefly reviews those basic electricity principles which are used in this book. Appendix B describes a simple systematic way to solve simultaneous equations by the use of determinants. Many of the circuit equations involve solving two simultaneous equations.

With this treatment it is believed that a clear, practical approach to the subject of discrete (transistor) and integrated circuits has been achieved.

I would like to acknowledge the advice and counsel of K. Metzger in the digital topics of Chapters 12 and 13, and the general discussions of J. L. Daws.

M. P. R.
Ann Arbor, Michigan

LIST OF SYMBOLS

A_i Amplifier current gain.
α Short circuit, common-base current gain; refers to either *dc* or *ac* value.
A_p Power gain.
A_v *ac* voltage gain from transistor input terminal to output terminal.
A'_v *ac* voltage gain from source voltage, V_s, to transistor output terminal.
A_V Closed-loop voltage gain from input to output when *dc* is included (as in op-amps).
A_{VOL} Open-loop voltage gain of operational amplifier (*dc* is included).
B Bandwidth.
β Short circuit, common-emitter current gain; refers to either *dc* or *ac* value.
B_C Capacitive susceptance.
B_L Inductive susceptance.
BV_{CBO} Breakdown voltage, collector to base, emitter open.
BV_{CEO} Breakdown voltage, collector to emitter, base open.
BV_{EBO} Breakdown voltage, emitter to base, collector open.
BW Bandwidth in cycles per second.
C Capacitance.
$C_{b'c}$ Bipolar, capacitance between internal base and collector.
$C_{b'e}$ Bipolar, capacitance between internal base and emitter.
C_C Coupling capacitor.
C_E Bipolar, emitter bypass capacitor.
$C_{gd} = C_{rss}$ FET, capacitance between gate and drain.
C_{gs} FET, capacitance between gate and source.
C_{iss} FET input capacitance $= C_{gs} + C_{gd}$.
C_{ob} Bipolar, common-base collector capacitance.
C_{oe} Bipolar, common-emitter collector capacitance.
C_{oss} FET output capacitance $= C_{gd} + C_{ds}$.
C_S FET, source bypass capacitor.
dB $= 10 \log_{10} \frac{P_0}{P_i} = 20 \log_{10} \frac{V_o}{V_i}$.
Δ Small change in.
Δ^h Determinant value of *h*-parameters.
E Electric field in volts per centimeter; also, sometimes source voltage.
F Feedback ratio (current or voltage).
f_H Upper 3-dB frequency point.
f_{Hf} Upper 3-dB frequency with feedback.
$f_{hfb} = f_{\alpha b}$ Common-base, small-signal short-circuit forward-current gain cutoff frequency.
$f_{hfe} = f_{\alpha e}$ Common-emitter, small-signal short-circuit forward-current gain cutoff frequency.
f_L Lower 3-dB frequency point.
f_{LC} Lower 3-dB frequency due to coupling capacitor.
f_{LE} Lower 3-dB frequency point due to emitter bypass capacitor.
f_{Lf} Lower 3-dB frequency with feedback.

G Conductance.
γ Conductivity in mhos per centimeter.
$g_m = g_{fs}$ Mutual transconductance.
h Refers to hybrid parameters in general.
h_{11} General input resistance.
h_{12} General voltage feedback ratio.
h_{21} General forward current ratio.
h_{22} General output admittance.
h_{fb} Common-base, small-signal short-circuit forward-current transfer ratio.
h_{fc} Common-collector, small-signal short-circuit forward-current transfer ratio.
h_{fe} Common-emitter, small-signal short-circuit forward-current transfer ratio.
h_{FE} Common-emitter, static or *dc* value of forward-current transfer ratio.
h_{ib}, h_{ie}, h_{ic} (Common-base, common-emitter, common-collector) small-signal input impedance, output *ac* short-circuited.
h_{ob}, h_{oe}, h_{oc} (Common-base, common-emitter, common-collector) small-signal output admittance, input *ac* open-circuited.
h_{rb}, h_{re}, h_{rc} (Common-base, common-emitter, common-collector) small-signal, reverse voltage transfer ratio, input *ac* open-circuited.
Hz Abbreviation for "hertz," the frequency unit, cycles per second.
I Current (effective value of sine wave, or *dc* value).
$I_{CBO}(I_{CO})$ *Dc* collector current when collector junction is reverse-biased and emitter is open-circuited.
I_{CEO} *Dc* collector current with collector junction reverse-biased and base open-circuited.
I_{CES} *Dc* reverse collector current with base shorted to emitter.
I_{CEX} *Dc* reverse collector current with base junction reverse-biased.
i_e, i_b, i_c Instantaneous incremental current for emitter, base, and collector.
i_E, i_B, i_C Instantaneous total current for emitter, base, and collector.
I_e, I_b, I_c Rms or effective value of *ac* sine wave incremental currents for emitter, base, and collector.
I_E, I_B, I_C *Dc* or operating point currents for emitter, base, and collector.
J Current density in amperes per square centimeter.
k Boltzmann's constant $= 1.38 \times 10^{-23}$ joules/°Kelvin.
K $\frac{kT}{q} = 25$ mV at room temperature (290°Kelvin).
L Inductance.
MAG Maximum available gain.
NF Noise factor noise figure in decibels.
NF_0 Noise factor at 1000 Hz for a 1 Hz bandwidth.
pF Pico-farads, equal 1×10^{-12} farads.
P Power.
P_D Maximum permissible collector dissipation as a function of temperature T.
$P_{D_{max}}$ Maximum permissible dissipation at reference temperature (usually 25°C).
Q *Dc* operating point, or digital voltage output.
R Resistance.

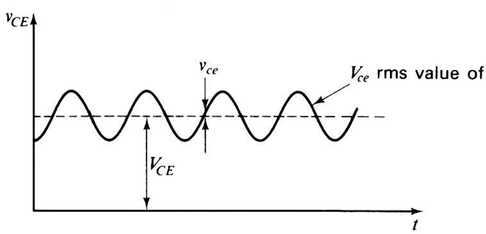
R_B Equivalent bias resistor ($R_1 \| R_2$).
$r_{b'}$ Bipolar, small-signal base bulk resistance.
$r_{b'c}$ Bipolar, small-signal resistance from internal base to collector.
$r_{b'e}$ Bipolar, small-signal resistance from internal base to emitter.
R_C Bipolar, external resistor in emitter lead.
R_D FET, external resistor in drain lead.
r_d Small-signal *ac* resistance of diode; $r_d \approx \dfrac{25}{I_E(\text{mA})}$ at room temperature.
r_D Static value of forward diode resistance.
r_E *Ac* (Unbypassed) resistance in emitter lead.
R_E Bipolar, bypassed external resistor in emitter lead.
R_F Feedback resistance.
R_i Input resistance at any stated amplifier terminals.
R_i' Input resistance of transistor itself (without bias resistors).
R_I Input resistor for operational amplifiers.
r_L *Ac* load in general (often $r_L = R_C \| R_L$ or $R_D \| R_L$).
R_L Load resistance.
R_o Output resistance at any stated amplifier terminals.
R_{o_1} $R_{C_1} \| R_{B_2}$ or $R_{D_1} \| R_{B_2}$.
R_S FET, external resistor in source lead.
R_1 Upper bias resistor.
R_2 Lower bias resistor.
$R_{\theta JA}$ The thermal resistance (steady state) from the semiconductor junction to the ambient.
$R_{\theta JC}$ The thermal resistance (steady state) from the semiconductor junction to the case.
S Stability factor for changes in I_{CBO}, V_{BE}, or h_{FE}.
T Temperature in degrees centigrade or degrees Kelvin.
T_r Reference temperature (usually 25°C).
T_1 Cycle time in triggered switching circuits.
V_{BB}, V_{EE}, V_{CC} Bipolar, *dc* supply voltages for base, emitter, and collector.
V_{BE} (For *npn*) base to emitter voltage (positive in active region).
V_{BET} Bipolar, V_{BE} threshold voltage where transistor goes from OFF to ON.
V_{CB} *Dc* collector to base voltage.
V_{CE} *Dc* collector to emitter voltage.
V_{DD}, V_{GG}, V_{SS} FET, *dc* supply voltages for drain, gate, and source.
V_{EB} (For *pnp*) emitter to base voltage (positive in active region).
v_e, v_b, v_c Instantaneous incremental voltages of emitter, base, and collector.
v_E, v_B, v_C Instantaneous total voltages of emitter, base, and collector.
V_e, V_b, V_c Effective or rms value of *ac* incremental voltages of emitter, base, and collector.
V_G, V_D, V_S Quiescent or *dc* voltages of gate, drain, and source.
V_g, V_d, V_s Effective or rms value of *ac* incremental voltages of gate, drain, and source.
v_G, v_D, v_S Instantaneous total voltages of gate, drain, and source.
v_g, v_d, v_s Instantaneous incremental voltages of gate, drain, and source.
V_i Rms, sine-wave *ac* input voltage.

v_i	Total *ac* input voltage.
v_I	Total input voltage when *dc* is included.
V_o	Rms, sine-wave *ac* output voltage.
v_o	Total *ac* output voltage.
v_O	Total output voltage when *dc* is included.
$\overline{v_n^2}$	Mean-square value of noise voltage.
V_s	Rms *ac* source voltage.
V_{th}	General threshold voltage.
X_C	Capacitive reactance.
X_L	Inductive reactance.
Y	Admittance.
Z	Impedance.
$\lvert Z \rvert$	Absolute magnitude of impedance.
Z_{in}	Input impedance of operational amplifier.

Summary of Bipolar Nomenclature	Voltages	Currents
Instantaneous total values	v_{BE}, v_{CE}	i_B, i_E, i_C
Instantaneous signal component	v_{be}, v_{ce}	i_b, i_e, i_c
Quiescent or *dc*	V_{BE}, V_{CE}	I_B, I_E, I_C
Effective (rms) value of signal	V_{be}, V_{ce}	I_b, I_e, I_c
Supply voltages (magnitude)	V_{BB}, V_{CC}	

Summary of FET Nomeclature	Voltages	Currents
Instantaneous total values	v_{GS}, v_{DS}	i_D, i_S
Instantaneous signal component	v_{gs}, v_{ds}	i_d, i_s
Quiescent or *dc*	V_{GS}, V_{DS}	I_D, I_S
Effective (rms) value of signal	V_{gs}, V_{ds}	I_d, I_s
Supply voltages (magnitude)	V_{GG}, V_{DD}	

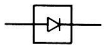
Example:



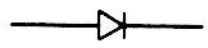
试读结束：需要全本请在线购买： www.ertongbook.com

Symbols

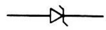
Diodes:



Ideal diode

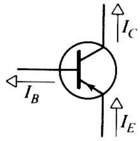


Semiconductor diode

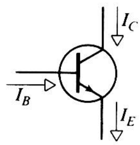


Zener diode

Bipolar transistors:



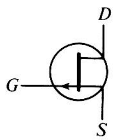
pnp



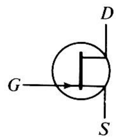
npn

Actual current directions

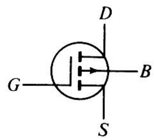
Field-effect transistors (FETS):



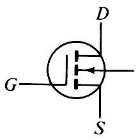
p-channel junction FET



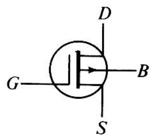
n-channel junction FET



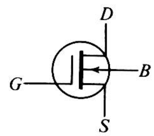
p-channel MOS (enhancement type)



n-channel MOS (enhancement type)



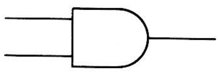
p-channel MOS (depletion type)



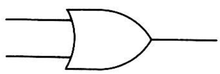
n-channel MOS (depletion type)

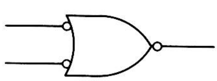
Logic:

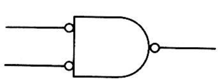
AND



OR







Positive logic convention

SEMICONDUCTOR
CIRCUITS:
Linear and Digital

7960986

CONTENTS

3

THE PHYSICAL ACTION IN TRANSISTORS 30

4

DIODES AND TRANSISTORS AS CIRCUIT ELEMENTS 51

5

BIAS CIRCUITS 83

6

SMALL-SIGNAL AMPLIFIERS 106

9

FEEDBACK PRINCIPLES 199

10

LINEAR INTEGRATED CIRCUITS 215

试读结束：需要全本请在线购买： www.ertongbook.com