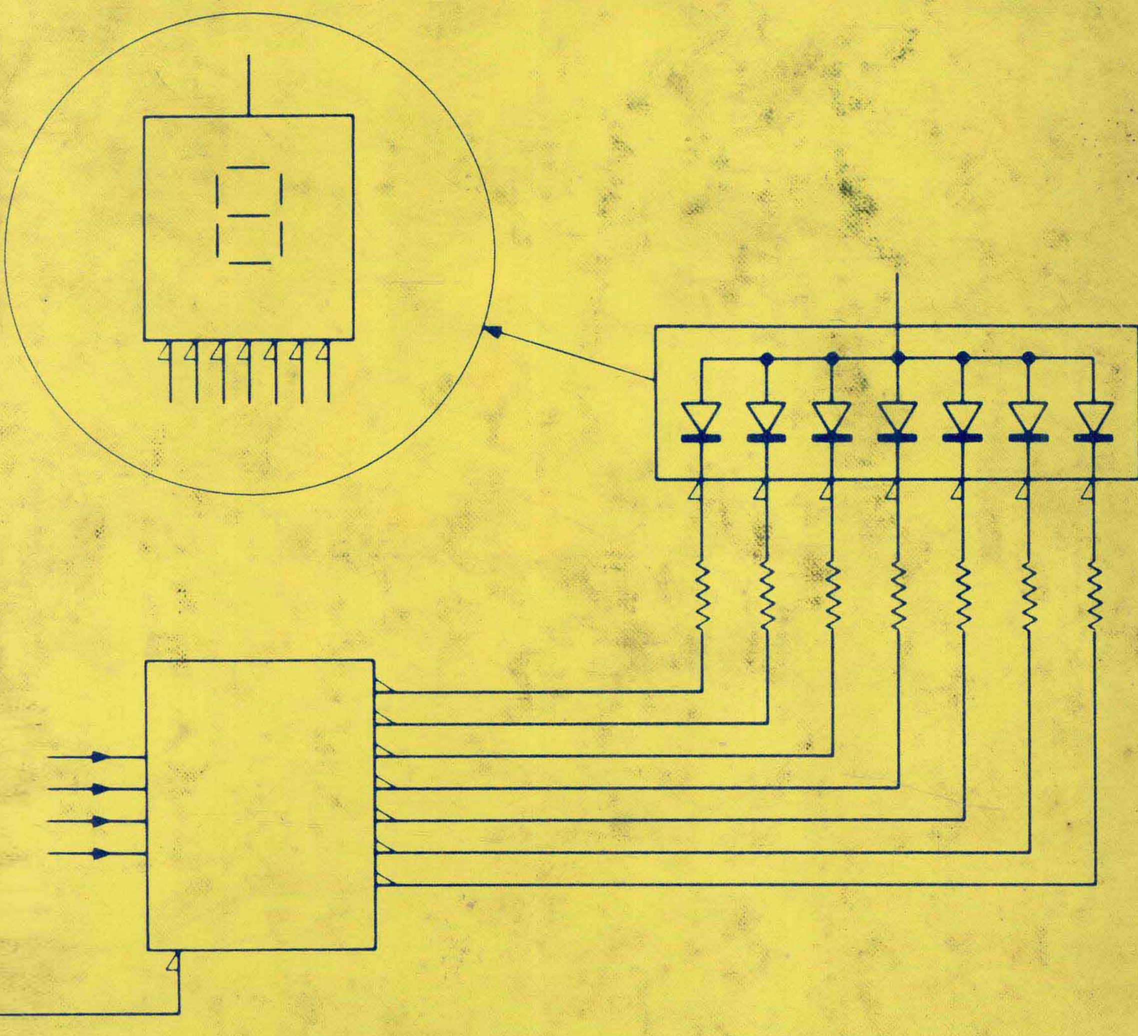
Digital Concepts Using Standard Integrated Circuits

Richard S. Sandige



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DIGITAL CONCEPTS USING STANDARD INTEGRATED CIRCUITS

FOR MOM AND DAD
Ruby and Elmer Sandige

PREFACE

The theme of this book is organization since I consider good organization the key to learning. This book is definitely different from almost any other book covering a first (introductory) course in digital IC devices. Small right triangles replace small circles (for positive logic) in practically all diagrams beginning with Chapter 5. This change was made to conform to the new ANSI (US), IEC (International) standard logic symbols for the polarity indicator system. I refer to this system as the *level indicator system* since the presence of a small right triangle indicates an active low level and its absence indicates an active high level. To utilize the level indicator system I introduce a new function called a *boolean level function* which greatly simplifies the implementation of output functions using NAND gates and NOR gates and also allows combinational logic circuits to be easily checked out on the bench. The negation indicator system (the system that uses small circles) is not ignored since I first introduce all basic logic gates in Chapter 4 using the negation indicator system. Teachers may think that they do not want to be bothered with a new system, but they may already have observed a gradual shift by other authors to incorporate the new standard symbols especially for flip-flops. The concepts presented in this text will give students a much better understanding of how to use digital ICs.

The specific organization of the text can be seen by observing the table of contents or by reading Section 1-2 presented in Chapter 1. The main purpose of this text is to provide a first course in digital IC devices that allows a student to walk from the lecture room into the laboratory and immediately use what was presented in the lecture. It is for this reason that Data-Book Information and Breadboarding (Chapter 2) is presented early.

Of course if you are teaching a first course without hands-on experience in the laboratory you may elect simply to ignore Chapter 2. Or if you are teaching a two-term course where hands-on experience is provided in the second term, you may elect to cover Chapters 2 and 7 later. In Chapters 2 to 8 I introduce combination logic circuits using small-scale integrated devices. In Chapters 9 to 12 combinational and sequential logic circuits using small- and medium-scale integration are introduced. In Chapter 13 a few special SSI, MSI, and LSI devices are introduced.

This text is written in a conversational style to be used in a lecture course; however, because of the large number of Review Exercises (approximately 715) keyed to each section, the text may also be used as a self-paced text. In this situation instructors may provide the student with all or part of the *Instructor's Manual.*

Some features of this digital-hardware-oriented text include the following:

1. New ANSI and IEC logic symbols for the polarity-indicator system are used.
2. The text is oriented toward student involvement in the laboratory.
3. A large number of example problems with complete solutions (approximately 170) are provided.
4. A very straightforward analysis and design procedure (the level method) is presented.
5. MSI devices such as data selectors and decoders are stressed.
6. Sequential logic circuits are described by a state-chart description which students can easily grasp.
7. Standard MSI counters principles and application are discussed in detail.
8. A well-organized method for designing and analyzing synchronous hard-wired controllers using a state-chart description and reduced K maps is stressed.
9. The 555 timer is presented in such a way that circuit operation can easily be understood by students.
10. Important concepts concerning semiconductor registers and memory used in microprocessor systems are emphasized.

The background necessary for a student to study this text successfully is a course in ac, dc circuits and preferably a course in electronic devices, although that is not essential. No prior knowledge of number systems or boolean algebra is necessary. The text is directed to anyone who wants to learn up-to-date digital electronics from scratch; however, if students are not familiar with a state-chart description an effort should be made to update them in this important area. The material in the text is more than adequate for a one-semester course. The text is supplemented with an Instructor's Manual, which contains the complete solution to all Review Exercises at the end of each chapter and a laboratory program keyed to the text. When a laboratory accompanies the course, I recommend students be required to obtain "The TTL Data Book for Design Engineers", 2d ed., by Texas Instruments Inc.

I am grateful to the many companies which supplied information in the form of pictures and practical circuit configurations: Hewlett-Packard, Texas Instruments, Inc., MITS, Inc., IMSAI Manufacturing Corp., Motorola Semiconductor Corp., National Semiconductor Corp., Teledyne Semiconductor, Signetics Corp., Analog Devices, and E&L Instruments, Inc.

I am indebted to Dr. Tom Rhyne and Dr. Philip Noe at Texas A&M University, for their many helpful comments during the writing of the manuscript. I am also indebted to Dr. Robert E. Swartwout at West Virginia University, who stressed good organization and helped shape some of my basic concepts. I would also like to acknowledge the encouragement provided by my department head, Dr. Everett R. Glazener. The one who deserves the most recognition, however, is my wife Edie, who turned my chicken scratch into a readable typed manuscript. My son Michael and daughter Heidi also helped by proofreading the manuscript.

Richard S. Sandige

List of Abbreviations

The following list is provided to aid the reader in identifying abbreviated words or expressions throughout the text.

A/D = analog to digital
ADDR = address
ALU = arithmetic logic unit
ANSI = American National Standards Institute
ASCII = American standard code for information interchange
AWG = American wire gauge
BCD = binary coded decimal
bit = binary digit
BJT = bipolar junction transistor
CE = chip enable
CK = clock
C-MOS = complementary metal-oxide semiconductor
CS = chip select
D/A = digital to analog
DIP = dual-in-line package
dis = discharge
DTL = diode-transistor logic
ECL = emitter-coupled logic
EN = enable
E-POS = expanded product of sums
EPROM = erasable programmable read-only memory
E-SOP = expanded sum of products

FF = flip-flop
GaAsP = gallium arsenide phosphide
GaP = gallium phosphide
GND = ground
H = high
Hex = six
HNIL = high-noise-immunity logic
HTL = high-threshold logic
ICs = integrated circuits or input conditions (depending on usage)
IEC = International Electrotechnical Commission
I^2L = integrated-injection logic
I/O = input output
K map = Karnaugh map
L = low
LED = light-emitting diode
LIS = level-indicator system
LSD = least significant digit
LSDT = longest signal-delay time
LSI = large-scale integration
LSB = least significant bit
m = minterm
max = maximum
μP = microprocessor
min = minimum
MOS = metal-oxide semiconductor
MOSFET = metal-oxide semiconductor field effect transistor
M-POS = minimum product of sums
MNR = a computer reduction program named from Dr. McKinney, Dr. Noe and Dr. Rhyne
MSB = most significant bit
MSD = most significant digit
MSI = medium-scale integration
M-SOP = minimum sum of products
MTL = merged-transistor logic
mod = modulus
M-XPOS = minimum exclusive product of sums
M-XSOP = minimum exclusive sum of products
NIS NL = negation-indicator system, negative logic
NIS PL = negation-indicator system, positive logic
N-MOS = N-channel metal oxide semiconductor
OC = open collector

OD = output disable
OE = open emitter
PC = package count
PLA = programmable logic array
P-MOS = P-channel metal oxide semiconductor
POS = product of sums
pot = potentiometer
PROM = programmable read-only memory
RAM = random-access memory
RF = radio frequency
ROM = read-only memory
RTL = resistor-transistor logic
sat = saturated
S1sC = signed 1s complement
S2sC = signed 2s complement
SM = signed magnitude
SOP = sum of products
SPDT = signal propagation-delay time
S-POS = simpler product of sums
S-R = set reset
S-SOP = simpler sum of products
SSI = small-scale integration
SW1 = switch 1
thresh = threshold
trig = trigger
TTL = transistor-transistor logic
VLSI = very large-scale integration
W/R = write read
XAND = exclusive AND
XNOR = exclusive NOR
XOR = exclusive OR
XS3 = excess three

CONTENTS

CHAPTER

ONE

INTRODUCTION

This chapter contains a brief introduction to the anatomy of digital systems and a preview of each chapter, explaining what it covers and why the material is important. Electronic circuits are generally classified according to how they process signals. When continuous signals are processed, the processing devices are called *analog devices*. In this text we are dealing with discrete signals, which are processed by *digital* or *logic devices*. Systems that contain mostly digital devices are called *digital systems*.

1-1 ANATOMY OF DIGITAL SYSTEMS

Figure 1-1 shows a basic block diagram of a digital system. Notice that it contains four major parts. Every digital system usually contains all these parts in one form or another, as we shall see.

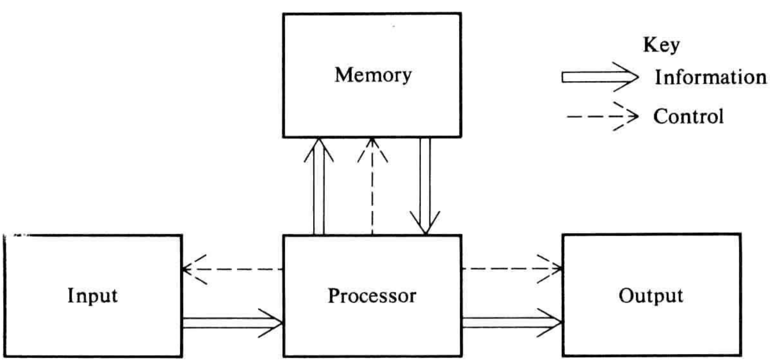


Figure 1-1 Basic block diagram of a digital system.

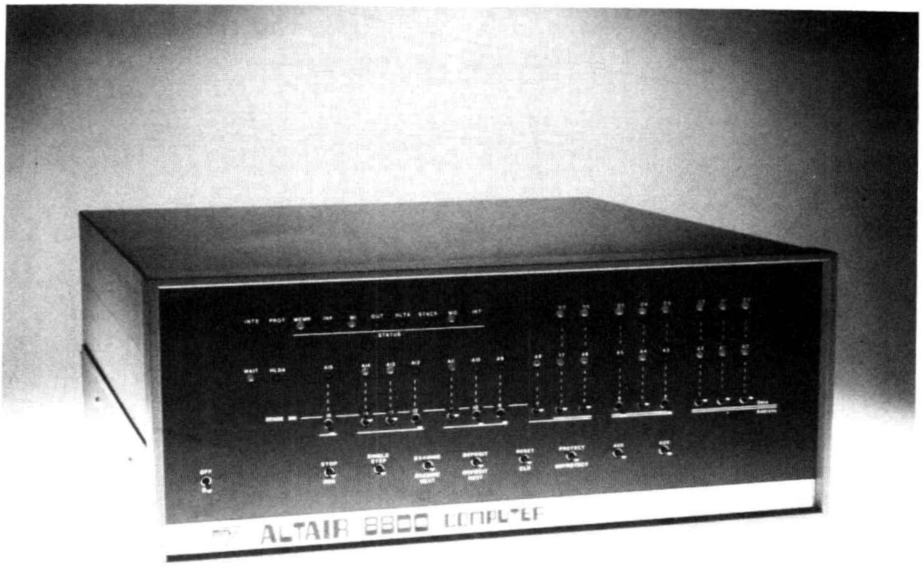
(a)

(b)

Figure 1-2 Hand-held calculators: *(a)* HP-21 *(Hewlett-Packard Company)*; *(b)* SR-51A *(Texas Instruments Incorporated).*

One of the most useful digital systems is a hand-held calculator. The calculators shown in Fig. 1-2 have a keyboard input, a light-emitting-diode (LED) output display, a read-only memory (ROM), and a calculator processor chip.

Other digital systems have a similar block diagram. The computers shown



(a)

(b)

Figure 1-3 Microprocessor-based computers: *(a)* Altair 8800 computer *(Micro Instrumentation & Telemetry Systems, Inc.)*; *(b)* IMSAI 8080 computer system *(IMSAI Manufacturing Corporation)*.