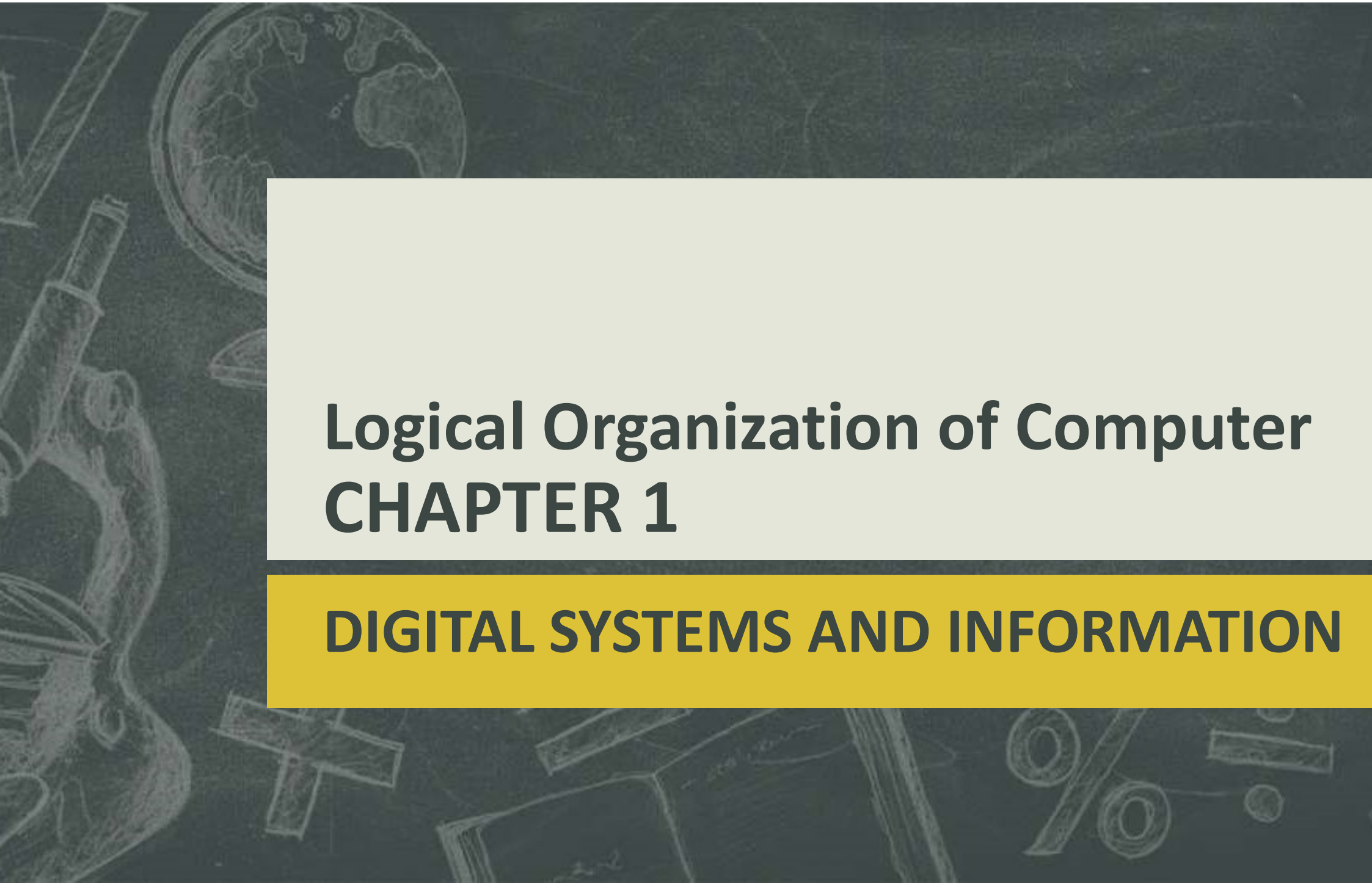


Logical Organization of Computer
CHAPTER 1

DIGITAL SYSTEMS AND INFORMATION

INFORMATION REPRESENTATION

he information represents a broad range of phenomena from
hysical and man-made world.

he physical world is characterized by parameters such as wei
emperature, pressure, velocity, flow, and sound intensity
equency.

lost physical parameters are continuous, typically capable
aking on all possible values over a defined range.

n contrast, in the man-made world, parameters can be discret
ature, such as business records using words, quantities,
urrencies.

INFORMATION REPRESENTATION

n general, information systems must be able to represent b
ontinuous and discrete information.

Ve refer to such a continuous voltage as an analog signal
iscrete voltage as digital signal.

he signals in most present-day electronic digital systems use
wo discrete values and are therefore said to be binary.

he two discrete values used are often called 0 and 1, the di
or the binary number system.

INFORMATION REPRESENTATION

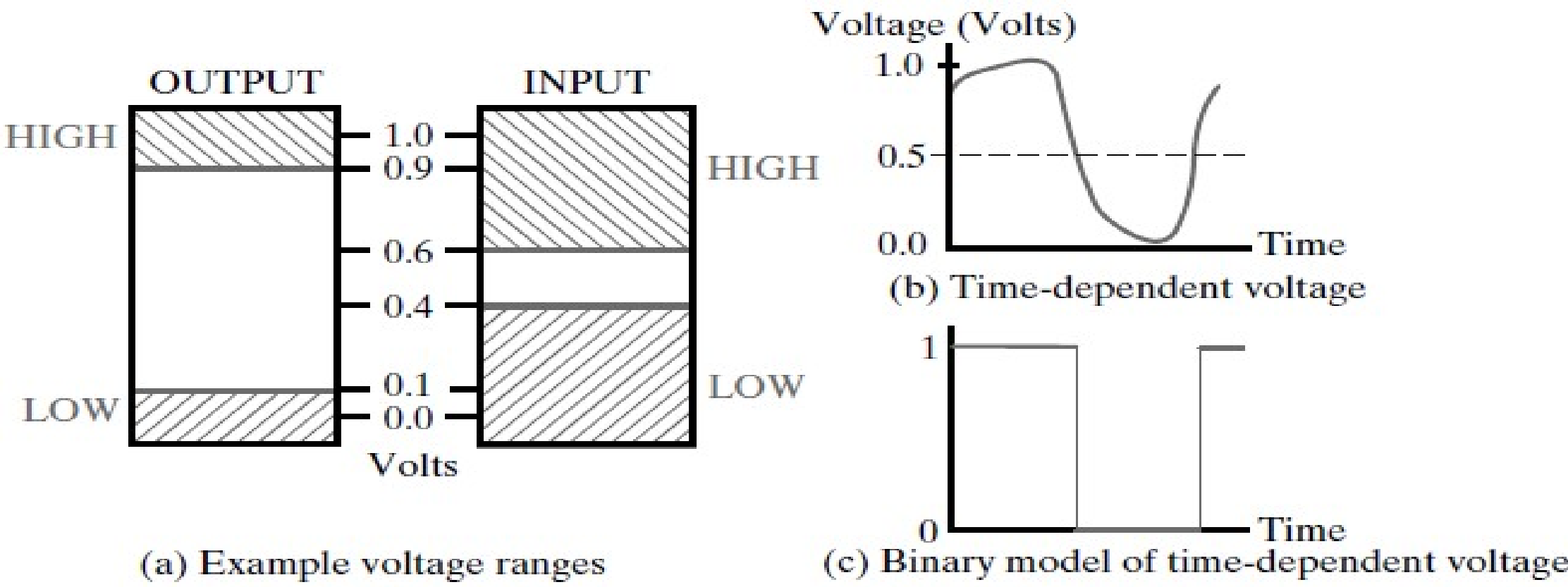


FIGURE 1
Examples of Voltage Ranges and Waveforms for Binary Signals

INFORMATION REPRESENTATION

ince 0 and 1 are associated with the binary number system, t
re the preferred names for the signal ranges. A binary digi
alled a bit. Information is represented in digital computers
roups of bits.

Why is binary used? In contrast to the situation in Diagram
onsider a system with 10 values representing the decimal digi

n such a system, the voltages available—say, 0 to 1.0 vol
ould be divided into 10 ranges, each of length 0.1 volt. A cir
ould provide an output voltage within each of these 10 ran
n input of a circuit would need to determine in which of the
anges an applied voltage lies.

The Digital Computer

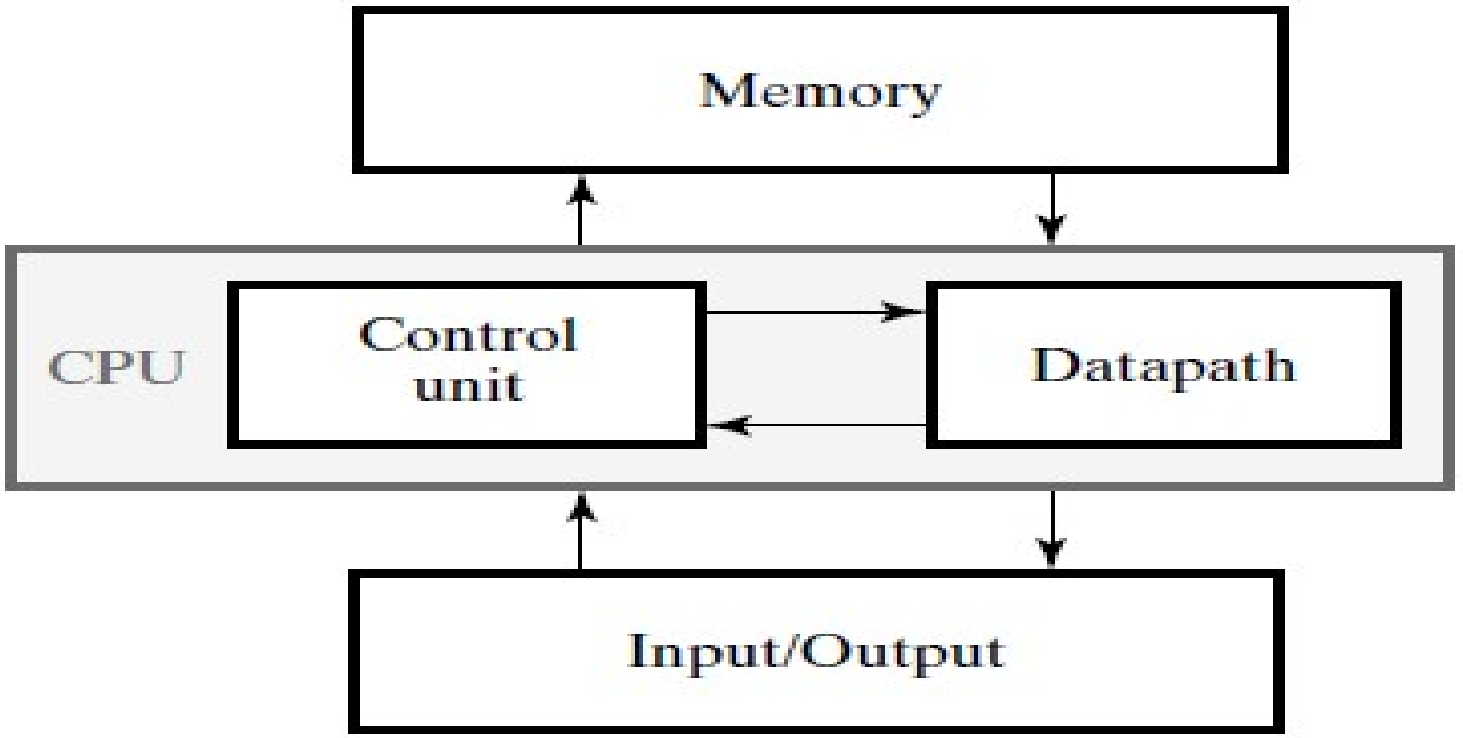


FIGURE 2
Block Diagram of a Digital Computer

The Digital Computer

he memory stores programs as well as input, output, ntermediate data.

he datapath performs arithmetic and other data-process perations as specified by the program.

he control unit supervises the flow of information between arious units.

datapath, when combined with the control unit, form omponent referred to as a *central processing unit, or CPU.*

The Digital Computer

he program and data prepared by the user are transferred
nemory by means of an input device such as a keyboard.

n output device, such as an LCD (liquid crystal display), displ
ne results of the computations and presents them to the user.

NUMBER SYSTEMS

he decimal number system is employed in everyday arithmeti
epresent numbers by strings of digits. Depending on its posi
n the string, each digit has an associated value of an inte
aised to the power of 10.

or example, the decimal number 724.5 is interpreted
epresent 7 hundreds plus 2 tens plus 4 units plus 5 tenths.

he hundreds, tens, units, and tenths are powers of 10 implied
he position of the digits. The value of the number is computed
ollows:

$$724.5 = 7 \times 10^2 + 2 \times 10^1 + 4 \times 10^0 + 5 \times 10^{-1}$$

. NUMBER SYSTEMS

he convention is to write only the digits and infer
orresponding powers of 10 from their positions.

n general, a decimal number with n digits to the left of
ecimal point and m digits to the right of the decimal poin
epresented by a string of coefficients:

$$A_{n-1}A_{n-2}\cdots A_1A_0.A_{-1}A_{-2}\cdots A_{-m+1}A_{-m}$$

NUMBER SYSTEMS

n general, the "." is called the *radix point*. *An – 1* is referred to
he *most significant digit* (*msd*) and *Am* as the *least significant d*
sd) of the number.

he following illustrates a base 5 number with $n = 3$ and m
nd its conversion to decimal:

$$(312.4)_5 = 3 \times 5^2 + 1 \times 5^1 + 2 \times 5^0 + 4 \times 5^{-1}$$
$$= 75 + 5 + 2 + 0.8 = (82.8)_{10}$$

Binary Numbers

Powers of Two

n	2^n	n	2^n	n	2^n
0	1	8	256	16	65,536
1	2	9	512	17	131,072
2	4	10	1,024	18	262,144
3	8	11	2,048	19	524,288
4	16	12	4,096	20	1,048,576
5	32	13	8,192	21	2,097,152
6	64	14	16,384	22	4,194,304
7	128	15	32,768	23	8,388,608

Binary Numbers

n digital systems, we refer to 2^{10} as K (kilo), 2^{20} as M (mega), 2
s G (giga), and 2^{40} as T (tera). Thus,

$$4K = 2^2 \times 2^{10} = 2^{12} = 4096$$

$$16M = 2^4 \times 2^{20} = 2^{24} = 16,777,216$$

Binary Numbers

Numbers with Different Bases

Decimal (base 10)	Binary (base 2)	Octal (base 8)	Hexadecimal (base 16)
00	0000	00	0
01	0001	01	1
02	0010	02	2
03	0011	03	3
04	0100	04	4
05	0101	05	5
06	0110	06	6
07	0111	07	7
08	1000	10	8
09	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

Binary Numbers

inary to Decimal Conversion

$$(11010)_2 = 1\times 2^4 + 1\times 2^3 + 0\times 2^2 + 1\times 2^1 + 0\times 2^0 = (26)_{10}$$

$$(110101.11)_2 = 32 + 16 + 4 + 1 + 0.5 + 0.25 = (53.75)_{10}$$

Binary Numbers

inary to Octal Conversion

$$(010\ 110\ 001\ 101\ 011.\ 111\ 100\ 000\ 110)_2 = (26153.7406)_8$$

Binary Numbers

inary to Hexadecimal Conversion

$$(0010\ 1100\ 0110\ 1011.\ 1111\ 0000\ 0110)_2 = (2C6B.F06)_{16}$$

Decimal Numbers

ecimal to Binary conversion

$625)_{10}$ = ?

$$625 - 512 = 113 = N_1 \qquad 512 = 2^9$$
$$113 - 64 = 49 = N_2 \qquad 64 = 2^6$$
$$49 - 32 = 17 = N_3 \qquad 32 = 2^5$$
$$17 - 16 = 1 = N_4 \qquad 16 = 2^4$$
$$1 - 1 = 0 = N_5 \qquad 1 = 2^0$$
$$(625)_{10} = 2^9 + 2^6 + 2^5 + 2^4 + 2^0 = (1001110001)_2$$

Binary Numbers

onversion of Decimal Integers to Binary

Convert decimal 41 to binary:

$41/2 = 20 + 1/2$	Remainder = 1	Least significant digit
$20/2 = 10$	= 0	
$10/2 = 5$	= 0	
$5/2 = 2 + 1/2$	= 1	
$2/2 = 1$	= 0	
$1/2 = 0 + 1/2$	= 1	Most significant digit

$(41)_{10} = (101001)_2$

Binary Numbers

onversion of Decimal Fractions to Binary

$$0.6875 \times 2 = 1.3750 \quad \text{Integer} = 1 \quad \text{Most significant digit}$$
$$0.3750 \times 2 = 0.7500 \quad = 0$$
$$0.7500 \times 2 = 1.5000 \quad = 1$$
$$0.5000 \times 2 = 1.0000 \quad = 1 \quad \text{Least significant digit}$$
$$(0.6875)_{10} = (0.1011)_2$$

Conversion from Decimal to Other Bases

onversion of Decimal Integers to Octal

$153/8 = 19 + 1/8$ Remainder = 1 — Least significant digit

$19/8 = 2 + 3/8$ = 3

$2/8 = 0 + 2/8$ = 2 — Most significant digit

$(153)_{10} = (231)_8$

Conversion from Decimal to Other Bases

onversion of Decimal Fractions to Octal

$$0.513 \times 8 = 4.104 \quad \text{Integer} = 4 \quad \text{Most significant digit}$$
$$0.104 \times 8 = 0.832 \quad = 0$$
$$0.832 \times 8 = 6.656 \quad = 6$$
$$0.656 \times 8 = 5.248 \quad = 5 \quad \text{Least significant digit}$$

$$(0.513)_{10} = (0.407)_8$$

Octal and Hexadecimal Numbers

Numbers with Different Bases

Decimal (base 10)	Binary (base 2)	Octal (base 8)	Hexadecimal (base 16)
00	0000	00	0
01	0001	01	1
02	0010	02	2
03	0011	03	3
04	0100	04	4
05	0101	05	5
06	0110	06	6
07	0111	07	7
08	1000	10	8
09	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

Octal and Hexadecimal Numbers

ctal to Decimal Conversion

$$(127.4)_8 = 1 \times 8^2 + 2 \times 8^1 + 7 \times 8^0 + 4 \times 8^{-1} = (87.5)_{10}$$

Octal and Hexadecimal Numbers

ctal to Binary Conversion

$$(673.12)_8 = 110\ 111\ 011.\ 001\ 010 = (110111011.00101)_2$$

Octal and Hexadecimal Numbers

Hexadecimal to Decimal Conversion

$$(B65F)_{16} = 11 \times 16^3 + 6 \times 16^2 + 5 \times 16^1 + 15 \times 16^0 = (46687)_{10}$$

Octal and Hexadecimal Numbers

Hexadecimal to Binary Conversion

$$(3A6.C)_{16} = 0011\ 1010\ 0110.\ 1100 = (1110100110.11)_2$$

ARITHMETIC OPERATIONS

inary Addition

00000	101100
01100	10110
+10001	+10111
11101	101101

ARITHMETIC OPERATIONS

inary Subtraction

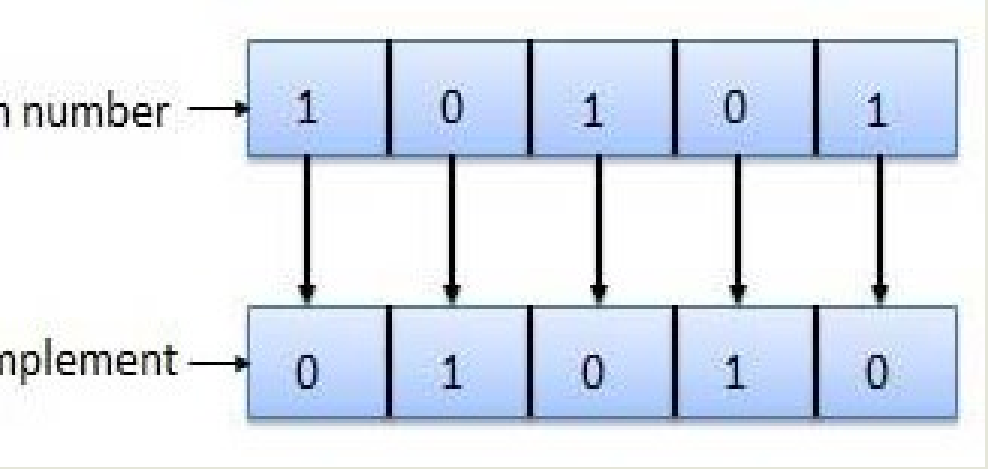
00000	00110
10110	10110
−10010	−10011
00100	00011

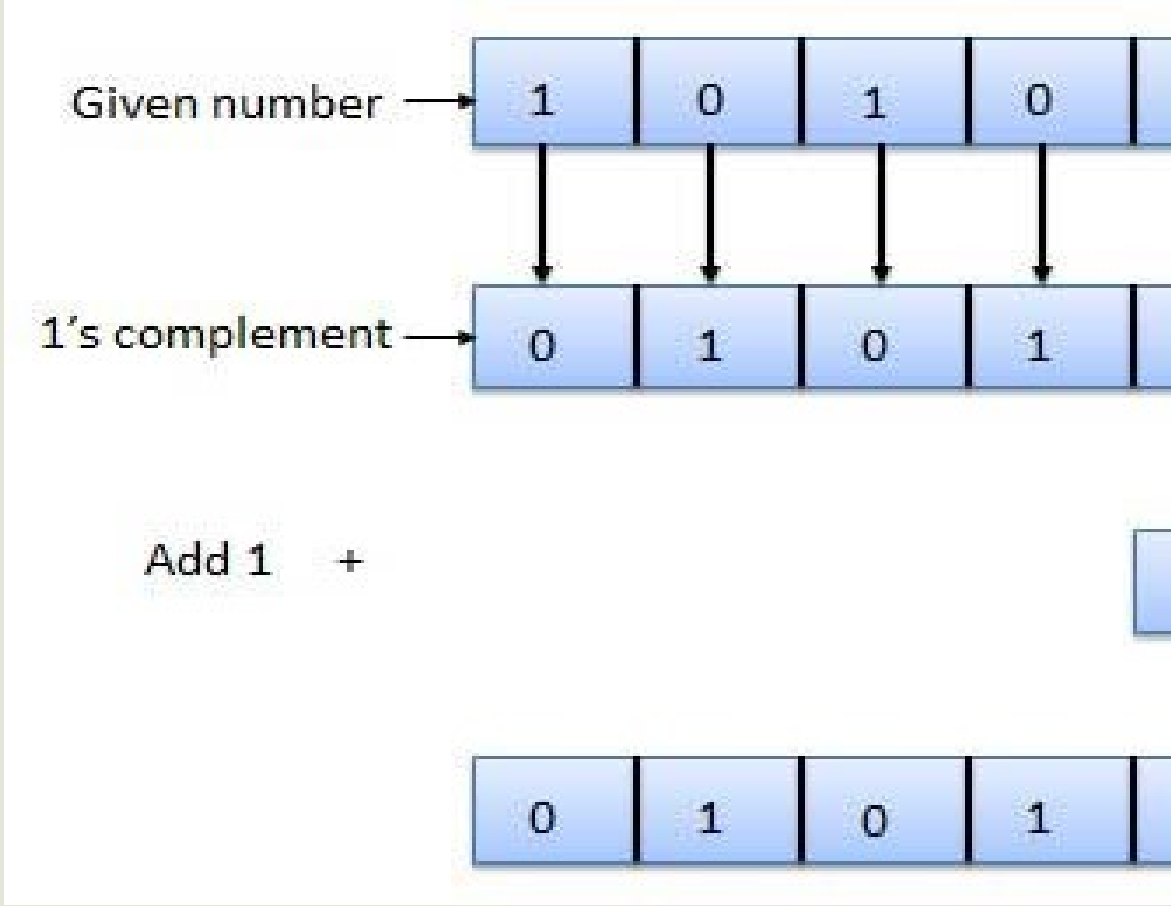
ARITHMETIC OPERATIONS

inary Multiplication

$$
\begin{array}{r}
1011 \\
\times\ 101 \\
\hline
1011 \\
0000 \\
1011 \\
\hline
110111
\end{array}
$$

1's & 2's complement





r's & (r-1)'s complement

xample: Find 3's complement and 2's complement of 121_3?

s complement of 121_3

222 – 121

101_3

nd 3's complement of 121_3

2's complement + 1

101_3+ 1

102_3

r's & (r-1)'s complement

xample: Find the 3's complement and 4's complement of 130_4

s complement of 130_4

333 – 130

203_4

s complement of 130_4

3's complement of 130_4 + 1

203_4+ 1

210_4

r's & (r-1)'s complement

xample: Find the 4's complement and 5's complement of 224_5

s complement of 224_5

444 – 224

220_5

s complement of 224_5

4's complement of 224_5 + 1

220_5+ 1

221_5

r's & (r-1)'s complement

xample: Find 10's complement and 11's complement of $1A1_{11}$?

0's complement of $1A1_{11}$

AAA – 1A1

909_{11}

1's complement of $1A1_{11}$

10's complement of $1A1_{11}$ + 1

909_{11}+ 1

$90A_{11}$

r's & (r-1)'s complement

xample: Find 11's complement and 12's complement of $AB0_{12}$?

1's complement of $AB0_{12}$

BBB – AB0

$10B_{12}$

2's complement of $AB0_{12}$

11's complement of $AB0_{12}$ + 1

$10B_{12}$+ 1

110_{12}

DECIMAL CODES

TABLE 4
Binary-Coded Decimal (BCD)

Decimal Symbol	BCD Digit
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

BCD Addition

110	BCD carry	1	1	
448		0100	0100	1000
+489		+0100	+1000	+1001
937	Binary sum	1001	1101	1 0001
	Add 6		+0110	+0110
	BCD sum		1 0011	1 0111
	BCD result	1001	0011	0111

. ALPHANUMERIC CODES

Many applications of digital computers require the handling
ata consisting not only of numbers, but also of letters.

or instance, an insurance company with thousands
olicyholders uses a computer to process its files.

o represent the names and other pertinent information, i
ecessary to formulate a binary code for the letters of
lphabet.

n addition, the same binary code must represent numerals
pecial characters such as $.

ASCII Character Code

he standard binary code for the alphanumeric characters
alled ASCII (American Standard Code for Informa
nterchange). It uses seven bits to code 128 characters.

he ASCII code contains 94 characters that can be printed and
onprinting characters used for various control functions.

he printing characters consist of the 26 uppercase letters, the
owercase letters, the 10 numerals, and 32 special printa
haracters such as %, @, and $.

ASCII Character Code

American Standard Code for Information Interchange (ASCII)

	$B_7B_6B_5$							
$B_4B_3B_2B_1$	000	001	010	011	100	101	110	111
0000	NULL	DLE	SP	0	@	P	`	p
0001	SOH	DC1	!	1	A	Q	a	q
0010	STX	DC2	"	2	B	R	b	r
0011	ETX	DC3	#	3	C	S	c	s
0100	EOT	DC4	$	4	D	T	d	t
0101	ENQ	NAK	%	5	E	U	e	u
0110	ACK	SYN	&	6	F	V	f	v
0111	BEL	ETB	'	7	G	W	g	w
1000	BS	CAN	(	8	H	X	h	x
1001	HT	EM	)	9	I	Y	i	y
1010	LF	SUB	*	:	J	Z	j	z
1011	VT	ESC	+	;	K	[	k	{
1100	FF	FS	,	<	L	\	l	|
1101	CR	GS	-	=	M	]	m	}
1110	SO	RS	.	>	N	^	n	~
1111	SI	US	/	?	O	_	o	DEL

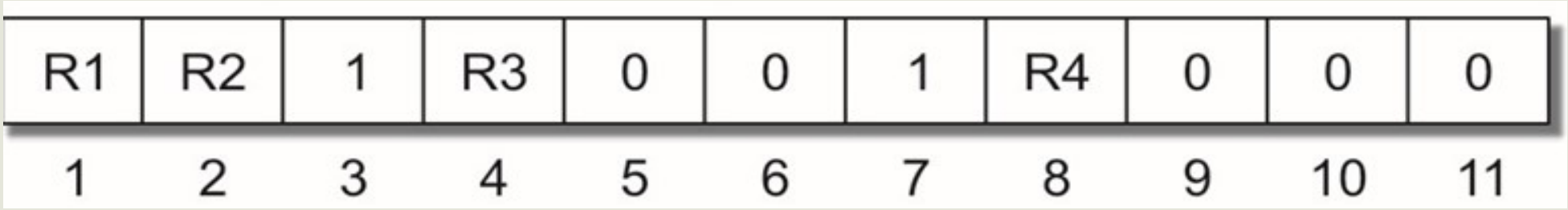
Parity Bit

	With Even Parity	With Odd Parity
1000001	01000001	11000001
1010100	11010100	01010100

Hamming Code

001000

$+r+1<2^r$



Hamming Code

1 = BIT NO. 1+3+5+7+9+11

2 = BIT NO. 2+3+6+7+10+11

3 = BIT NO. 4+5+6+7

4 = BIT NO. 8+9+10+11

EBCDIC

xtended Binary Coded Decimal Interchange Code (EBCDIC) is
-bit character encoding used on IBM mainframe
inicomputer operating systems.

ll IBM mainframe peripherals and operating systems
upport EBCDIC, although the operating systems also pro
SCII and Unicode modes to allow translation between diffe
ncodings.

EBCDIC

Character	EBDIC Bit Configuration	Character	EBDIC Bit Configuration
A	1100 0001	S	1110 0010
B	1100 0010	T	1110 0011
C	1100 0011	U	1110 0100
D	1100 0100	V	1110 0101
E	1100 0101	W	1110 0110
F	1100 0110	X	1110 0111
G	1100 0111	Y	1110 1000
H	1100 1000	Z	1110 1001
I	1100 1001	0	1111 0000
J	1101 0001	1	1111 0001
K	1101 0010	2	1111 0010
L	1101 0011	3	1111 0011
M	1101 0100	4	1111 0100
N	1101 0101	5	1111 0101
O	1101 0110	6	1111 0110
P	1101 0111	7	1111 0111
Q	1101 1000	8	1111 1000
R	1101 1001	9	1111 1001

UNICODE

he Unicode character set has the capacity to support over
illion characters, and is being developed with an aim to hav
ngle character set that supports all characters from all scri
s well as many symbols, that are in common use around
orld today or in the past.

urrently, the Standard supports over 96,000 charac
epresenting a large number of scripts. UTF-8, UTF-16 and U
2 are part of Unicode.