Week 2

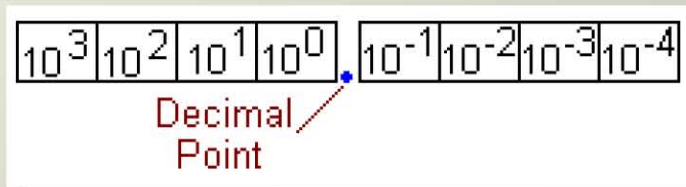# Binary Numbers, Binary Digits, Logic Levels, and Digital Waveforms

Binary Numbers, Binary Digits, Logic Levels, and Digital Waveforms

Decimal Numbers

- The decimal number system has ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9

- The decimal numbering system has a base of 10 with each position weighted by a factor of 10:

10^3	10^2	10^1	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-4}

Decimal Point

Binary Numbers

- The binary number system has two digits: 0 and 1

- The binary numbering system has a base of 2 with each position weighted by a factor of 2:

POSITIVE POWERS OF TWO (WHOLE NUMBERS)								
2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
256	128	64	32	16	8	4	2	1

Binary Numbers

	2 bits	3 bits	4 bits	5 bits	8 bits word (byte)
0	00	000	0000	00000	00000000
1	01	001	0001	00001	00000001
2	10	010	0010	00010	00000010
3	11	011	0011		
4		100	0100		
5		101	0101		
6		110	0110		
7		111	0111		
8			1000		
9			1001		
10			1010	01010	00001010

2 bits word represents 4 different codes $2^2=4$

3 bits word gives $2^3=8$ codes

4 bits word gives $2^4=16$ codes

8 bits word (byte)   gives $2^8=256$ codes,   n bits word, 2^n codes

Digital Codes

- ASCII code (control characters)

NAME	DEC	BINARY	HEX	NAME	DEC	BINARY	HEX
NUL	0	0000000	00	DLE	16	0010000	10
SOH	1	0000001	01	DC1	17	0010001	11
STX	2	0000010	02	DC2	18	0010010	12
ETX	3	0000011	03	DC3	19	0010011	13
EOT	4	0000100	04	DC4	20	0010100	14
ENQ	5	0000101	05	NAK	21	0010101	15
ACK	6	0000110	06	SYN	22	0010110	16
BEL	7	0000111	07	ETB	23	0010111	17
BS	8	0001000	08	CAN	24	0011000	18
HT	9	0001001	09	EM	25	0011001	19
LF	10	0001010	0A	SUB	26	0011010	1A
VT	11	0001011	0B	ESC	27	0011011	1B
FF	12	0001100	0C	FS	28	0011100	1C
CR	13	0001101	0D	GS	29	0011101	1D
SO	14	0001110	0E	RS	30	0011110	1E
SI	15	0001111	0F	US	31	0011111	1F

Digital Codes

- ## ASCII code (graphic symbols 20h – 3Fh)

SYMBOL	DEC	BINARY	HEX	SYMBOL	DEC	BINARY	HEX
space	32	0100000	20	0	48	0110000	30
!	33	0100001	21	1	49	0110001	31
"	34	0100010	22	2	50	0110010	32
#	35	0100011	23	3	51	0110011	33
$	36	0100100	24	4	52	0110100	34
%	37	0100101	25	5	53	0110101	35
&	38	0100110	26	6	54	0110110	36
'	39	0100111	27	7	55	0110111	37
(	40	0101000	28	8	56	0111000	38
)	41	0101001	29	9	57	0111001	39
*	42	0101010	2A	:	58	0111010	3A
+	43	0101011	2B	;	59	0111011	3B
,	44	0101100	2C	<	60	0111100	3C
–	45	0101101	2D	=	61	0111101	3D
.	46	0101110	2E	>	62	0111110	3E
/	47	0101111	2F	?	63	0111111	3F

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Digital Codes

- ## ASCII code (graphic symbols 40h – 5Fh)

SYMBOL	DEC	BINARY	HEX	SYMBOL	DEC	BINARY	HEX
@	64	1000000	40	P	80	1010000	50
A	65	1000001	41	Q	81	1010001	51
B	66	1000010	42	R	82	1010010	52
C	67	1000011	43	S	83	1010011	53
D	68	1000100	44	T	84	1010100	54
E	69	1000101	45	U	85	1010101	55
F	70	1000110	46	V	86	1010110	56
G	71	1000111	47	W	87	1010111	57
H	72	1001000	48	X	88	1011000	58
I	73	1001001	49	Y	89	1011001	59
J	74	1001010	4A	Z	90	1011010	5A
K	75	1001011	4B	[	91	1011011	5B
L	76	1001100	4C	\	92	1011100	5C
M	77	1001101	4D	]	93	1011101	5D
N	78	1001110	4E	^	94	1011110	5E
O	79	1001111	4F	_	95	1011111	5F

Digital Codes

- ASCII code (graphic symbols 60h – 7Fh)

SYMBOL	DEC	BINARY	HEX	SYMBOL	DEC	BINARY	HEX
`	96	1100000	60	p	112	1110000	70
a	97	1100001	61	q	113	1110001	71
b	98	1100010	62	r	114	1110010	72
c	99	1100011	63	s	115	1110011	73
d	100	1100100	64	t	116	1110100	74
e	101	1100101	65	u	117	1110101	75
f	102	1100110	66	v	118	1110110	76
g	103	1100111	67	w	119	1110111	77
h	104	1101000	68	x	120	1111000	78
i	105	1101001	69	y	121	1111001	79
j	106	1101010	6A	z	122	1111010	7A
k	107	1101011	6B	{	123	1111011	7B
l	108	1101100	6C	|	124	1111100	7C
m	109	1101101	6D	}	125	1111101	7D
n	110	1101110	6E	~	126	1111110	7E
o	111	1101111	6F	Del	127	1111111	7F

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Digital Codes

Extended ASCII code (80h – FFh)

- Non-English alphabetic characters
- Currency symbols
- Greek letters
- Math symbols
- Drawing characters
- Bar graphing characters
- Shading characters

**Figure 1–21** An encoder used to encode a calculator keystroke into a binary code for storage or for calculation.
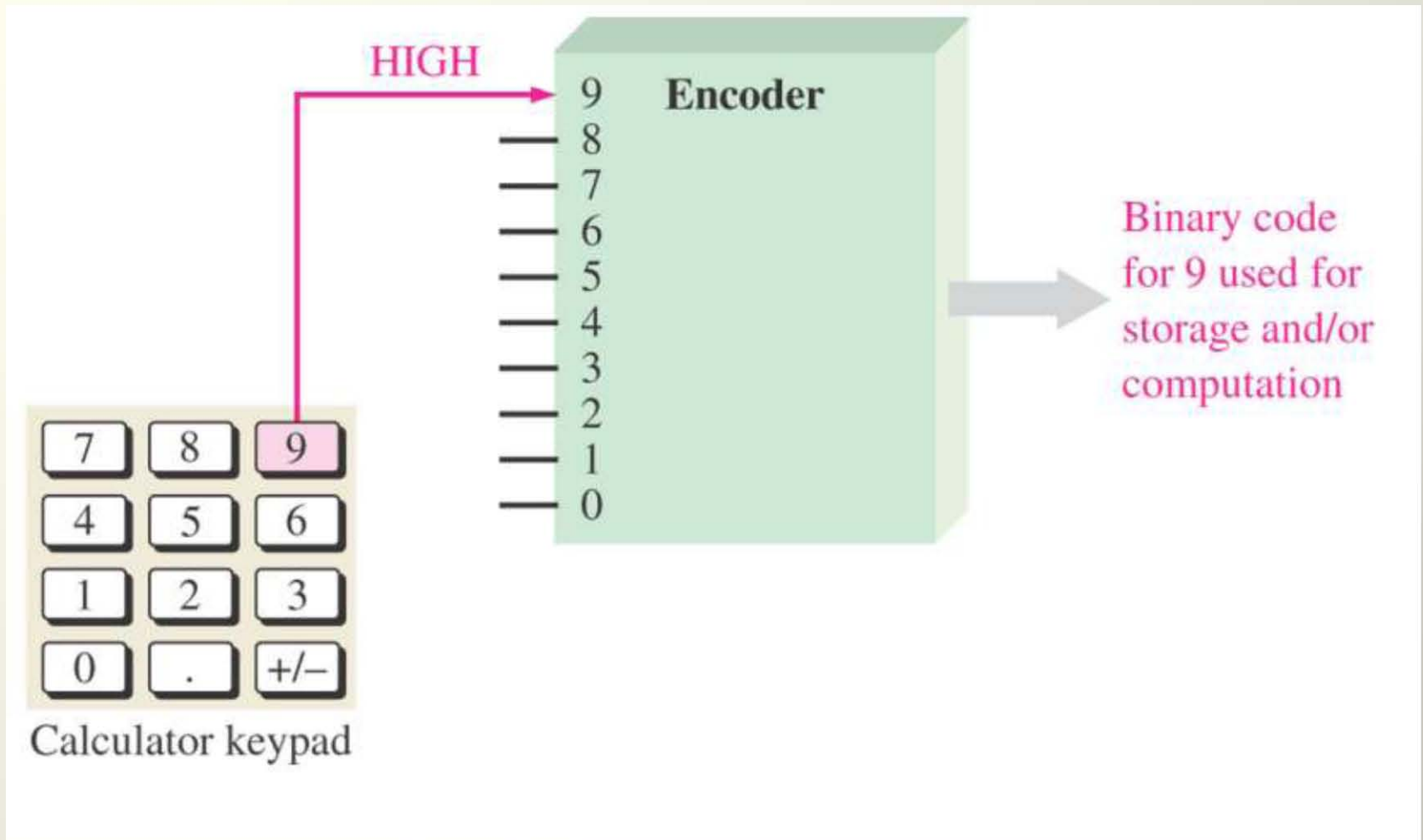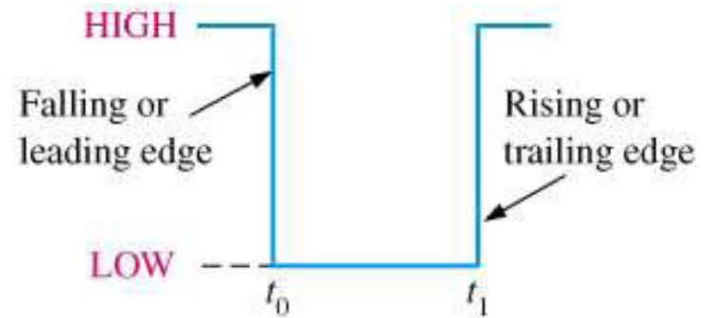
Binary Digits, Logic Levels, and Digital Waveforms

- ## The two binary digits are designated **0** and **1**

- ## They can also be called LOW and HIGH, where **LOW = 0** and **HIGH = 1**

Binary Digits, Logic Levels, and Digital Waveforms

Binary values are also represented by voltage levels
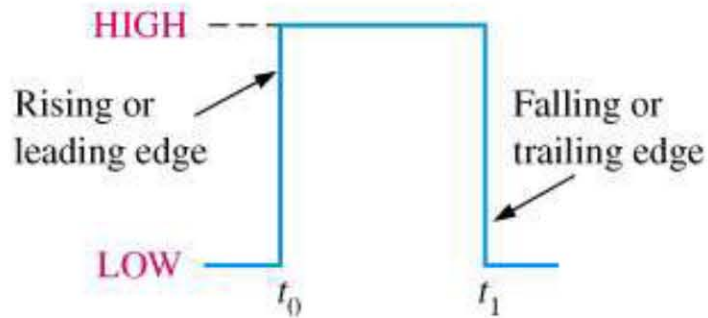
(a) Positive–going pulse

(b) Negative–going pulse
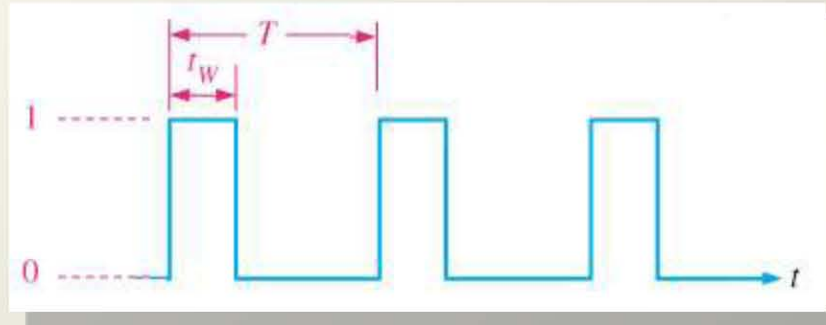
Binary Digits, Logic Levels, and Digital Waveforms

Major parts of a digital pulse

- Base line
- Amplitude
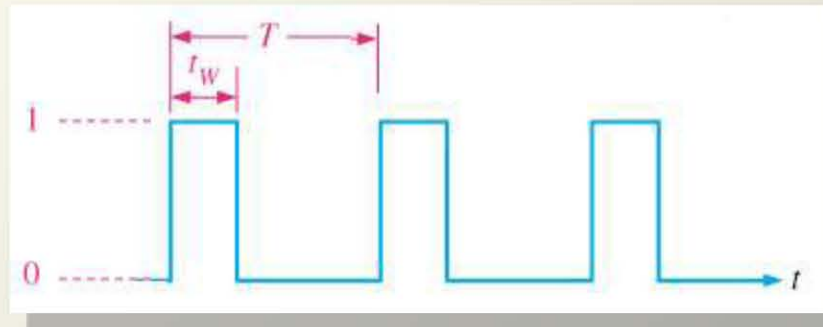- Rise time (t_r)
- Pulse width (t_w)
- Fall time (t_f)
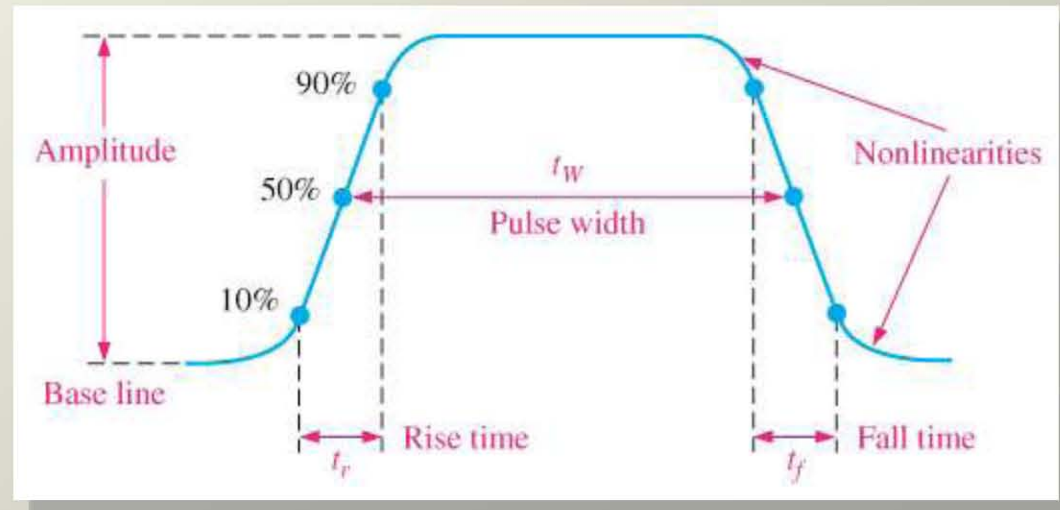
Binary Digits, Logic Levels, and Digital Waveforms

- t_w = pulse width
- T = period of the waveform
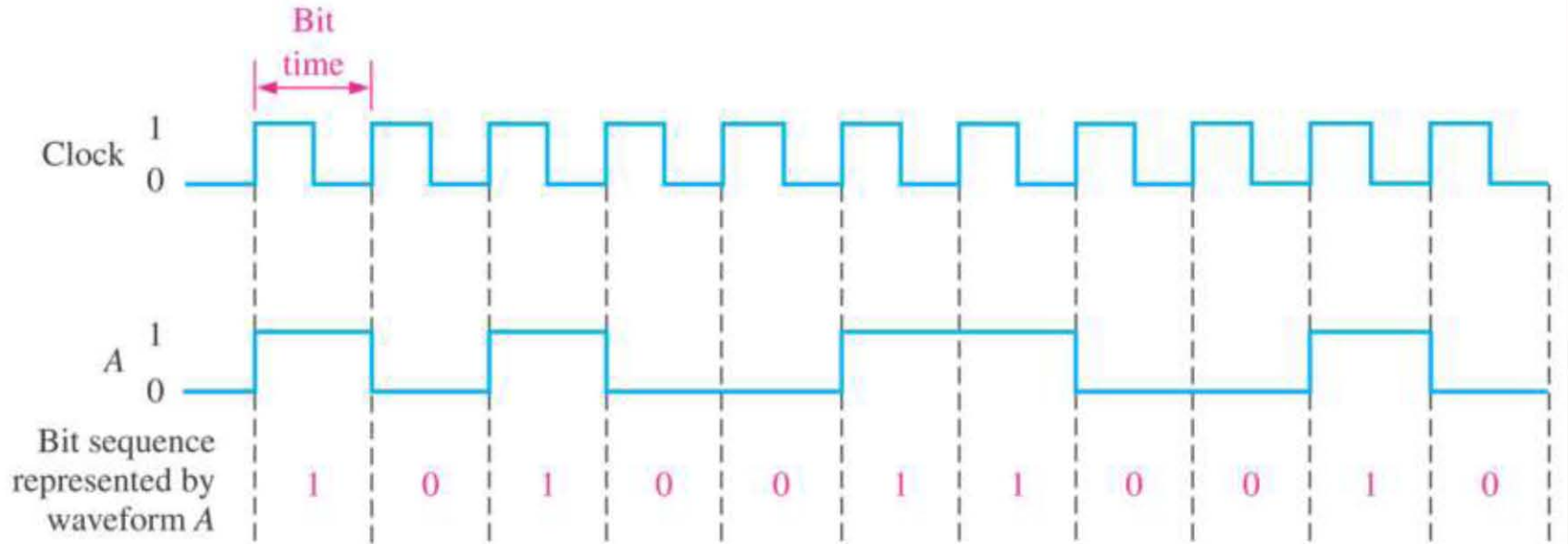- f = frequency of the waveform

$$f = \frac{1}{T}$$

Binary Digits, Logic Levels, and Digital Waveforms

The duty cycle of a binary waveform is defined as:

$$\textbf{Duty cycle} = \left(\frac{\textbf{t}_\textbf{w}}{\textbf{T}}\right)\textbf{100\%}$$

Figure 1–10   Example of a clock waveform synchronized with a waveform representation of a sequence of bits.

(a) Serial transfer of 8 bits of binary data from computer to modem. Interval t_0 to t_1 is first.

(b) Parallel transfer of 8 bits of binary data from computer to printer. The beginning time is t_0.