TEKNIK DIGITAL

SISTEM BILANGAN

Pengampu:
Fatchul Arifin
fatchul@uny.ac.id

Sumber acuan: Digital Systems: Principles and Applications, 11/e
Ronald J. Tocci, Neal S. Widmer, Gregory L. Moss

Cakupan

- Konversi Bilangan
  - Decimal, binary, Octal, hexadecimal.
- Representasi angka Desimal menggunakan Kode BCD
- Kode ASCII
- Deteksi Kesalahan menggunakan Parity method

Konversi Binary ke Decimal

- Convert binary to decimal by summing the positions that contain a 1:

$$
\begin{array}{ccccc} 1 & 1 & 0 & 1 & 1_2 \end{array}
$$

$$
2^4 + 2^3 + 0 + 2^1 + 2^0 = 16 + 8 + 2 + 1 = 27_{10}
$$

- An example with a greater number of bits:

$$
\begin{array}{cccccccc} 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1_2 = \end{array}
$$

$$
2^7 + 0 + 2^5 + 2^4 + 0 + 2^2 + 0 + 2^0 = 181_{10}
$$

Konversi Binary ke Decimal

- The double-dabble method avoids addition of large numbers:
  - Write down the left-most 1 in the binary number.
  - Double it and add the next bit to the right.
  - Write down the result under the next bit.
  - Continue with steps 2 and 3 until finished with the binary number.

Konversi Binary ke Decimal

- Binary numbers verify the double-dabble method:

Given: $1 \quad 1 \quad 0 \quad 1 \quad 1_2$

Results:

$$1 \times 2 = 2$$
$$\underline{+1}$$
$$3 \times 2 = 6$$
$$\underline{+0}$$
$$6 \times 2 = 12$$
$$\underline{+1}$$
$$13 \times 2 = 26$$
$$\underline{+1}$$
$$27_{10}$$

Konversi Binary ke Decimal

- Reverse process described in 2-1.
  - Note that all positions must be accounted for.

$$45_{10} = 32 + 8 + 4 + 1 = 2^5 + 0 + 2^3 + 2^2 + 0 + 2^0$$
$$= 1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 1_2$$

- Another example:

$$76_{10} = 64 + 8 + 4 = 2^6 + 0 + 0 + 2^3 + 2^2 + 0 + 0$$
$$= 1 \quad 0 \quad 0 \quad 1 \quad 1 \quad 0 \quad 0_2$$

Konversi Desimal ke Binary

Repeated Division

Divide the decimal number by 2.

Write the remainder after each division until a quotient of zero is obtained.

The first remainder is the LSB.

The last is the MSB.

$$\frac{25}{2} = \boxed{12} + \text{remainder of } 1 \quad \text{LSB}$$

$$\frac{\boxed{12}}{2} = 6 + \text{remainder of } 0$$

$$\frac{6}{2} = 3 + \text{remainder of } 0$$

$$\frac{3}{2} = 1 + \text{remainder of } 1$$

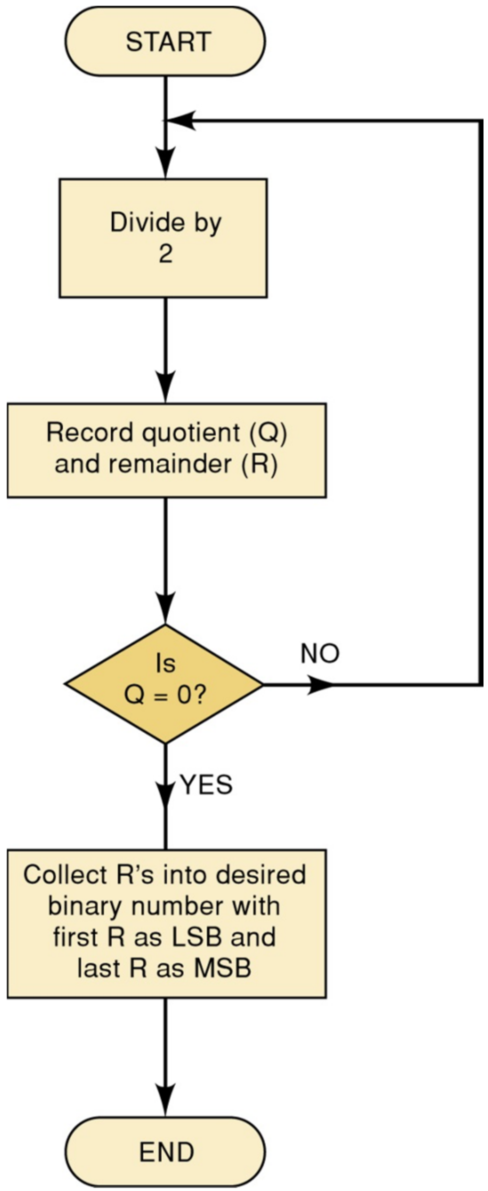
$$\frac{1}{2} = 0 + \text{remainder of } 1 \quad \text{MSB}$$

$$25_{10} = \boxed{1 \quad 1 \quad 0 \quad 0 \quad 1_2}$$

Konversi Desimal ke Binary

Repeated Division

This flowchart describes the process and can be used to convert from decimal to any other number system.



Konversi Desimal ke Binary

- Convert 37_{10} to binary:

$$\frac{37}{2} = 18.5 \longrightarrow \text{remainder of 1 (LSB)}$$

$$\frac{18}{2} = 9.0 \longrightarrow \quad 0$$

$$\frac{9}{2} = 4.5 \longrightarrow \quad 1$$

$$\frac{4}{2} = 2.0 \longrightarrow \quad 0$$

$$\frac{2}{2} = 1.0 \longrightarrow \quad 0$$

$$\frac{1}{2} = 0.5 \longrightarrow \quad 1 \text{ (MSB)}$$

Sistem Bilangan Hexadecimal

- Hexadecimal allows convenient handling of long binary strings, using groups of 4 bits—Base 16
  - 16 possible symbols: 0-9 and A-F

16^4	16^3	16^2	16^1	16^0	16^{-1}	16^{-2}	16^{-3}	16^{-4}

Hexadecimal point

Sistem Bilangan Hexadecimal

Relationships between hexadecimal, decimal, and binary numbers.

Hexadecimal	Decimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111

Konversi Bilangan Hexadecimal ke Desimal

- Convert from hex to decimal by multiplying each hex digit by its positional weight.

$$
\begin{aligned}
356_{16} &= 3 \times 16^2 + 5 \times 16^1 + 6 \times 16^0 \\
&= 768 + 80 + 6 \\
&= 854_{10}
\end{aligned}
$$

- In a 2nd example, the value 10 was substituted for A and 15 substituted for F.

$$
\begin{aligned}
2AF_{16} &= 2 \times 16^2 + 10 \times 16^1 + 15 \times 16^0 \\
&= 512 + 160 + 15 \\
&= 687_{10}
\end{aligned}
$$

For practice, verify that $1BC2_{16}$ is equal to 7106_{10}

Konversi Bilangan Hexadecimal ke Desimal

- Convert from decimal to hex by using the repeated division method used for decimal to binary conversion.
- Divide the decimal number by 16
  - The first remainder is the LSB—the last is the MSB.

Konversi Bilangan Desimal ke Hexadecimal

- Convert 423_{10} to hex:

$$\frac{423}{16} = \boxed{26} + \text{remainder of } 7$$

$$\frac{\boxed{26}}{16} = 1 + \text{remainder of } 10$$

$$\frac{1}{16} = 0 + \text{remainder of } 1$$

$$423_{10} = \boxed{1A7_{16}}$$

Konversi Bilangan Desimal ke Hexadecimal

- Convert 214_{10} to hex:

$$\frac{214}{16} = 13 + \text{remainder of } 6$$

$$\frac{13}{16} = 0 + \text{remainder of } 13$$

$$214_{10} = \boxed{D6_{16}}$$

Konversi Bilangan Hexadecimal ke Binary

- Leading zeros can be added to the left of the MSB to fill out the last group.

$$
\begin{aligned}
9F2_{16} &= \quad 9 \qquad\qquad F \qquad\qquad 2 \\
& \quad\ \downarrow \qquad\qquad \downarrow \qquad\qquad \downarrow \\
&= 1\ 0\ 0\ 1 \quad 1\ 1\ 1\ 1 \quad 0\ 0\ 1\ 0 \\
&= 100111110010_2
\end{aligned}
$$

For practice, verify that $BA6_{16} = 101110100110_2$

Konversi Bilangan Binary ke Hexadecimal

- Convert from binary to hex by grouping bits in four starting with the LSB.
  – Each group is then converted to the hex equivalent
- The binary number is grouped into groups of four bits & each is converted to its equivalent hex digit.

$$1\,1\,1\,0\,1\,0\,0\,1\,1\,0_2 = \underbrace{0\;0\;1\;1}_{3}\;\underbrace{1\;0\;1\;0}_{A}\;\underbrace{0\;1\;1\;0}_{6}$$

$$= 3A6_{16}$$

For practice, verify that 101011111 2 = $15F_{16}$

Konversi Hexadecimal– ke Binary

- Convert decimal 378 to a 16-bit binary number by first converting to hexadecimal.

$$\frac{378}{16} = 23 + \text{remainder of } 10_{10} = A_{16}$$

$$\frac{23}{16} = 1 + \text{remainder of } 7$$

$$\frac{1}{16} = 0 + \text{remainder of } 1$$

Hexadecimal

To perform conversions between hex & binary, it is necessary to know the four-bit binary numbers (0000 - 1111), and their equivalent hex digits.

Hex	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Hexadecimal Number System – Counting in Hex

- When counting in hex, each digit position can be incremented (increased by 1) from 0 to F.
  - On reaching value F, it is reset to 0, and the next digit position is incremented.

Example:

38,39,3A,3B,3C,3D,3E,3F,40,41,42

When there is a 9 in a digit position, it becomes an A when it is incremented.

With three hex digits, we can count from 000_{16} to FFF_{16} which is 0_{10} to 4095_{10} — a total of $4096 = 16^3$ values.

BCD Code

- Binary Coded Decimal (BCD) is a widely used way to present decimal numbers in binary form.
  - Combines features of both decimal and binary systems.
    - Each digit is converted to a binary equivalent.
- BCD is *not* a number system.
  - It is a decimal number with each digit encoded to its binary equivalent.
- A BCD number is *not* the same as a straight binary number.
  - The primary advantage of BCD is the relative ease of converting to and from decimal.

BCD Code

- Convert the number 874_{10} to BCD:
  - Each decimal digit is represented using 4 bits.
    - Each 4-bit group can never be greater than 9.

8	7	4	(decimal)
↓	↓	↓	
1000	0111	0100	(BCD)

- Reverse the process to convert BCD to decimal.

9	4	3	(decimal)
↓	↓	↓	
1001	0100	0011	(BCD)

BCD Code

- Convert 0110100000111001 (BCD) to its decimal equivalent.

$$\underbrace{0110}_{6}\ \underbrace{1000}_{8}\ \underbrace{0011}_{3}\ \underbrace{1001}_{9}$$

Divide the BCD number into four-bit groups and convert each to decimal.

BCD Code

- Convert 0110100000111001 (BCD) to its decimal equivalent.

$$\underbrace{0110}_{6}\ \underbrace{1000}_{8}\ \underbrace{0011}_{3}\ \underbrace{1001}_{9}$$

Divide the BCD number into four-bit groups and convert each to decimal.

BCD Code

- Convert BCD 011111000001 to its decimal equivalent.

$$\underbrace{0111}_{7}\ \underset{\downarrow}{1100}\ \underbrace{0001}_{1}$$

The forbidden group represents an error in the BCD number.

Byte, Nibble, and Word

- Most microcomputers handle and store binary data and information in groups of eight bits.
  - 8 bits = 1 byte.
    - A byte can represent numerous types of data/information.
- Binary numbers are often broken into groups of four bits.
  - Because a group of four bits is half as big as a byte, it was named a **nibble**.
- A **word** is a group of bits that represents a certain unit of information.
  - **Word size** can be defined as the number of bits in the binary word a digital system operates on.
    - PC word size is eight bytes (64 bits).

Alphanumeric Codes

- Represents characters and functions found on a computer keyboard.
  - 26 lowercase & 26 uppercase letters, 10 digits, 7 punctuation marks, 20 to 40 other characters.
- ASCII – American Standard Code for Information Interchange.
  - Seven bit code: $2^7 = 128$ possible code groups
  - Examples of use: transfer information between computers; computers & printers; internal storage.

ASCII – American Standard Code for Information Interchange

Character	HEX	Decimal	Character	HEX	Decimal	Character	HEX	Decimal	Character	HEX	Decimal
NUL (null)	0	0	Space	20	32	@	40	64	.	60	96
Start Heading	1	1	!	21	33	A	41	65	a	61	97
Start Text	2	2	“	22	34	B	42	66	b	62	98
End Text	3	3	#	23	35	C	43	67	c	63	99
End Transmit.	4	4	$	24	36	D	44	68	d	64	100
Enquiry	5	5	%	25	37	E	45	69	e	65	101
Acknowlege	6	6	&	26	38	F	46	70	f	66	102
Bell	7	7	`	27	39	G	47	71	g	67	103
Backspace	8	8	(	28	40	H	48	72	h	68	104
Horiz. Tab	9	9	)	29	41	I	49	73	i	69	105
Line Feed	A	10	*	2A	42	J	4A	74	j	6A	106
Vert. Tab	B	11	+	2B	43	K	4B	75	k	6B	107
Form Feed	C	12	,	2C	44	L	4C	76	l	6C	108
Carriage Return	D	13	-	2D	45	M	4D	77	m	6D	109
Shift Out	E	14	.	2E	46	N	4E	78	n	6E	110

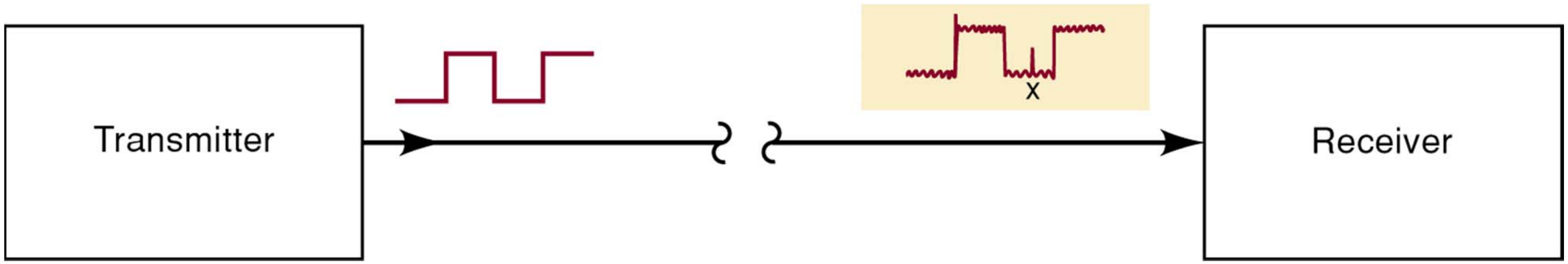
See the entire table on page 49 of your textbook.

Parity Method for Error Detection

- Binary data and codes are frequently moved between locations:
  - Digitized voice over a microwave link.
  - Storage/retrieval of data from magnetic/optical disks.
  - Communication between computer systems over telephone lines, using a modem.

Parity Method for Error Detection

- Electrical noise can cause errors during transmission.
  - Spurious fluctuations in voltage or current present in all electronic systems.



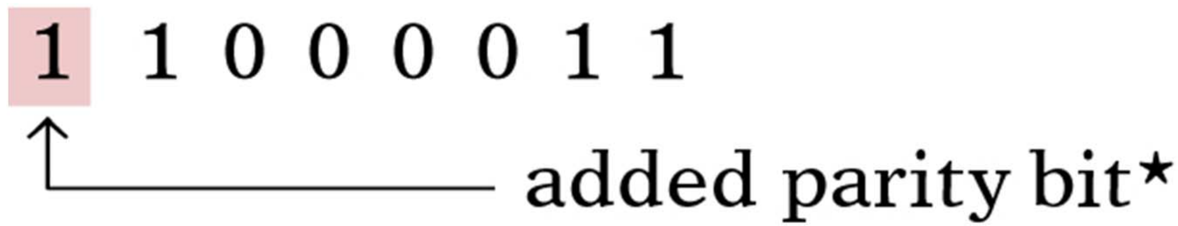
- Many digital systems employ methods for error detection—and sometimes correction.
  - One of the simplest and most widely used schemes for error detection is the **parity method**.

Parity Method for Error Detection

- The parity method of error detection requires the addition of an extra bit to a code group.
  - Called the parity bit, it can be either a 0 or 1, depending on the number of 1s in the code group.
- There are two parity methods, even and odd.
  - The transmitter and receiver must “agree” on the type of parity checking used.
    - Even seems to be used more often.

Parity Method for Error Detection

- Even parity method—the total number of bits in a group *including* the parity bit must add up to an *even* number.
  - The binary group **1 0 1 1** would require the addition of a parity bit 1, making the group 1 **1 0 1 1**.
    - The parity bit may be added at either end of a group.



Parity Method for Error Detection

- Odd parity method—the total number of bits in a group *including* the parity bit must add up to an *odd* number.
  - The binary group **1 1 1 1** would require the addition of a parity bit 1, making the group **1 1 1 1 1**.

The parity bit becomes a part of the code word.

Adding a parity bit to the seven-bit ASCII code produces an eight-bit code.

Applications

- When ASCII characters are transmitted there must be a way to tell the receiver a new character is coming.
  - There is often a need to detect errors in the transmission as well.
- The method of transfer is called asynchronous data communication.

Applications

- An ASCII character must be "framed" so the receiver knows where the data begins and ends.
  - The first bit must always be a start bit (logic 0).
- ASCII code is sent LSB first and MSB last.
  - After the MSB, a parity bit is appended to check for transmission errors.
  - Transmission is ended by sending a stop bit (logic 1).