CE102 Digital Logic Design

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Week-2 (Introduction to Digital Logic Design)

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PART 1: BINARY SYSTEMS

Binary Systems

- Analog Vs Digital
- Digital Systems Binarynumbers
- Number base conversions Compliments Binary Systems
    - Octal and Hexadecimal Numbers
- Signed Binary Numbers

Analog and Digital

- Analog information is made up of a continuum of values within a given range.
- At its most basic, digital information can assume only one of two possible values:
  - `one/zero`,
  - `on/off`,
  - `high/low`,
  - `true/false`, etc.
- Digital Information is less susceptible to noise than analog information
- Exact voltage values are not important, only their class `(1 or 0)`
- The complexity of operations is reduced, thus it is easier to implement them with high accuracy in digital form.

Digital Systems

- **Digital**;
  - generates stores
  - processes data

    $\downarrow$
    - **two states**:
      - `positive` (1) and
      - `non-postitive` (0)

Digital Systems

- A "digital system" is a data technology that uses discrete (discontinuous) values represented by high and low states known as bits.
- non-digital (or analog) systems use a continuous range of values to represent information

Binary Number System

- **Binary**;
  - describes a numbering scheme in which there are only two possible values for each digit: 0 and 1
- **Binary Number System**
  - a numbering system
  - represents numeric values using `0` and `1`
  - known as the `base-2` number system

BINARY NUMBER EXAMPLE

- `10`
- `111`
- `10101`
- `11110`

COMPLIMENTS

- used in digital computers to simplify the subtraction operation and for logical manipulation
- There are 2 types of complements for each base r system
  - (1) The radix complement
  - (2) Diminished radix compliment

Radix compliment: Also referred to as the r"s compliment. Diminished radix compliment:Also referred to as (r-1)"s compliment

OCTAL NUMBERS

- a binary number is divided up into groups of only 3 bits
  - set of bits having a distinct value of between `000 (0)` and `111( 7 )`.
- Octal numbers therefore have a range of just “8” digits, `(0, 1, 2, 3, 4, 5, 6, 7)` making them a Base-8 numbering system and therefore, q is equal to “8”

HEXADECIMAL NUMBERING SYSTEM

- main disadvantage of binary numbers
  - the binary string equivalent of a large decimal base-10 number can be quite long
  - Working with large digital systems, such as computers, it is common to find binary numbers consisting of 8, 16 and even 32 digits
- Overcome the above problem:
  - to arrange the binary numbers into groups or sets of four bits (4-bits)
  - These groups of 4-bits uses another type of numbering system also commonly used in computer and digital systems called Hexadecimal Numbers
  - uses the Base of 16 system
  - Hexdecimal system format is quite compact and much easier to understand

HEXADECIMAL NUMBERING SYSTEM

Decimal	Binary	Octal	Hexadecimal
0	0000	0	0
1	0001	1	1
2	0010	2	2
3	0011	3	3
4	0100	4	4
5	0101	5	5
6	0110	6	6
7	0111	7	7
8	1000	10	8

SIGNED BINARY NUMBERS

- **In mathematics**,
  - positive numbers (*including zero*) are represented as unsigned numbers we do not put the (+) ve sign in front of them to show that they are positive numbers
  - When dealing with negative numbers we do use a (−) sign in front of the number to show that the number is negative in value and different from a positive unsigned value and the same is true with signed binary numbers

- However in digital circuits
  - there is no provision made to put a plus or even a minus sign to a number
  - digital systems operate with binary numbers that are represented in terms of "0"s" and "1"s"
- to represent a positive `(N)` and a negative `(-N)` binary number we can use the binary numbers with sign

- For signed binary numbers the most significant bit (MSB) is used as the sign
- If the sign bit is "0":
  - the number is positive
- If the sign bit is "1":
  - the number is negative
- The remaining bits are used to represent the magnitude of the binary number in the usual unsigned binary number format.

Positive Signed Binary Number

- 8-bit word

$$\left[\;\mid \overbrace{0}^{+sign} \mid 0 \mid 1 \mid \overbrace{1}^{magnitude} \mid 0 \mid 1 \mid 0 \mid 1 \mid\;\right] = 53$$

Negative Signed Binary Number

- 8-bit word

$$\left[\ \Big|\ \overbrace{1}^{-sign}\ \Big|\ 0\ \Big|\ 1\ \Big|\ \overbrace{1}^{magnitude}\ \Big|\ 0\ \Big|\ 1\ \Big|\ 0\ \Big|\ 1\ \Big|\ \right] = -53$$

BINARY CODES

- In the coding,
  - when numbers, letters or words are represented by a specific group of symbols, it is said that the number, letter or word is being encoded
- The group of symbols is called as a code
- digital data is represented, stored and transmitted as group of binary bits
- called BINARYCODE

Advantages of Binary Code

- Binary codes are suitable for the computer applications.
- Binary codes are suitable for the digital communications.
- Binary codes make the analysis and designing of digital circuits if we use the binary codes.
- Since only 0 & 1 are being used, implementation becomes easy.

Classification of Binary Codes

- Weighted Codes
- Non-Weighted Codes
- Binary Coded Decimal Code
- Alphanumeric Codes
- Error Detecting Codes
- Error Correcting Codes

Weighted Codes

- obey the positional weight principle
- Each position of the number represents a specific weight
- Several systems of the codes are used to express the decimal digits 0 through 9

$$= 24$$

$$= \overbrace{2}^{0010}\ \overbrace{4}^{0100}$$

$$\downarrow$$

$$\overbrace{0}^{8}\ \overbrace{0}^{4}\ \overbrace{1}^{2}\ \overbrace{0}^{1} = 2$$

$$\overbrace{0}^{8}\ \overbrace{1}^{4}\ \overbrace{0}^{2}\ \overbrace{0}^{1} = 4$$

Non-Weighted Codes

- In this type of binary codes,
    - The positional weights are not assigned
    - The examples of nonweighted codes are Excess-3 code and Gray code

Excess-3 Code

- also called `XS-3` code
- It is non-weighted code used to express decimal numbers
- The Excess-3 code words are derived from the 8421 BCD code words adding $(0011)_2$ or $(3)_{10}$ to each code word in 8421

The excess-3 codes are obtained as follows

Example : **Decimal** $\Longrightarrow 8421_{BCD} \Longrightarrow$ **Excess-3**

```
Decimal    BCD   Excess-3
           8421  BCD+0011
-------------------------
0          0000  0011
1          0001  0100
2          0010  0101
3          0011  0110
4          0100  0111
5          0101  1000
6          0110  1001
7          0111  1010
```

Gray Code

- It is the non-weighted code and it is not arithmetic codes
- Application of Gray code
  - Gray code is popularly used in the shaft position encoders
  - A shaft position encoder produces a code word which represents the angular position of the shaft

Binary Coded Decimal (BCD) Code

- In this code each decimal digit is represented by a 4-bit binary number
- BCD is a way to express each of the decimal digits with a binary code
- In the BCD, with four bits we can represent sixteen numbers (0000 to 1111)

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

Alphanumeric Codes

- Abinary digit or bit can represent only two symbols as it has only two states '0' or '1'
- But this is not enough for communication between two computers because there we need many more symbols for communication.
- These symbols are required to represent 26 alphabets with capital and small letters, numbers from 0 to 9, punctuation marks and other symbols
- The alphanumeric codes are the codes that represent numbers and alphabetic characters
- Mostly such codes also represent other characters such as symbol and various instructions necessary for conveying information

- The following three alphanumeric codes are very commonly used for the data representation.
    - American Standard Code for Information Interchange (ASCII)
    - Extended Binary Coded Decimal Interchange Code (EBCDIC)
    - Five bit Baudot Code

Number Base Conversions

- Binary to BCD Conversion
- BCD to Binary Conversion
- BCD to Excess-3
- Excess-3 to BCD

Binary to BCD Conversion

- **Step-1**: Convert the binary number to decimal
- **Step-2**: Convert decimal number to BCD

Step-1 : Binary to Decimal Conversion

Convert to **Decimal** Equivalent

Example : Convert $(11101)_2$ to **BCD**

$$= (11101)_2$$
$$= ((1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0))_{10}$$
$$= (16 + 8 + 4 + 0 + 1)_{10}$$
$$= 29_{10}$$
$$\downarrow$$
$$(11101)_2 = 29_{10}$$

Step-2: Decimal to BCD Conversion

Convert to **BCD** Equivalent

Example : Convert $(11101)_2$ to **BCD**

Convert each digit into groups of four binary digits equivalent

$$= (11101)_2 = 29_{10}$$
$$= 29_{10}$$
$$= 0010_2 1001_2$$
$$= (00101001)_{BCD}$$
$$\downarrow$$
$$(11101)_2 = (00101001)_{BCD}$$

BCD to Decimal Conversion

- Calculating Decimal Equivalent
  - Convert each four digit into a group and get decimal equivalent for each group

$$
\begin{aligned}
&= (00101001)_{BCD} \\
&= 0010_2 1001_2 \\
&= 2_{10} 9_{10} \\
&= 29_{10} \\
&\downarrow \\
&(00101001)_{BCD} = 29_{10}
\end{aligned}
$$

- Calculating Binary Equivalent of 29_{10}
  - *Used long division method for decimal to binary conversion*

$$\text{Step-1} = 29/2 \implies result : 14\ remainder : 1$$
$$\text{Step-2} = 14/2 \implies result : 7\ remainder : 0$$
$$\text{Step-3} = 7/2 \implies result : 3\ remainder : 1$$
$$\text{Step-4} = 3/2 \implies result : 1\ remainder : 1$$
$$\text{Step-5} = 1/2 \implies result : 0\ remainder : 1$$
$$\downarrow$$
$$29_{10} = (11101)_2 = (00101001)_{BCD}$$

BCD to Excess-3 Conversion

Step 1: Convert BCD to decimal

Step 2: Add $(3)_{10}$ to this decimal number

Step 3:Convert into binary to get excess-3 code

BCD to Excess-3 Conversion

Example – convert $(1001)_{BCD}$ to **Excess-3**

$$= \text{Step-1:Convert to Decimal} \rightarrow (1001)_{BCD} = 9_{10}$$

$$= \text{Step-2:Add 3 to decimal} \rightarrow 9_{10} + 3_{10} = 12_{10}$$

$$= \text{Step-3:Convert to Excess-3} \rightarrow 12_{10} = (1100)_2$$

$$\downarrow$$

$$(1001)_{BCD} = (1100)_{XS-3}$$

Excess-3 to BCD Conversion

- Subtract $(0011)_2$ from each 4 bit of `excess-3` digit to obtain the corresponding BCD code

Excess-3 to BCD Conversion

Example: Convert $(10011010)_{XS-3}$ to **BCD**.

```
Given XS-3 number  = 1 0 0 1 1 0 1 0
Subtract (0011)_2  = 0 0 1 1 0 0 1 1
-------------------------------------
BCD                = 0 1 1 0 0 1 1 1
```

Result

$$(10011010)_{XS-3} = (01100111)_{BCD}$$

PART 2: BINARY ARITHMETIC SYSTEMS

References

$$End - Of - Week - 2 - Module$$