UNIT 1 : LOGIC SIMPLIFICATION AND COMBINATIONAL LOGIC DESIGN

Today's Target

- **Binary-coded decimal**
- BCD Representation
- **BCD Addition**
- **BCD Subtraction: by 1's and by 9's complement method**
- **DPP**

Binary-coded decimal

- **Binary-coded decimal** (**BCD**) is: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- a class of binary encodings of decimal numbers
- each digit is represented by a fixed number of bits, usually four or eight.
- Sometimes, special bit patterns are used for a sign or other indications (e.g. error or overflow).

$\pm 9 = 0\,1001$ $\quad \ominus 9 = 1\,1001$

$-9 =$

BCD Representation for Decimal Digits

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

dec.	BCD
10	0001 (1) 0000 (0)
11 =	0001 0001
435	0100 0011 0101
78	0111 1000

$(1001\ 0110)_{BCD} = (96)_{10}$

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BCD ARITHMATIC

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- BCD Addition
- BCD Subtraction

BCD Addition

1) At first the given number are to be added using the rule of binary.

2) Result of addition consider two cases:

$0 + 0 = 0$
$0 + 1 = 1$
$1 + 0 = 1$
$1 + 1 = 0$ | 1 = carry
$1 + 1 + 1 = 1$ | 1 = carry

- **Case 1:** the result of addition is greater than 9 or if a carry bit is present in the result which is not valid for BCD number => Add 6 whose binary equivalent is $(0110)_2$ to the result of addition.

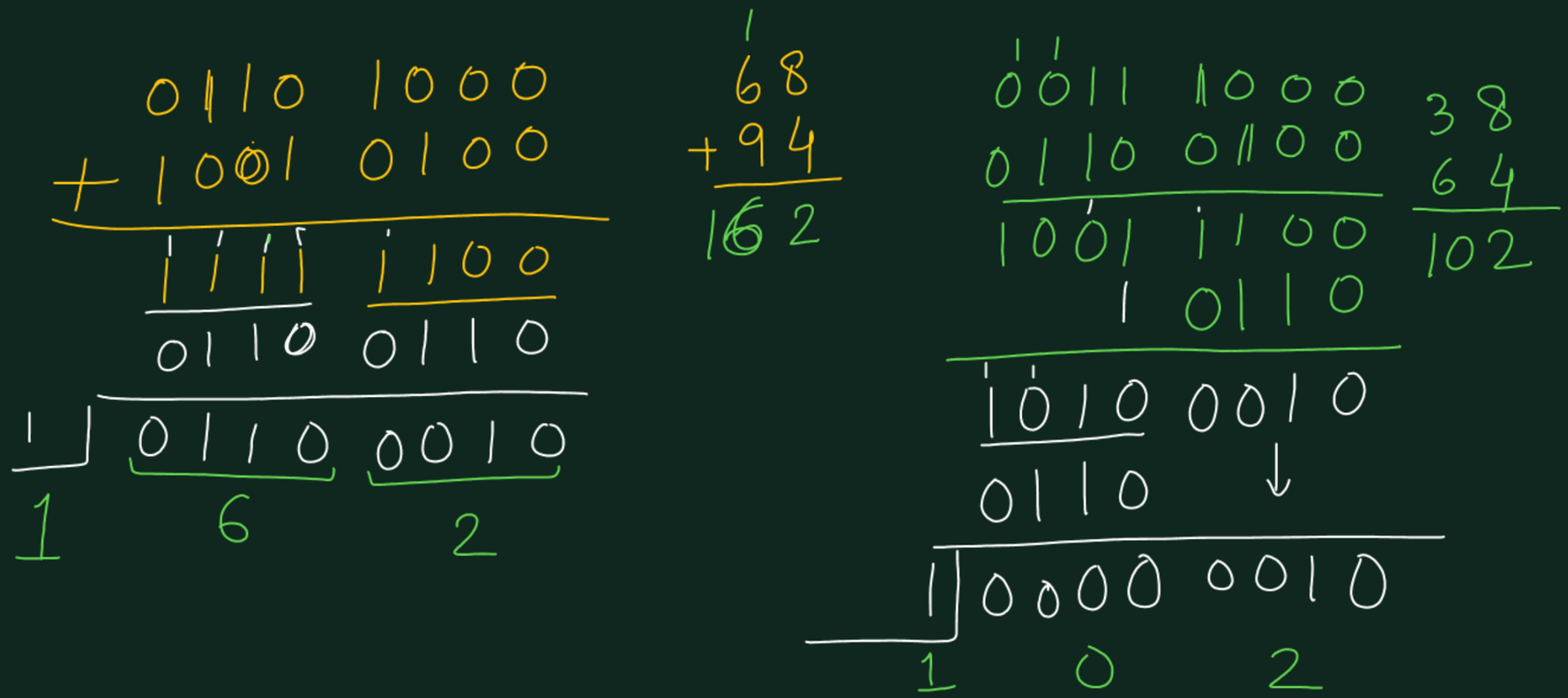
- **Case 2:** The result of addition in is less than 9, which is valid for BCD numbers.

Examples: (i) 1010 + 0101
(ii) 0001 + 0101
(iii) 0001 0001 + 0010 0110

```
  1 0 1 0   = (10)
+ 0 1 0 1   = (5)
-----------
  1 1 1 1  ⇐ Invalid BCD
+ 0 1 1 0
-----------
0001 | 0 1 0 1 |
-----------
  1      5
```

```
    1
  0 0 0 1
+ 0 1 0 1
---------
  0 1 1 0  ⇐ Result
```

```
0001 0001  = 11
+0010 0110  +26
-----------  ---
 0011 0111   37
-----------
   3    7
```


0110 1000
+1001 0100
1111 1100
0110 0110
1 0110 0010
1 6 2
1
68
+94
162
0011 1000
0110 0100
1001 1100
1 0110
1010 0010
0110
1 0000 0010
1 0 2
38
64
102

BCD Subtraction

- Method of BCD Subtraction : using 1's complement method

- Method of BCD Subtraction: using 9's complement method

1's complement

1 → 0

0 → 1

1's ⇒ 1 1 0 1 → 0 0 1 0

9's Complement

47 → 99 − 47 = 52 ← 9's of no.

Example : (i) 0101 0100 0001 - 0010 0001 0110 (ii) $(49)_{10} - (51)_{10}$

(iii) $(57)_{10} - (78)_{10}$

```
  0 1 0 1  0 1 0 0  0 0 0 1
- 0 0 1 0  0 0 0 1  0 1 1 0
-----------------------------
```

```
  5 4 1
- 2 1 6
-------
  3 2 5
```

```
I  : 0101  0100  0001
1's:+1101  1110  1001
-----------------------
  1  0011  0010  1010   <= Result +ve
```

```
  0011  0010  1010
⊗       1010
-----------------
  0011  0010  0100
                  1
-----------------
  0011  0010  0101
    3     2     5
```

```
  0 1 1 0   <= 6
  1 0 1 0   <= 2's of 6
```

```
  49   0 1 0 0  1 0 0 1
- 51   0 1 0 1  0 0 0 1
```

```
I:  0100  1001
1's:+1010 1110
---------------
 X  1111  0111   <= Result -ve
    0000  1000   <= 1's of Result
          1010   <= 2's of 6
⊗
---------------
    0000  0010
   -(0     2)
```

$(57)_{10} - (78)_{10}$

$$\begin{array}{r} 0101\ \ 0111 \\ -\ 0111\ \ 1000 \\ \hline \end{array}$$

$$\begin{array}{lll} & \overset{\otimes}{0}101 & 0111 \\ \text{I:} & \hline & \hline \\ \text{1's of II:} & +1000 & 0111 \\ \hline \end{array}$$

$$\times\ \ 1101\ \ 1110 \Leftarrow \text{No carry, Result -ve}$$

$$\underbrace{0010}_{(2}\ \ \underbrace{0001}_{1)} \Leftarrow \text{1's of Result}$$

1) Take I no.
2) Add 1's of II no. (-ve no.)
3) If carry is generated, Result is +ve
   ⇒ If all digits are valid BCD ⇒ Result ok
   ⇒ If digit is invalid BCD add 2's of 6 (i.e. 1010) to invalid digit
4) If no carry → Result is -ve
   ⇒ take 1's of Result
   ⇒ Check if carry was generated from I nibble to 2 nibble
      → If carry generated → add 0110 to lower nibble
      → otherwise take result as it is.

Example : (iv) $(57)_{10} - (82)_{10}$

I's : 0 1 0 1 0 1 1 1

1's of II : +0 1 1 1 1 1 0 1

1 1 0 1 0 1 0 0 ⇐ Result -ve

0 0 1 0 1 0 1 1 ⇐ 1's of Result

⊗ 1 0 1 0 ⇐ 2's of 6

0 0 1 0 0 1 0 1

−(2 5)

(v) $(46)_{10} - (78)_{10}$

I : 0 1 0 0 0 1 1 0

1's of II : + 1 0 0 0 0 1 1 1

1 1 0 0 1 1 0 1 ⇐ Result -ve

0 0 1 1 0 0 1 0 ⇐ 1's of Result

−(3 2)

BCD Subtraction: using 9's complement method

- (0101 0001) – (0010 0001)

$$\begin{array}{r} 51 \\ -21 \\ \hline \end{array}$$

$$\begin{array}{r} 99 \\ -21 \\ \hline 78 \end{array} \Leftarrow 9\text{'s of } 21$$

I : 51

9's of II : 78

$$\begin{array}{r} 129 \\ \hookrightarrow 1 \\ \hline 30 \end{array} \Leftarrow \text{Result +ve}$$

21 – 51

$$\begin{array}{r} 99 \\ -51 \\ \hline 48 \end{array} \Leftarrow 9\text{'s of } 51$$

I : 21

9's of II : 48

$$\begin{array}{r} 69 \\ \hline \end{array} \Leftarrow \text{Result -ve}$$

$-(30) \Leftarrow$ 9's of Result

$$\begin{array}{r} 99 \\ -69 \\ \hline 30 \end{array}$$

DPP

Write :

a) $(1011010.10110)_2 = (\ )_{BCD}$

b) $(247)_{10} = (\ )_{BCD}$

c) $(0.01010010)_{BCD} = (\ )_{10}$

d) $(421)_{10} + (179)_{10} = (\ )_{BCD}$

e) $(125)_{10} - (562)_{10} = (\ )_{BCD}$ using 1's and 9's complement

f) $(721)_{10} - (158)_{10} = (\ )_{BCD}$ using 1's and 9's complement

g) $(845)_{10} - (123)_{10} = (\ )_{BCD}$ using 1's and 9's complement

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Thank You

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