+20

- signed mag.
- 1's Complement
- 2's Complement

8 bit

+20

00010100

+20   +0

$\boxed{-0}$

-20

signed

1's

2's

(-20)

10010100

16 8 4 2 1

1 0 1 0 0

1's comp → 11101011 = (-20)

2's Com → 11101100 → (-20)

11101011
+1

11101100

32 bit

$2^{31} \ldots 2^{3} \quad 2^{2} \quad 2^{1} \quad 2^{0}$

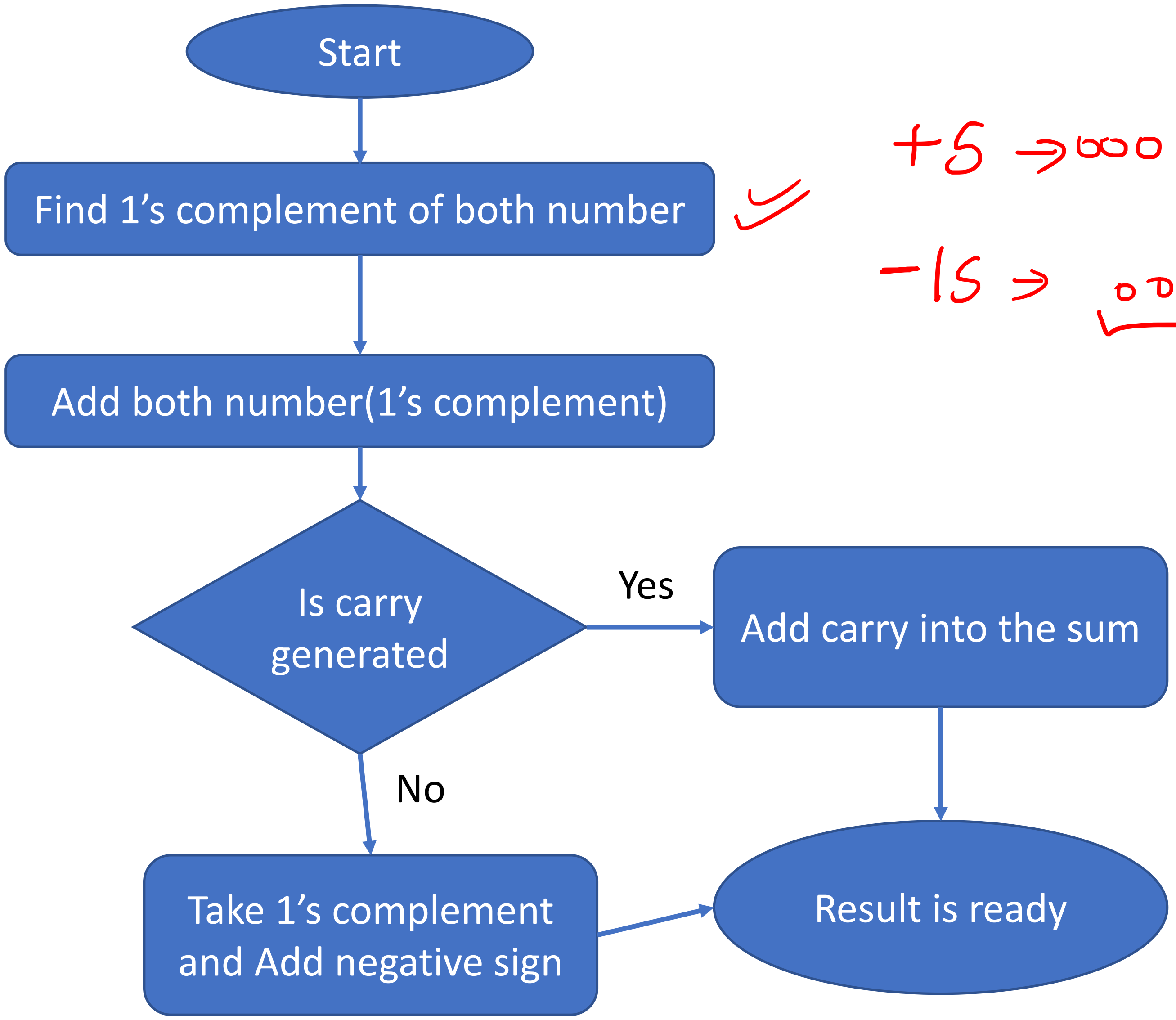
8 4 2 1

20+5

20-5

Subtraction using 1's complement

8 bit



+5 - 15

+5 → 00000101

-15 → $\underbrace{00001111}_{+15}$ $\xrightarrow{1\text{'s com}}$ $\underbrace{\boxed{11110000}}_{-15}$

$$\begin{array}{r} 00000101 \\ +\ 11110000 \\ \hline 11110101 \end{array}$$

No carry

$\boxed{-\ 00001010}$

-10

Subtraction using 1's complement

19 − 5

00000101   +5

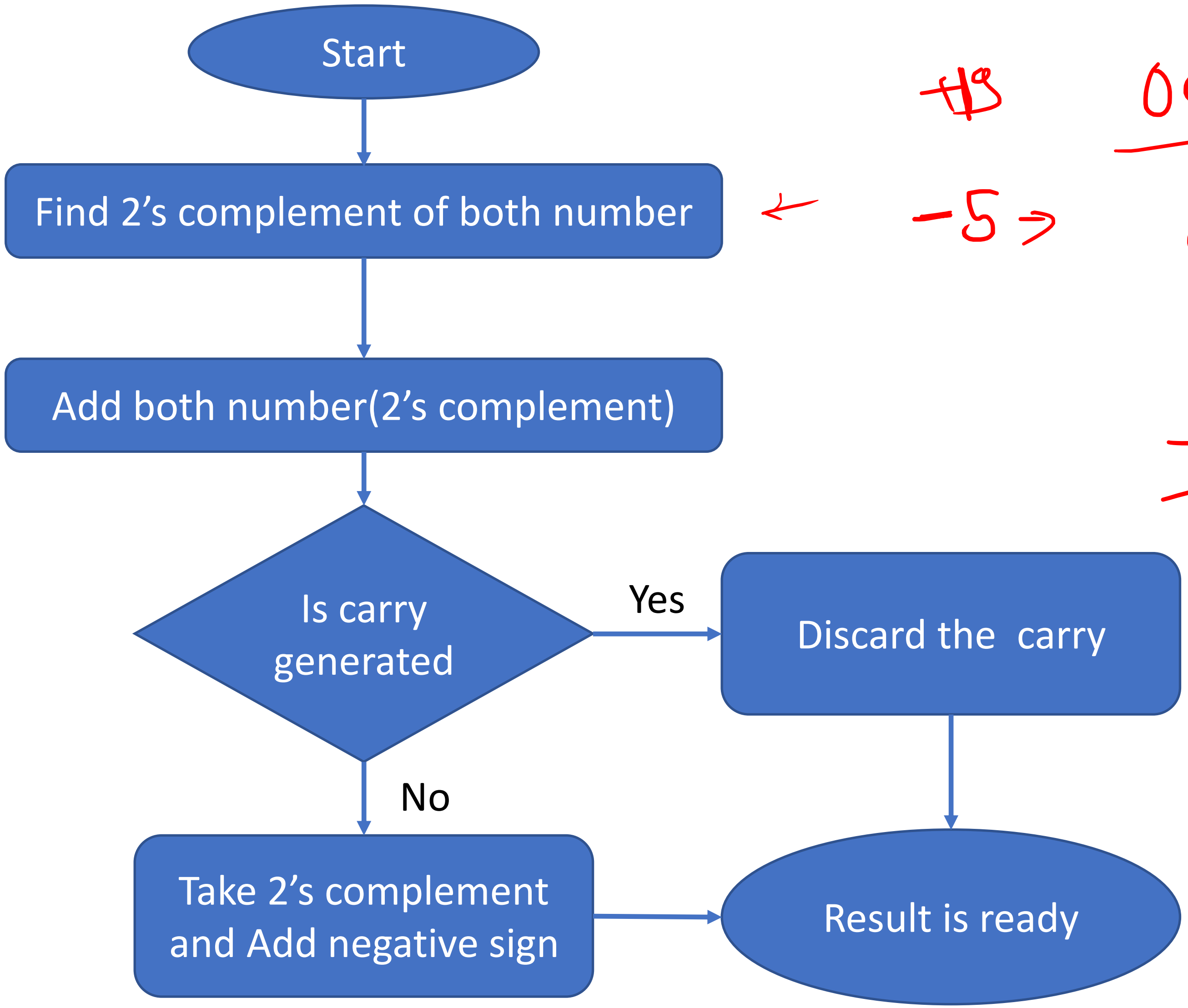
00010011
+ 11111010

1 00001101
+ 1

00001110   +14

10 − 20

Subtraction using 2's complement



11111011

19 − 5

+19   00010011

−5 → 00000101 → 11111010
+5
+ 1
11111011

−5
2's

00010011
11111011
x1) 00001110
Ans.

Subtraction using 2's complement

−10 →

+10

00001010

1's

11110101

+1

11110110

11110110

2's

16 8 4 2 1

00011110

+15 − 30

00001111

11100010

No carry

11110001

− 00001111

Ans

11100010

Binary Coded Decimal (BCD)

8421
1 5
0001 0101

- **The BCD code is the 8,4,2,1 code.**
- **8, 4, 2, and 1 are weights**
- **BCD is a *weighted* code**
- **This code is the simplest, most intuitive binary code for decimal digits and uses the same powers of 2 as a binary number, but only encodes the first ten values from 0 to 9.**
- **Example: 1001 (9) = 1000 (8) + 0001 (1)**

85
1000 0101

Think

- **How many “invalid” code words are there?**
- **What are the “invalid” code words?**

$0 \rightarrow 9$

0000 1001

1010 ← Binary

10

$\boxed{0001\ 0000}$ BCD

65

$\boxed{0110\ 0101}$

1000
1011
1100
1101
1110
1111

99

1001 1001

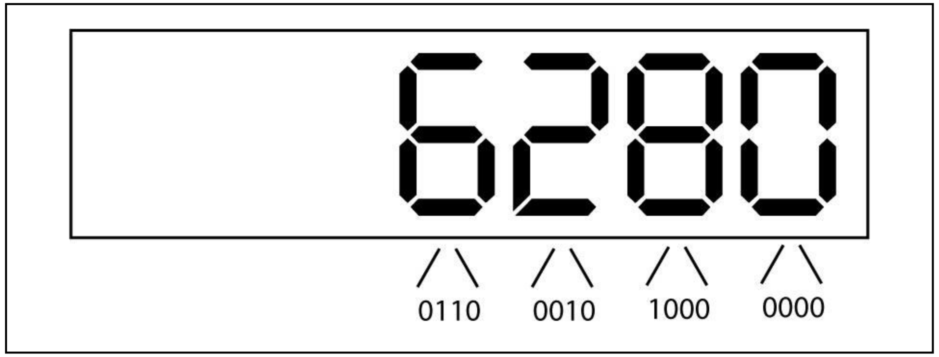
100

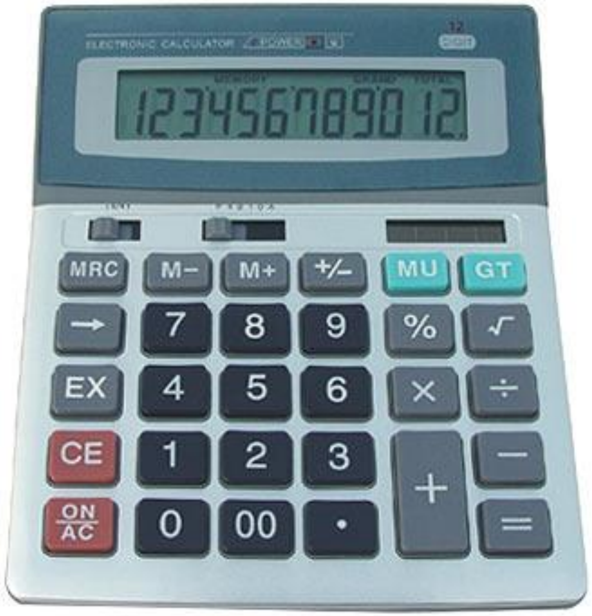
0001 0000 0000

$\boxed{8421}$

Uses of BCD

- BCD enables fast conversions from denary to binary for applications such as pocket calculators.
- Each digit on a calculator corresponds directly to a four-bit block in BCD.





BCD

8421

Excess 3 Code and 8, 4, –2, –1 Code

8 4 -2 -1

6

Decimal	Excess 3	8, 4, –2, –1
0	0011	0000
1	0100	0111
2	0101	0110
3	0110	0101
4	0111	0100
5	1000	1011
6	1001	1010
7	1010	1001
8	1011	1000
9	1100	1111

1010

7

1001

5

1011

- **What interesting property is common to these two codes?**

Warning: Conversion or Coding?

- **Do NOT mix up conversion of a decimal number to a binary number with coding a decimal number with a BINARY CODE.**
- **$13_{10} = 1101_2$ (This is conversion)**
- **13 $\Leftrightarrow$ 0001|0011 (This is coding)**

BCD Addition

- Consider the following BCD operation
  - Decimal: Add 4 + 1
  - Covert to binary 0 1 0 0
  - And <u>0 0 0 1</u>
  - Getting 0 1 0 1
  - Which is still a BCD representation of a decimal digit

Another

- A second example
  - 3 0 0 1 1
  - +3 <u>0 0 1 1</u>
  - Getting 6 or 0 1 1 0
  - And in range and a BCD digit representation

0110
0100
1010
0110
000 1 0000
1 0

6
+4

1001

0110
0100
1010

+6

0000, 0001, 0010 ...
0 1 2

1001, 1010, 1011, 1100, 1101, 1110, 1111
9

0001 0000

BCD Arithmetic

Given a BCD code, we use binary arithmetic to add the digits:

8	**1000**	**Eight**
+5	**+0101**	**Plus 5**
13	**1101**	**is 13 (> 9)**

Note that the result is MORE THAN 9, so must be represented by two digits!

To correct the digit, adding 6.

8	**1000**	**Eight**
+5	**+0101**	**Plus 5**
13	**1101**	**is 13 (> 9)**
	+0110	**so add 6**
	carry = 1 0011	**leaving 3 + cy**
	0001 | 0011	**Final answer (two digits)**

If the digit sum is > 9, add one to the next significant digit

BCD Addition Example

- **Add 2905_{BCD} to 1897_{BCD} showing carries and digit corrections.**

1897

2905

				0
	0001	**1000**	**1001**	**0111**
+	**0010**	**1001**	**0000**	**0101**
	____	____	____	____

Number of Bits Required

2

- **Given M elements to be represented by a binary code, the minimum number of bits, *n*, needed, satisfies the following relationships:**

$$\boxed{2^n \geq M > 2^{(n-1)}}$$

$$n = \lceil \log_2 M \rceil$$

where $\lceil x \rceil$, called the *ceiling function,* is the integer greater than or equal to *x*.

$2^5 \quad 2^4 \quad 2^3 \quad 2^2 \quad 2^1 \quad 2^0$

$32 \quad 16 \quad 8 \quad 4 \quad 2 \quad 1$

- **Example: How many bits are required to represent <u>decimal digits</u> with a binary code?**

21

$2^5 \leq 21 < 2^4$

8

$2^3 \geq 8 < 2^2$

Number of Elements Represented

- **Given *n* digits in radix *r*, there are r^n distinct elements that can be represented.**
- **But, you can represent m elements, m < r^n**
- **Examples:**
  - **You can represent 4 elements in radix *r* = 2 with *n* = 2 digits: (00, 01, 10, 11).**
  - **You can represent 4 elements in radix *r* = 2 with *n* = 4 digits: (0001, 0010, 0100, 1000).**
  - **This second code is called a "one hot" code.**

1 will appear only one time.