Sep 28

Admin

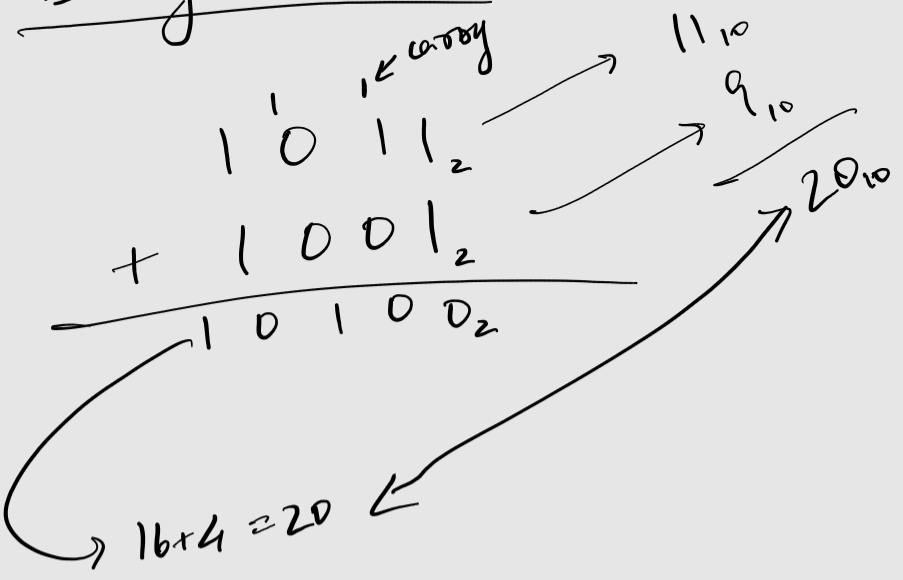
Exam
↳ Thu, Oct 1
in-class, 90 mins

content previous week
Sep 23/24/25

Agenda

- Binary addition
- Two's complement
- Practice Exam.

Binary Addition



1+1 = 10

9+9 = 18

Subtraction (via addition): $4 - 3 = 4 + (-3)$

1st idea: use a "sign bit" so $-3 \rightarrow$ 1 11
"-" "3"

+3 → 011

Two's Complement

1. Decide # of bits to use. In our eg. 8 bits
2. Positive numbers → usual binary but only up to 7 bits

$$0_______$$

eg. $3_{10} = 00000011_2$ → 2's complement

3. Negative numbers "$-n$" → i) usual binary for "n" → (limited to using 7 bits)
   ii) flip all bits
   iii) add 1.

eg: -3_{10} → i) $\underbrace{0000011}_{\text{7 bits}}$ ✓

ii) 1111 1100

iii) 1111 1101 → -3 in 2's complement

eg. $4 - 3 = 4 + (-3)$

4 bit 2's complement

$4 \rightarrow 0100$

$-3 \rightarrow$ i) 0011
ii) 1100
iii) 1101

$$\begin{array}{r} 4 \rightarrow 0100 \\ +(-3) \rightarrow +\ 1101 \\ \hline 0001 \end{array}$$

(carry 1)

0001 → 2's complement

$-4 \rightarrow 0100 \xrightarrow{\text{flip}} 1011 \xrightarrow{+1} 1100$

$+3 \rightarrow 0011 \qquad\qquad 0011$

1111

↳ -1 in 2's complement

4 bit 2's comp

$$\begin{array}{r} {\scriptstyle 1\ 1\ \ \ \ } \\ 0111 \\ +\ 0010 \\ \hline 1001 \end{array} \quad \begin{array}{l} \rightarrow 7 \\ \rightarrow 2 \\ \hline 9 \xrightarrow{\text{binary}} 1001 \end{array}$$

true + true → -ve is an overflow

positive +

1001 in 2's complement → decimal

i) subtract 1 → 1000

ii) flip bits → 0111

iii) convert to decimal with a minus sign in front. → -7

4-bit 2's complement

$-2^3, \ldots -2, -1, 0, 1, 2, \ldots, 2^3 - 1$, ~~8~~

0111 → 7
0110 → 6
0101 → 5
⋮ ⋮
0001 → 1
0000 → 0
1111 → -1
1110 → -2
⋮

n-bit 2's complement

$-2^{n-1} \ldots\ldots 2^{n-1} - 1, \ 2^{n-1}$ ~~X~~ can't be repr.

8

1000 → −8