# Lecture 02: Binary Arithmatic

**Electronics, Devices and Circuits Part II**

Prakash Gaikwad, AASE

January 13, 2026

# Base Conversion (Decimal $\leftrightarrow$ Binary)

- Convert $(567)_{10}$ to binary
- $567/2$

# Base Conversion (Decimal $\leftrightarrow$ Binary)

- Convert $(567)_{10}$ to binary
- $567/2$
- Quotient $\rightarrow 283 \rightarrow 141 \rightarrow 70 \rightarrow 35 \rightarrow 17 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1 \rightarrow 0$
- Remainder $\rightarrow 1 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 0 \rightarrow 0 \rightarrow 1$

# Base Conversion (Decimal $\leftrightarrow$ Binary)

- Convert $(567)_{10}$ to binary
- 567/2
- Quotient $\rightarrow 283 \rightarrow 141 \rightarrow 70 \rightarrow 35 \rightarrow 17 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1 \rightarrow 0$
- Remainder $\rightarrow 1 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 0 \rightarrow 0 \rightarrow 1$
- Write the binary representation in reverse order i.e. left to right $\leftarrow$
- $(567)_{10} = (1000110111)_2$

# Base Conversion (Decimal $\leftrightarrow$ Binary)

- Convert $(567)_{10}$ to binary
- $567/2$
- Quotient $\rightarrow 283 \rightarrow 141 \rightarrow 70 \rightarrow 35 \rightarrow 17 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1 \rightarrow 0$
- Remainder $\rightarrow 1 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 0 \rightarrow 0 \rightarrow 1$
- Write the binary representation in reverse order i.e. left to right $\leftarrow$
- $(567)_{10} = (1000110111)_2$
- Check if it correct
- $1 \times 2^9 + 0 \times 2^8 + 0 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$
- $512 + 0 + 0 + 0 + 32 + 16 + 0 + 4 + 2 + 1 = 567$

# Base Conversion (Decimal $\leftrightarrow$ Binary)

- Convert $(567)_{10}$ to binary
- $567/2$
- Quotient $\rightarrow 283 \rightarrow 141 \rightarrow 70 \rightarrow 35 \rightarrow 17 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1 \rightarrow 0$
- Remainder $\rightarrow 1 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 1 \rightarrow 1 \rightarrow 0 \rightarrow 0 \rightarrow 0 \rightarrow 1$
- Write the binary representation in reverse order i.e. left to right $\leftarrow$
- $(567)_{10} = (1000110111)_2$
- Check if it correct
- $1 \times 2^9 + 0 \times 2^8 + 0 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$
- $512 + 0 + 0 + 0 + 32 + 16 + 0 + 4 + 2 + 1 = 567$
- How to convert this in to Quaternary (4), Octal (8) or Hexadecimal (16)?

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)

- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $0 \times 10^9 + 1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(0 \times 10^9 + 1 \times 10^8) + (2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4) + (6 \times 10^3 + 7 \times 10^2) + (8 \times 10^1 + 9 \times 10^0)$

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $0 \times 10^9 + 1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(0 \times 10^9 + 1 \times 10^8) + (2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4) + (6 \times 10^3 + 7 \times 10^2) + (8 \times 10^1 + 9 \times 10^0)$
- $(0 \times 10 + 1) \times 10^8 + (20 + 3) \times 10^6 + (40 + 5) \times 10^4 + (60 + 7) \times 10^2 + (80 + 9) \times 10^0$

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $0 \times 10^9 + 1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(0 \times 10^9 + 1 \times 10^8) + (2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4) + (6 \times 10^3 + 7 \times 10^2) + (8 \times 10^1 + 9 \times 10^0)$
- $(0 \times 10 + 1) \times 10^8 + (20 + 3) \times 10^6 + (40 + 5) \times 10^4 + (60 + 7) \times 10^2 + (80 + 9) \times 10^0$
- $(0 \times 10 + 1) \times 100^4 + (20 + 3) \times 100^3 + (40 + 5) \times 100^2 + (60 + 7) \times 100^1 + (80 + 9) \times 100^0$

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $0 \times 10^9 + 1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(0 \times 10^9 + 1 \times 10^8) + (2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4) + (6 \times 10^3 + 7 \times 10^2) + (8 \times 10^1 + 9 \times 10^0)$
- $(0 \times 10 + 1) \times 10^8 + (20 + 3) \times 10^6 + (40 + 5) \times 10^4 + (60 + 7) \times 10^2 + (80 + 9) \times 10^0$
- $(0 \times 10 + 1) \times 100^4 + (20 + 3) \times 100^3 + (40 + 5) \times 100^2 + (60 + 7) \times 100^1 + (80 + 9) \times 100^0$
- For base $b$ we must have $b$ unique symbols e.g., binary has 2, decimal has 10 and hexadecimal has 16 unique symbols

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $0 \times 10^9 + 1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(0 \times 10^9 + 1 \times 10^8) + (2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4) + (6 \times 10^3 + 7 \times 10^2) + (8 \times 10^1 + 9 \times 10^0)$
- $(0 \times 10 + 1) \times 10^8 + (20 + 3) \times 10^6 + (40 + 5) \times 10^4 + (60 + 7) \times 10^2 + (80 + 9) \times 10^0$
- $(0 \times 10 + 1) \times 100^4 + (20 + 3) \times 100^3 + (40 + 5) \times 100^2 + (60 + 7) \times 100^1 + (80 + 9) \times 100^0$
- For base $b$ we must have $b$ unique symbols e.g., binary has 2, decimal has 10 and hexadecimal has 16 unique symbols
- Let base 100 has unique symbols $a_{00}, a_{01}, a_{02}, a_{03}, \cdots a_{98}, a_{99}$

# Base Conversion (Base 10 $\leftrightarrow$ Base 100)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $0 \times 10^9 + 1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(0 \times 10^9 + 1 \times 10^8) + (2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4) + (6 \times 10^3 + 7 \times 10^2) + (8 \times 10^1 + 9 \times 10^0)$
- $(0 \times 10 + 1) \times 10^8 + (20 + 3) \times 10^6 + (40 + 5) \times 10^4 + (60 + 7) \times 10^2 + (80 + 9) \times 10^0$
- $(0 \times 10 + 1) \times 100^4 + (20 + 3) \times 100^3 + (40 + 5) \times 100^2 + (60 + 7) \times 100^1 + (80 + 9) \times 100^0$
- For base $b$ we must have $b$ unique symbols e.g., binary has 2, decimal has 10 and hexadecimal has 16 unique symbols
- Let base 100 has unique symbols $a_{00}, a_{01}, a_{02}, a_{03}, \cdots a_{98}, a_{99}$
- $a_{01} \times 100^4 + a_{23} \times 100^3 + a_{45} \times 100^2 + a_{67} \times 100^1 + a_{89} \times 100^0$
- $(a_{01}a_{23}a_{45}a_{67}a_{89})_{100} = (123456789)_{10}$

# Base Conversion (Base 10 $\leftrightarrow$ Base 1000)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3) + (7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0)$

# Base Conversion (Base 10 $\leftrightarrow$ Base 1000)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3) + (7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0)$
- $(100 + 20 + 3) \times 10^6 + (400 + 50 + 6) \times 10^3 + (700 + 80 + 9) \times 10^0$

# Base Conversion (Base 10 $\leftrightarrow$ Base 1000)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3) + (7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0)$
- $(100 + 20 + 3) \times 10^6 + (400 + 50 + 6) \times 10^3 + (700 + 80 + 9) \times 10^0$
- $(123) \times 1000^2 + (456) \times 1000^1 + (789) \times 1000^0$

# Base Conversion (Base 10 $\leftrightarrow$ Base 1000)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3) + (7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0)$
- $(100 + 20 + 3) \times 10^6 + (400 + 50 + 6) \times 10^3 + (700 + 80 + 9) \times 10^0$
- $(123) \times 1000^2 + (456) \times 1000^1 + (789) \times 1000^0$
- Base 1000 has unique symbols $a_{000}, a_{001}, a_{002}, \cdots, a_{500}, \cdots, a_{998}, a_{999}$
- $a_{123} \times 1000^2 + a_{456} \times 1000^1 + a_{789} \times 1000^0$

# Base Conversion (Base 10 $\leftrightarrow$ Base 1000)

- Consider a number $(123456789)_{10} = (?)_{100}$ (How to convert to base 100?)
- $1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6 + 4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3 + 7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0$
- $(1 \times 10^8 + 2 \times 10^7 + 3 \times 10^6) + (4 \times 10^5 + 5 \times 10^4 + 6 \times 10^3) + (7 \times 10^2 + 8 \times 10^1 + 9 \times 10^0)$
- $(100 + 20 + 3) \times 10^6 + (400 + 50 + 6) \times 10^3 + (700 + 80 + 9) \times 10^0$
- $(123) \times 1000^2 + (456) \times 1000^1 + (789) \times 1000^0$
- Base 1000 has unique symbols $a_{000}, a_{001}, a_{002}, \cdots, a_{500}, \cdots, a_{998}, a_{999}$
- $a_{123} \times 1000^2 + a_{456} \times 1000^1 + a_{789} \times 1000^0$
- $(a_{123}a_{456}a_{789})_{1000} = (123456789)_{10}$

# Base Conversion

- We have $(123456789)_{10} = (a_{01} a_{23} a_{45} a_{67} a_{89})_{100} = (a_{123} a_{456} a_{678})_{1000}$
- What is the pattern?

# Base Conversion

- We have $(123456789)_{10} = (a_{01}a_{23}a_{45}a_{67}a_{89})_{100} = (a_{123}a_{456}a_{678})_{1000}$
- What is the pattern?
- If we have number in base 10 and convert to base $10^2 = 100$
- Group the number in 2 digits 123456789 starting from left most
- $123456789 \to 1234567\ \underline{89} \to 12345\ \underline{67}\ \underline{89} \to 123\ \underline{45}\ \underline{67}\ \underline{89} \to 1\ \underline{23}\ \underline{45}\ \underline{67}\ \underline{89} \to \underline{01}\ \underline{23}\ \underline{45}\ \underline{67}\ \underline{89}$
- Replace each group of two with unique symbols $a_{01}a_{23}a_{45}a_{67}a_{89}$

# Base Conversion

- We have $(123456789)_{10} = (a_{01}a_{23}a_{45}a_{67}a_{89})_{100} = (a_{123}a_{456}a_{678})_{1000}$
- What is the pattern?
- If we have number in base 10 and convert to base $10^2 = 100$
- Group the number in 2 digits 123456789 starting from left most
- $123456789 \rightarrow 1234567\ \underline{89} \rightarrow 12345\ \underline{67}\ \underline{89} \rightarrow 123\ \underline{45}\ \underline{67}\ \underline{89} \rightarrow 1\ \underline{23}\ \underline{45}\ \underline{67}\ \underline{89} \rightarrow \underline{01}\ \underline{23}\ \underline{45}\ \underline{67}\ \underline{89}$
- Replace each group of two with unique symbols $a_{01}a_{23}a_{45}a_{67}a_{89}$
- If we have number in base 10 and convert to base $10^3 = 1000$
- Group the number in 3 digits 123456789 starting from left most
- $123456789 \rightarrow 123456\ \underline{789} \rightarrow 123\ \underline{456}\ \underline{789} \rightarrow \underline{123}\ \underline{456}\ \underline{789}$
- Replace them group of two with unique symbols $a_{123}a_{456}a_{789}$
- How do we convert binary (base 2) to hexadecimal (base 16)?

# Base Conversion (Binary $\leftrightarrow$ Hexadecimal)

- Suppose we want to convert $(1000110111)_2$ to hexadecimal ($2^4$)

# Base Conversion (Binary $\leftrightarrow$ Hexadecimal)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Suppose we want to convert $(1000110111)_2$ to hexadecimal ($2^4$)
- Write decimal-binary-hexadecimal table

# Base Conversion (Binary $\leftrightarrow$ Hexadecimal)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Suppose we want to convert $(1000110111)_2$ to hexadecimal $(2^4)$
- Write decimal-binary-hexadecimal table
- Group them in 4 from left most digits
- $(1000110111)_2 = (\underline{0010}\ \underline{0011}\ \underline{0111})_2$

# Base Conversion (Binary $\leftrightarrow$ Hexadecimal)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Suppose we want to convert $(1000110111)_2$ to hexadecimal $(2^4)$
- Write decimal-binary-hexadecimal table
- Group them in 4 from left most digits
- $(1000110111)_2 = (\underline{0010}\ \underline{0011}\ \underline{0111})_2$
- Look for hexadecimal symbols for 0010, 0011 and 0111
- $(0010)_2 = (2)_{16}$
- $(0011)_2 = (3)_{16}$
- $(0111)_2 = (7)_{16}$

# Base Conversion (Binary $\leftrightarrow$ Hexadecimal)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Suppose we want to convert $(1000110111)_2$ to hexadecimal ($2^4$)
- Write decimal-binary-hexadecimal table
- Group them in 4 from left most digits
- $(1000110111)_2 = (\underline{0010}\ \underline{0011}\ \underline{0111})_2$
- Look for hexadecimal symbols for 0010, 0011 and 0111
- $(0010)_2 = (2)_{16}$
- $(0011)_2 = (3)_{16}$
- $(0111)_2 = (7)_{16}$
- $(1000110111)_2 = (237)_{16}$

# Base Conversion (Binary $\leftrightarrow$ Hexadecimal)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Suppose we want to convert $(1000110111)_2$ to hexadecimal ($2^4$)
- Write decimal-binary-hexadecimal table
- Group them in 4 from left most digits
- $(1000110111)_2 = (\underline{0010}\ \underline{0011}\ \underline{0111})_2$
- Look for hexadecimal symbols for 0010, 0011 and 0111
- $(0010)_2 = (2)_{16}$
- $(0011)_2 = (3)_{16}$
- $(0111)_2 = (7)_{16}$
- $(1000110111)_2 = (237)_{16}$
- $2 \times 16^2 + 3 \times 16^1 + 7 \times 16^0 = 567$

## Base Conversion (Decimal $\leftrightarrow$ Binary)

- Convert $(829)_{10}$ and $(754)_{10}$ to binary

# Base Conversion (Decimal $\leftrightarrow$ Binary)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Convert $(829)_{10}$ and $(754)_{10}$ to binary
- $(829)_{10}$ Convert to base 16 for efficiency
- Q $\rightarrow$ 51 $\rightarrow$ 3 $\rightarrow$ 0
- R $\rightarrow$ 13 $\rightarrow$ 3 $\rightarrow$ 3
- Ans: $(33\mathrm{D})_{16} = (\underline{0011}\ \underline{0011}\ \underline{1101})_2$
- $(754)_{10}$ Convert to base 16 for efficiency

# Base Conversion (Decimal $\leftrightarrow$ Binary)

| 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 |
| 9 | 1001 | 11 | 9 |
| 10 | 1010 | 12 | A |
| 11 | 1011 | 13 | B |
| 12 | 1100 | 14 | C |
| 13 | 1101 | 15 | D |
| 14 | 1110 | 16 | E |
| 15 | 1111 | 17 | F |

- Convert $(829)_{10}$ and $(754)_{10}$ to binary
- $(829)_{10}$ Convert to base 16 for efficiency
- Q $\rightarrow$ 51 $\rightarrow$ 3 $\rightarrow$ 0
- R $\rightarrow$ 13 $\rightarrow$ 3 $\rightarrow$ 3
- Ans: $(33\mathrm{D})_{16} = (\underline{0011}\ \underline{0011}\ \underline{1101})_2$
- $(754)_{10}$ Convert to base 16 for efficiency
- Q $\rightarrow$ 47 $\rightarrow$ 2 $\rightarrow$ 0
- R $\rightarrow$ 2 $\rightarrow$ 15 $\rightarrow$ 2
- Ans: $(2\mathrm{F}2)_{16} = (\underline{0010}\ \underline{1111}\ \underline{0010})_2$

# Binary Arithmatic

- Basic Arithmatic Operations : Addition, Subtraction, Multiplication, Division

## Binary Arithmatic

- Basic Arithmatic Operations : Addition, Subtraction, Multiplication, Division

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1{+}1 = 0\ (\mathrm{Carry}\ 1)$

# Binary Arithmatic

- Basic Arithmatic Operations : Addition, Subtraction, Multiplication, Division

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1{+}1 = 0\ (\text{Carry } 1)$

**Subtraction Rules**

- $0 - 0 = 0$
- $1 - 0 = 1$
- $1 - 1 = 0$
- $0 - 1 = 1\ (\text{Borrow } 1)$

# Binary Arithmatic

- Basic Arithmatic Operations : Addition, Subtraction, Multiplication, Division

## Addition Rules

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1+1 = 0 \text{ (Carry 1)}$

## Subtraction Rules

- $0 - 0 = 0$
- $1 - 0 = 1$
- $1 - 1 = 0$
- $0 - 1 = 1 \text{ (Borrow 1)}$

## Multiplication Rules

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

# Binary Arithmatic

- Basic Arithmatic Operations : Addition, Subtraction, Multiplication, Division

### Addition Rules

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1+1 = 0 \text{ (Carry 1)}$

### Subtraction Rules

- $0 - 0 = 0$
- $1 - 0 = 1$
- $1 - 1 = 0$
- $0 - 1 = 1 \text{ (Borrow 1)}$

### Multiplication Rules

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

### Division Rules

- $0 \div 0 = \text{Undefined}$
- $0 \div 1 = 0$
- $1 \div 0 = \text{Undefined}$
- $1 \div 1 = 1$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$
\begin{array}{r}
1\ 1\ 0\ 0\ 1\ 1\ 1\ 1\ 0\ 1 \\
+\ \ 1\ 0\ 1\ 1\ 1\ 1\ 0\ 0\ 1\ 0 \\
\hline
\end{array}
$$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$
\begin{array}{r}
1\,1\,0\,0\,1\,1\,1\,1\,0\,1 \\
+\;\; 1\,0\,1\,1\,1\,1\,0\,0\,1\,0 \\
\hline
0\,1\,1\,1\,1
\end{array}
$$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$\begin{array}{rr}
 & 1\ 1\ 0\ 0\ 1\ 1\ 1\ 1\ 0\ 1 \\
+ & 1\ 0\ 1\ 1\ 1\ 1\ 0\ 0\ 1\ 0 \\
\text{Carry} \rightarrow & 1\ 1\ 1\ 1\ 1\phantom{\ 0\ 0\ 0\ 0\ 0} \\
\hline
 & 1\ 1\ 0\ 0\ 0\ 1\ 0\ 1\ 1\ 1\ 1
\end{array}$$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$
\begin{array}{rccccccccccc}
 & & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\
 & + & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\
\text{Carry} & \rightarrow & 1 & 1 & 1 & 1 & 1 & & & & & \\
\hline
 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1
\end{array}
$$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$\begin{array}{rccccccccccc}
 & & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\
+ & & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\
\text{Carry} \rightarrow & & 1 & 1 & 1 & 1 & 1 & & & & & \\
\hline
 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1
\end{array}$$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$
\begin{array}{rccccccccccc}
 & & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\
+ & & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\
\text{Carry} \rightarrow & & 1 & 1 & 1 & 1 & 1 & & & & & \\
\hline
 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1
\end{array}
$$

# Binary Arithmatic : Addition

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} + (754)_{10} = (1583)_{10}$
- Do we get same number in binary addition?
- $(829)_{10} = (1100111101)_2$ and $(754)_{10} = (1011110010)_2$

$$
\begin{array}{rcccccccccccc}
 & & & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\
 & + & & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\
\text{Carry} & \rightarrow & & \color{orange}{1} & \color{magenta}{1} & \color{green}{1} & \color{red}{1} & \color{blue}{1} & & & & & \\
\hline
 & & \color{orange}{1} & \color{orange}{1} & \color{magenta}{0} & \color{green}{0} & \color{red}{0} & \color{blue}{1} & 0 & 1 & 1 & 1 & 1
\end{array}
$$

- $2^{10} + 2^9 + 2^5 + 2^3 + 2^2 + 2^1 + 2^0$
- $1024 + 512 + 32 + 8 + 4 + 2 + 1 = 1583$

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | |
|---|---|
| First Original Number | 1 1 0 0 1 1 1 1 0 1 |
| Second Original Number | 1 0 1 1 1 1 0 0 1 0 |
| Answer | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | |
|---|---|
| First Original Number | 1 1 0 0 1 1 1 1 0 1 |
| Second Original Number | 1 0 1 1 1 1 0 0 1 0 |
| Answer | 0 0 0 1 0 0 1 0 1 1 |

Start with right most digit and perform subtraction

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| First Original Number | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| Second Original Number | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Answer | | | | | | | | | | 1 |

Can not subtract 1 from 0, need to borrow 1 from adjacent left digit

## Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | |
|---|---|
| First Modified Number | 1 1 0 0 1 1 1 0 10 1 |
| Second Original Number | 1 0 1 1 1 1 0 0 1 0 |
| Answer | 1 1 |

The adjacent digit becomes 0 and we borrow 1

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| First Modified Number | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| Second Original Number | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Answer | | | | | 0 | 0 | 1 | 0 | 1 | 1 |

Apply simple subtraction rules to next 4 digits

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| First Modified Number | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| Second Original Number | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Answer | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |

Need to borrow 1 from adjacent left digit but it is 0

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | |
|---|---|
| First Modified Number | 1 1 0 0 1 1 1 0 0 1 |
| Second Original Number | 1 0 1 1 1 1 0 0 1 0 |
| Answer | 0 0 0 1 0 0 1 0 1 1 |

Go to the adjacent left until we get 1

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

$$\begin{array}{r|l} \text{First Modified Number} & 1\ 0\ 10\ 0\ 1\ 1\ 1\ 0\ 0\ 1 \\ \text{Second Original Number} & 1\ 0\ \ 1\ 1\ 1\ 1\ 0\ 0\ 1\ 0 \\ \hline \text{Answer} & \quad\quad\quad\ 0\ 0\ 1\ 0\ 1\ 1 \end{array}$$

Now we can borrow 1 in the middle

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| First Modified Number | 1 | 0 | 1 | 10 | 1 | 1 | 1 | 0 | 0 | 1 |
| Second Original Number | 1 | 0 | 1 | 01 | 1 | 1 | 0 | 0 | 1 | 0 |
| Answer | 0 | 0 | 0 | 01 | 0 | 0 | 1 | 0 | 1 | 1 |

Now we can borrow 1 in the left, the middle digit becomes $(10)_2 - (01)_2 = (1)_2$

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

$$\begin{array}{r c c c c c c c c c c}
\text{First Modified Number} & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 \\
\text{Second Original Number} & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\
\hline
\text{Answer} & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1
\end{array}$$

Perform Simple Subtraction for next three digits

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Subtraction Rules**

- $0 - 0 = 0$
- $0 - 1 = 1$ (Borrow 1)
- $1 - 0 = 1$
- $1 - 1 = 0$

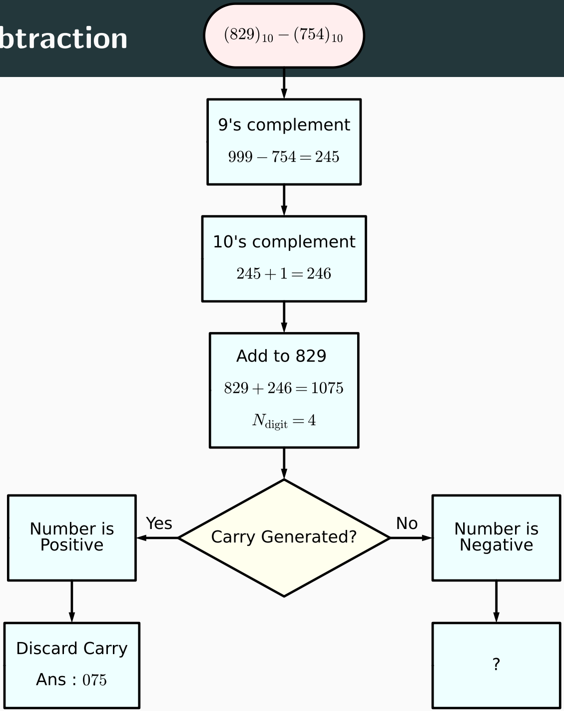
$$\begin{array}{r c c c c c c c c c c}
\text{First Modified Number} & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 \\
\text{Second Original Number} & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\
\hline
\text{Answer} & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1
\end{array}$$

Check final answer: $2^6 + 2^3 + 2^1 + 2^0 = 75$

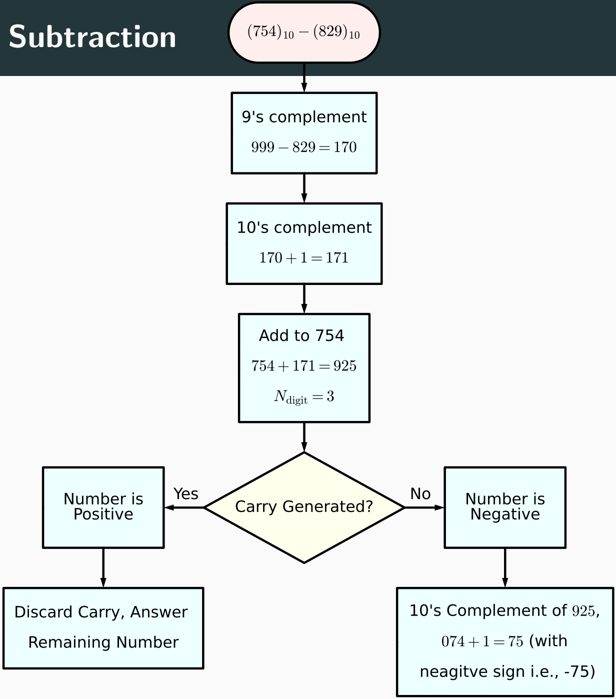
# Decimal Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Can we do this subtraction without Borrow method?

# Decimal Arithmatic : Subtraction



# Decimal Arithmatic : Subtraction



# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0 \text{ (Carry 1)}$

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| Second Original Number : | | 1 0 1 1 1 1 0 0 1 0 |
| Ones Complement : | | 0 1 0 0 0 0 1 1 0 1 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 1 0 0 0 0 1 1 1 0 |
| Add First Number : | | 1 1 0 0 1 1 1 1 0 1 |
| Answer : | 1 | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| Second Original Number : | | 1 0 1 1 1 1 0 0 1 0 |
| Ones Complement : | | 0 1 0 0 0 0 1 1 0 1 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 1 0 0 0 0 1 1 1 0 |
| Add First Number : | | 1 1 0 0 1 1 1 1 0 1 |
| Answer : | 1 | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Second Original Number : | | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Ones Complement : | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| Add 1 to ones Complement : | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Twos Complement : | | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| Add First Number : | | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| Answer : | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |

## Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| Second Original Number : | | 1 0 1 1 1 1 0 0 1 0 |
| Ones Complement : | | 0 1 0 0 0 0 1 1 0 1 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 1 0 0 0 0 1 1 1 0 |
| Add First Number : | | 1 1 0 0 1 1 1 1 0 1 |
| Answer : | 1 | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| Second Original Number : | | 1 0 1 1 1 1 0 0 1 0 |
| Ones Complement : | | 0 1 0 0 0 0 1 1 0 1 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 1 0 0 0 0 1 1 1 0 |
| Add First Number : | | 1 1 0 0 1 1 1 1 0 1 |
| Answer : | 1 | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(829)_{10} - (754)_{10} = (75)_{10}$
- Do we get same number in binary subtraction?
- $(1100111101)_2 - (1011110010)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| Second Original Number : | | 1 0 1 1 1 1 0 0 1 0 |
| Ones Complement : | | 0 1 0 0 0 0 1 1 0 1 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 1 0 0 0 0 1 1 1 0 |
| Add First Number : | | 1 1 0 0 1 1 1 1 0 1 |
| Answer : | 1 | 0 0 0 1 0 0 1 0 1 1 |

Carry is Generated Result is positive, Answer: $2^6 + 2^3 + 2^1 + 2^0 = 75$

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

## Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| $(829)_{10}$ : | | 1 1 0 0 1 1 1 1 0 1 |
| Ones Complement : | | 0 0 1 1 0 0 0 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 0 1 1 0 0 0 0 1 1 |
| Add $(754)_{10}$ : | | 1 0 1 1 1 1 0 0 1 0 |
| No Carry Generated : | − | 1 1 1 0 1 1 0 1 0 1 |
| Ones complement : | | 0 0 0 1 0 0 1 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Answer with Negative Sign : | | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | |
|---|---|
| $(829)_{10}$ : | 1 1 0 0 1 1 1 1 0 1 |
| Ones Complement : | 0 0 1 1 0 0 0 0 1 0 |
| Add 1 to ones Complement : | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | 0 0 1 1 0 0 0 0 1 1 |
| Add $(754)_{10}$ : | 1 0 1 1 1 1 0 0 1 0 |
| No Carry Generated : $-$ | 1 1 1 0 1 1 0 1 0 1 |
| Ones complement : | 0 0 0 1 0 0 1 0 1 0 |
| Add 1 to ones Complement : | 0 0 0 0 0 0 0 0 0 1 |
| Answer with Negative Sign : | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | |
|---|---|
| $(829)_{10}$ : | 1 1 0 0 1 1 1 1 0 1 |
| Ones Complement : | 0 0 1 1 0 0 0 0 1 0 |
| Add 1 to ones Complement : | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | 0 0 1 1 0 0 0 0 1 1 |
| Add $(754)_{10}$ : | 1 0 1 1 1 1 0 0 1 0 |
| No Carry Generated : $-$ | 1 1 1 0 1 1 0 1 0 1 |
| Ones complement : | 0 0 0 1 0 0 1 0 1 0 |
| Add 1 to ones Complement : | 0 0 0 0 0 0 0 0 0 1 |
| Answer with Negative Sign : | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| $(829)_{10}$ : | | 1 1 0 0 1 1 1 1 0 1 |
| Ones Complement : | | 0 0 1 1 0 0 0 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 0 1 1 0 0 0 0 1 1 |
| Add $(754)_{10}$ : | | 1 0 1 1 1 1 0 0 1 0 |
| No Carry Generated : | − | 1 1 1 0 1 1 0 1 0 1 |
| Ones complement : | | 0 0 0 1 0 0 1 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Answer with Negative Sign : | | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| $(829)_{10}$ : | | 1 1 0 0 1 1 1 1 0 1 |
| Ones Complement : | | 0 0 1 1 0 0 0 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 0 1 1 0 0 0 0 1 1 |
| Add $(754)_{10}$ : | | 1 0 1 1 1 1 0 0 1 0 |
| No Carry Generated : | $-$ | 1 1 1 0 1 1 0 1 0 1 |
| Ones complement : | | 0 0 0 1 0 0 1 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Answer with Negative Sign : | | 0 0 0 1 0 0 1 0 1 1 |

# Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

| | | |
|---|---|---|
| $(829)_{10}$ : | | 1 1 0 0 1 1 1 1 0 1 |
| Ones Complement : | | 0 0 1 1 0 0 0 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Twos Complement : | | 0 0 1 1 0 0 0 0 1 1 |
| Add $(754)_{10}$ : | | 1 0 1 1 1 1 0 0 1 0 |
| No Carry Generated : | $-$ | 1 1 1 0 1 1 0 1 0 1 |
| Ones complement : | | 0 0 0 1 0 0 1 0 1 0 |
| Add 1 to ones Complement : | | 0 0 0 0 0 0 0 0 0 1 |
| Answer with Negative Sign : | | 0 0 0 1 0 0 1 0 1 1 |

## Binary Arithmatic : Subtraction

- Consider two numbers $(829)_{10}$ and $(754)_{10}$
- We know that $(754)_{10} - (829)_{10} = (-75)_{10}$
- Do we get same number in binary subtraction?
- $(1011110010)_2 - (1100111101)_2$

**Addition Rules**

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 0$ (Carry 1)

$$
\begin{array}{rcc}
(829)_{10}: & & 1\ 1\ 0\ 0\ 1\ 1\ 1\ 1\ 0\ 1 \\
\hline
\text{Ones Complement}: & & 0\ 0\ 1\ 1\ 0\ 0\ 0\ 0\ 1\ 0 \\
\text{Add 1 to ones Complement}: & & 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1 \\
\hline
\text{Twos Complement}: & & 0\ 0\ 1\ 1\ 0\ 0\ 0\ 0\ 1\ 1 \\
\text{Add } (754)_{10}: & & 1\ 0\ 1\ 1\ 1\ 1\ 0\ 0\ 1\ 0 \\
\hline
\text{No Carry Generated}: & - & 1\ 1\ 1\ 0\ 1\ 1\ 0\ 1\ 0\ 1 \\
\hline
\text{Ones complement}: & & 0\ 0\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 0 \\
\text{Add 1 to ones Complement}: & & 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1 \\
\hline
\text{Answer with Negative Sign}: & & 0\ 0\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1 \\
\hline
\end{array}
$$

## Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

# Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

$$\begin{array}{r}
(53)_{10} : 1\ 1\ 0\ 1\ 0\ 1 \\
(25)_{10} : 0\ 1\ 1\ 0\ 0\ 1 \\
\hline
0\ 1\ 1\ 0\ 0\ 1 \\
0\ 0\ 0\ 0\ 0\ 0\ \times \\
0\ 1\ 1\ 0\ 0\ 1\ \times\ \times \\
0\ 0\ 0\ 0\ 0\ 0\ \times\ \times\ \times \\
0\ 1\ 1\ 0\ 0\ 1\ \times\ \times\ \times\ \times \\
0\ 1\ 1\ 0\ 0\ 1\ \times\ \times\ \times\ \times\ \times \\
\hline
\text{Answer : } 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1
\end{array}$$

# Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

$$
\begin{array}{rr}
(53)_{10}: & 1\ 1\ 0\ 1\ 0\ 1 \\
(25)_{10}: & 0\ 1\ 1\ 0\ 0\ 1 \\
\hline
 & 0\ 1\ 1\ 0\ 0\ 1 \\
 & 0\ 0\ 0\ 0\ 0\ 0\ \times \\
 & 0\ 1\ 1\ 0\ 0\ 1\ \times\ \times \\
 & 0\ 0\ 0\ 0\ 0\ 0\ \times\ \times\ \times \\
 & 0\ 1\ 1\ 0\ 0\ 1\ \times\ \times\ \times\ \times \\
 & 0\ 1\ 1\ 0\ 0\ 1\ \times\ \times\ \times\ \times\ \times \\
\hline
\text{Answer}: & 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1
\end{array}
$$

# Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

$$
\begin{array}{r}
(53)_{10} : 1\ 1\ 0\ 1\ 0\ 1 \\
(25)_{10} : 0\ 1\ 1\ 0\ 0\ 1 \\
\hline
0\ 1\ 1\ 0\ 0\ 1 \\
0\ 0\ 0\ 0\ 0\ 0\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x \\
0\ 0\ 0\ 0\ 0\ 0\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x\ x \\
\hline
\text{Answer} : 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1
\end{array}
$$

# Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

$$
\begin{array}{r}
(53)_{10} : 1\ 1\ 0\ 1\ 0\ 1 \\
(25)_{10} : 0\ 1\ 1\ 0\ 0\ 1 \\
\hline
0\ 1\ 1\ 0\ 0\ 1 \\
0\ 0\ 0\ 0\ 0\ 0\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x \\
0\ 0\ 0\ 0\ 0\ 0\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x\ x \\
\hline
\text{Answer : } 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1
\end{array}
$$

# Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

$$
\begin{array}{r}
(53)_{10} : 1\ 1\ 0\ 1\ 0\ 1 \\
(25)_{10} : 0\ 1\ 1\ 0\ 0\ 1 \\
\hline
0\ 1\ 1\ 0\ 0\ 1 \\
0\ 0\ 0\ 0\ 0\ 0\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x \\
0\ 0\ 0\ 0\ 0\ 0\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x\ x \\
\hline
\text{Answer} : 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1
\end{array}
$$

# Binary Arithmatic : Multiplication

- Consider two numbers $(53)_{10}$ and $(25)_{10}$
- We know that $(53)_{10} \times (25)_{10} = (1325)_{10}$
- $(110101)_2 \times (011001)_2 = ?$

**Multiplication Rules**

- $0 \times 0 = 0$
- $0 \times 1 = 0$
- $1 \times 0 = 0$
- $1 \times 1 = 1$

$$
\begin{array}{r}
(53)_{10} : 1\ 1\ 0\ 1\ 0\ 1 \\
(25)_{10} : 0\ 1\ 1\ 0\ 0\ 1 \\
\hline
0\ 1\ 1\ 0\ 0\ 1 \\
0\ 0\ 0\ 0\ 0\ 0\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x \\
0\ 0\ 0\ 0\ 0\ 0\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x \\
0\ 1\ 1\ 0\ 0\ 1\ x\ x\ x\ x\ x \\
\hline
\text{Answer} : 1\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1
\end{array}
$$