SE311: Design of Digital Systems

Lecture 2: Numbering Systems

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(Term 041)

Numbering System

Decimal

Base 10

Digits: 0,1,2,3,4,5,6,7,8,9

Binary

Base 2

Digits: 0,1

Octal

Base 8

Digits: 0,1,2,3,4,5,6,7

Hexadecimal

Base 16

Digits: 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

Decimal → Binary

(5 2) D = (1 1 0 1 0 0)B

52	
26	0
13	0
6	1
3	0
1	1
0	1

52 = 26 * 2 + 0

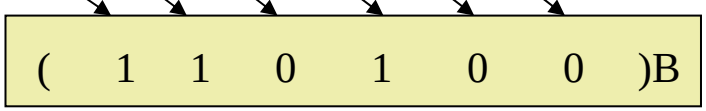
26 = 13 * 2 + 0

13 = 6 * 2 + 1

6 = 3 * 2 + 0

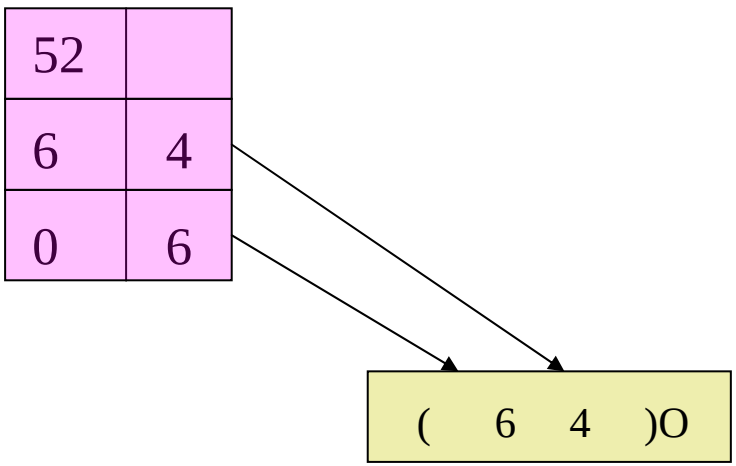
3 = 1 * 2 + 1

1 = 0 * 2 + 1



Decimal → Octal

(5 2) D = (1 1 0 1 0 0)B=(64)O

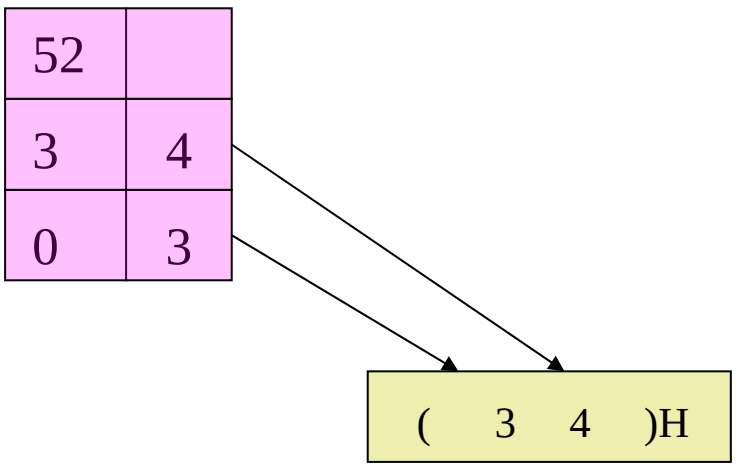


52 = 6 * 8 + 4

6 = 0 * 8 + 6

Decimal → Hexadecimal

(5 2) D = (1 1 0 1 0 0)B=(34)H



52 = 3 * 16 + 4

3 = 0 * 16 + 3

Binary ⟷ Hexadecimal

H ⟶ B : Convert each hexadecimal digit to exactly 4 binary digits

B ⟶ H : Convert each 4 binary digits to a hexadecimal digit

(start from the binary point)

Hexadecimal	Binary	Hexadecimal	Binary	Hexadecimal	Binary
0	0000	6	0110	C	1100
1	0001	7	0111	D	1101
2	0010	8	1000	E	1110
3	0011	9	1001	F	1111
4	0100	A	1010		
5	0101	B	1011		

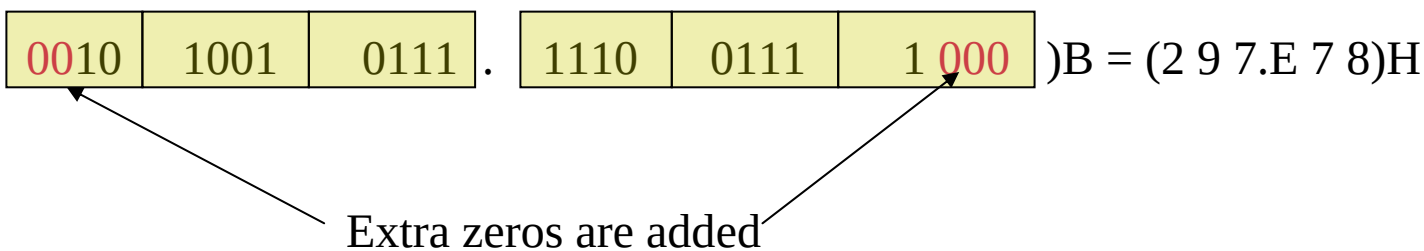
Binary ⟷ Hexadecimal

Example

(2 3 A)H = (0 0 1 0 0 0 1 1 1010)B

(1 4 B . C E)H = (0 0 0 1 0 1 0 0 1 0 1 1 . 1 1 0 0 1 1 1 0)B

(1010010111.111001111)B= (10 1001 0111. 1110 0111 1)B



Binary ⟷ Octal

O → B : Convert each octal digit to exactly 3 binary digits

B → O : Convert each 3 binary digits to an octal digit

(start from the binary point)

Octal	Binary	Octal	Binary
0	000	4	100
1	001	5	101
2	010	6	110
3	011	7	111

Binary ⟷ Octal

Example

(2 3 7)O = (0 1 0 0 1 1 111)B

(1 4 2 . 5 3)O = (0 0 1 1 0 0 0 1 0 . 1 0 1 0 1 1)B

(1011.1111010)B= (1 011.111 101 0)B

(001 011 . 111 101 0 00)B = (1 3 . 7 5 0)O

Adding Binary Numbers

		1	1	0	1	0	1	1
+		0	1	1	1	1	0	1
	1	0	1	0	1	0	0	0
	Carry				sum			

Adding Octal Numbers

		1	6	0	5	0	2	5
+		3	1	2	5	1	5	4
	0	4	7	3	2	2	0	1

Carry sum

Adding Hexadecimal Numbers

		A	6	0	3	0	E	A
+		8	1	B	5	C	5	4
	1	2	7	B	8	D	3	E
	Carry			sum				

Learning Objectives

- Be able to convert real numbers between the binary, decimal, octal and hexadecimal systems.
- Be able to perform addition problems in base 2, 8 and 16.
- Be able to determine the minimum number of bits needed to represent a given set of items.