



Computer Engineering
Suan Sunandha Rajabhat University

Number Systems

Dr.Pongrapee Kaewsaiha

CPE1405 – Fundamentals of ...



<https://pongrapee.net>

Number systems

- **Base 10** (Decimal)
Represent any number using 10 digits [0–9]
- **Base 2** (Binary)
Represent any number using 2 digits [0–1]
- **Base 8** (Octal)
Represent any number using 8 digits [0–7]
- **Base 16** (Hexadecimal)
Represent any number using 10 digits and 6 characters [0–9, A, B, C, D, E, F]

Base 10 (Decimal) [0..9]

$$\begin{aligned} 3245 &= (3 \times 10^3) + (2 \times 10^2) + (4 \times 10^1) + (5 \times 10^0) \\ &= (3 \times 1000) + (2 \times 100) + (4 \times 10) + (5 \times 1) \\ &= (3000) + (200) + (40) + (5) \\ &= 3245 \end{aligned}$$

Remark: 3245 can be written as 3245_{10}

Base 2 (Binary) [0..1]

$$\begin{aligned} 1010_2 &= (1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (0 \times 2^0) \\ &= (1 \times 8) + (0 \times 4) + (1 \times 2) + (0 \times 1) \\ &= (8) + (0) + (2) + (0) \\ &= 10 \end{aligned}$$

Base 8 (Octal) [0..7]

$$\begin{aligned}\mathbf{1024}_8 &= (\mathbf{1} \times \mathbf{8}^3) + (\mathbf{0} \times \mathbf{8}^2) + (\mathbf{2} \times \mathbf{8}^1) + (\mathbf{4} \times \mathbf{8}^0) \\ &= (1 \times 512) + (0 \times 64) + (2 \times 8) + (4 \times 1) \\ &= (512) + (0) + (16) + (4) \\ &= 532\end{aligned}$$

Base 16 (Hexadecimal) [0..9, ¹⁰A, ¹¹B, ¹²C, ¹³D, ¹⁴E, ¹⁵F]

$$\mathbf{2AB}_{16} = (\mathbf{2} \times \mathbf{16}^2) + (\mathbf{10} \times \mathbf{16}^1) + (\mathbf{11} \times \mathbf{16}^0)$$

$$= (2 \times 256) + (10 \times 16) + (11 \times 1)$$

$$= (512) + (160) + (11)$$

$$= 683$$

HTML color

Specifying colors using 6-digit codes (instead of 9) can save space in the HTML document.

		R	G	B	
		255	0	0	FF0000
		255	127	0	FF7F00
		255	255	0	FFFF00
		127	255	0	7FFF00
		0	255	0	00FF00
		0	255	127	00FF7F
		0	255	255	00FFFF
		0	127	255	007FFF

		R	G	B	
		240	160	160	F0A0A0
		220	180	140	DCB48C
		200	200	120	C8C878
		180	220	140	B4DC8C
		160	240	160	A0F0A0
		140	220	180	8CDCB4
		120	200	200	78C8C8
		140	180	220	8CB4DC

		R	G	B	
		238	170	170	EEAAAA
		221	187	153	DDBB99
		204	204	136	CCCC88
		187	221	153	BBDD99
		170	238	170	AAEEAA
		153	221	187	99DDBB
		136	204	204	88CCCC
		153	187	221	99BBDD

Source: R. A. Nonenmacher from Wikimedia Commons

Attempt a quiz

Exercise **7**, Page **1**,
Questions **1.1–1.3**

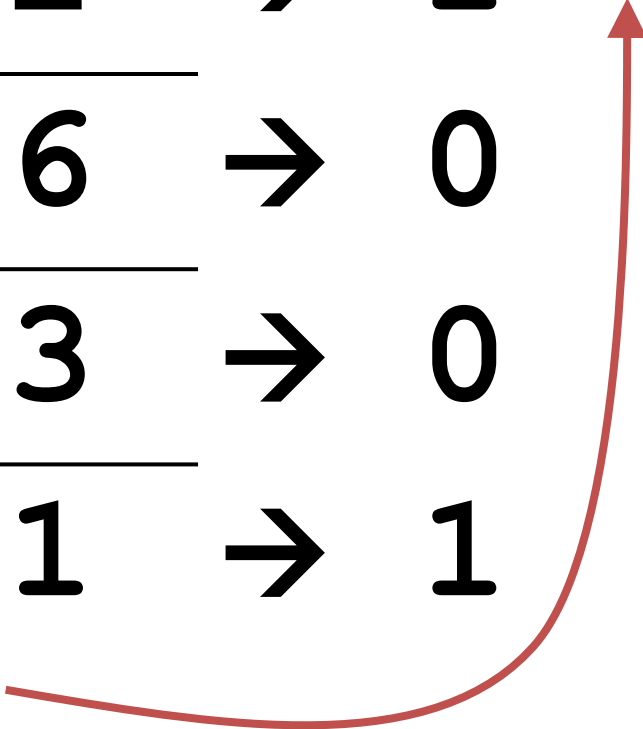
Conversion from base-10 to base-2

	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	64	32	16	8	4	2	1
	$\frac{25}{64}$	$\frac{25}{32}$	$\frac{25}{16}$	$\frac{9}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{1}$
25 =	0	0	1	1	0	0	1
							2

Diagram illustrating the conversion of the decimal number 25 to binary (base-2) using the division-by-2 method. The powers of 2 (2^6 to 2^0) are listed at the top. The decimal number 25 is divided by each power of 2, and the remainder is recorded as a binary digit (0 or 1). The remainders, read from bottom to top, form the binary representation of 25: 11001₂.

Conversion from base-10 to base-2

2	25		
2	12	→	1
2	6	→	0
2	3	→	0
	1	→	1



$$25 = 11001_2$$

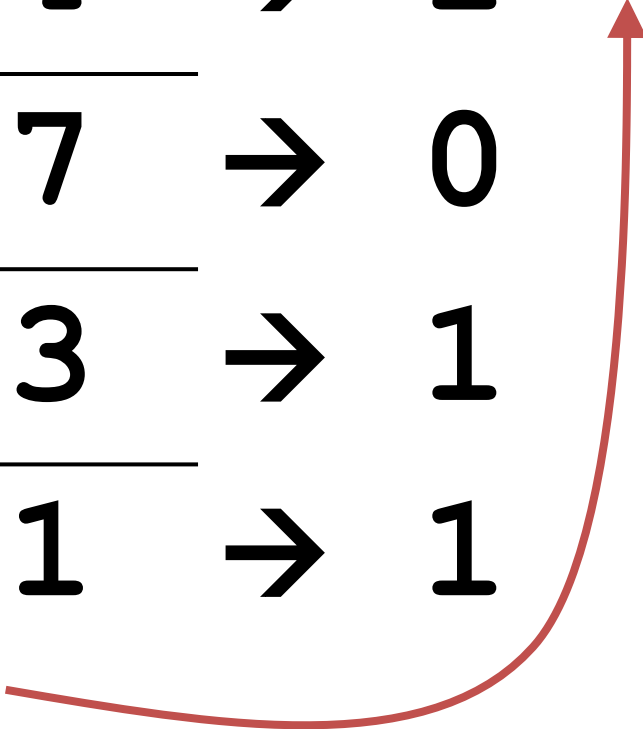
Conversion from base-10 to base-2

	2^6	2^5	2^4	2^3	2^2	2^1	2^0
	64	32	16	8	4	2	1
	$\frac{29}{64}$	$\frac{29}{32}$	$\frac{29}{16}$	$\frac{13}{8}$	$\frac{5}{4}$	$\frac{1}{2}$	$\frac{1}{1}$
29 =	0	0	1	1	1	0	1 ₂

Diagram illustrating the conversion of the decimal number 29 to binary (base-2) using the division-by-2 method. The powers of 2 (2^6 to 2^0) are listed at the top. The corresponding decimal values (64, 32, 16, 8, 4, 2, 1) are shown below. The division process is shown in the third row, with the quotient and remainder (0 or 1) recorded in the bottom row. Arrows indicate the sequence of divisions: 29 is divided by 64, 32, 16, 8, 4, 2, and finally 1. The remainders, read from bottom to top, form the binary representation 11101₂.

Conversion from base-10 to base-2

2	29		
2	14	→	1
2	7	→	0
2	3	→	1
	1	→	1



$$25 = 11101_2$$

Conversion from base-10 to base-16

16^3	16^2	16^1	16^0
4096	256	16	1

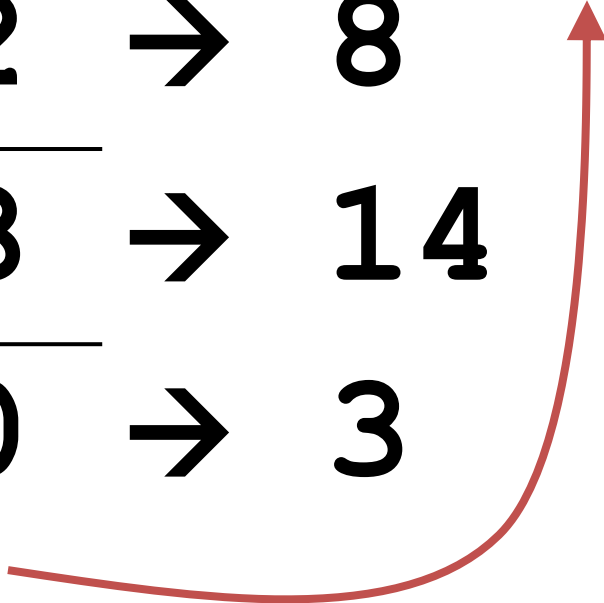
$\frac{1000}{256}$	$\frac{232}{16}$	$\frac{8}{1}$
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1000 =

	232	8	
3	↑	↑	
3	14	8	
	E	8	16

Conversion from base-10 to base-16

16	1000	
16	62	→ 8
16	3	→ 14
	0	→ 3



A = 10

B = 11

C = 12

D = 13

E = 14

F = 15

$$1000 = 3E8_{16}$$

Attempt a quiz

Exercise **7**, Page **2**,
Questions **2.1–2.2**