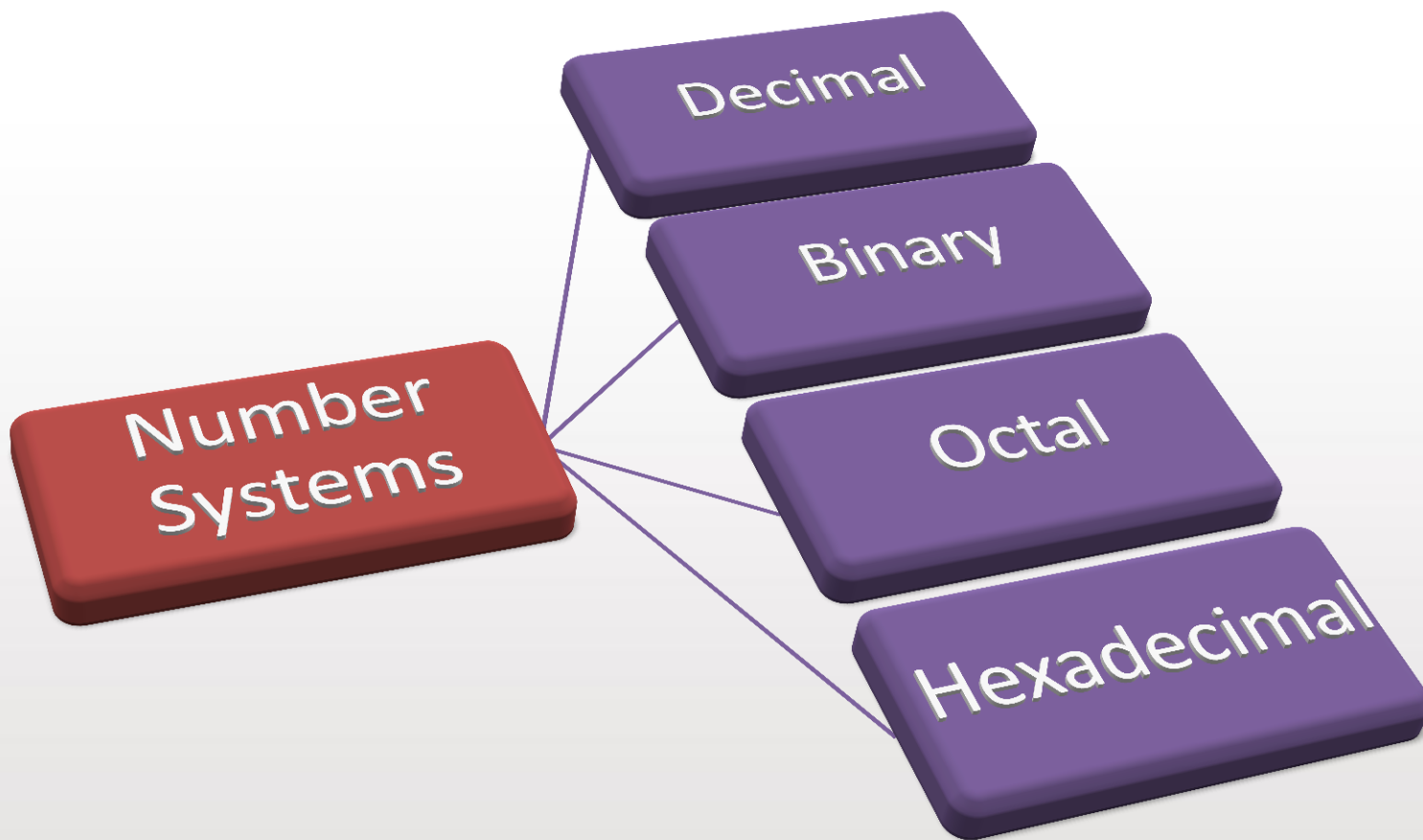# Digital Electronics (SKEE1223)
Number Systems

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# Number Systems for Digital Devices

System	Radix	Digits	Notes
Decimal	10	0,1,2,3,4,5,6,7,8.9	Human count using 10 fingers
Binary	2	0,1	Machines only know 2 digits
Octal	8	0,1,2,3,4,6,7	Shortens long binary sequences by groups of 3
Hexadecimal	16	0,1,2,3,4,5,6,7,8.9, A, B, C, D, E, F	Shortens long binary sequences by groups of 4

Why Binary System?

- **Digital circuits are made of a series of switches**
- **Each switch has two states: ON or OFF**
- **Each state can be represented by a number**
  - **1 for "ON"**
  - **0 for "OFF"**
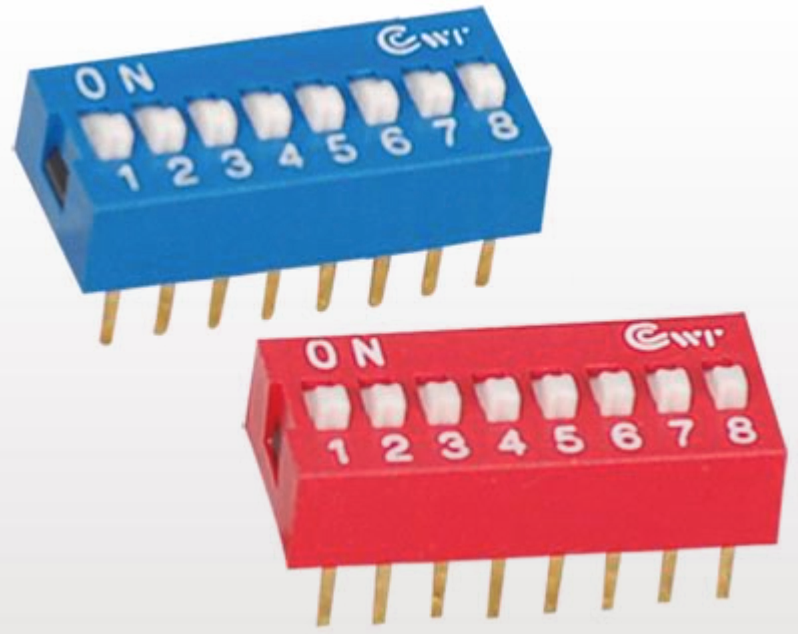
Binary Weights

a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0	a_{-1}	a_{-2}
1	1	1	1	1	1	1	1	1	1
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}
128	64	32	16	8	4	2	1	0.5	0.25

Groups of Bits
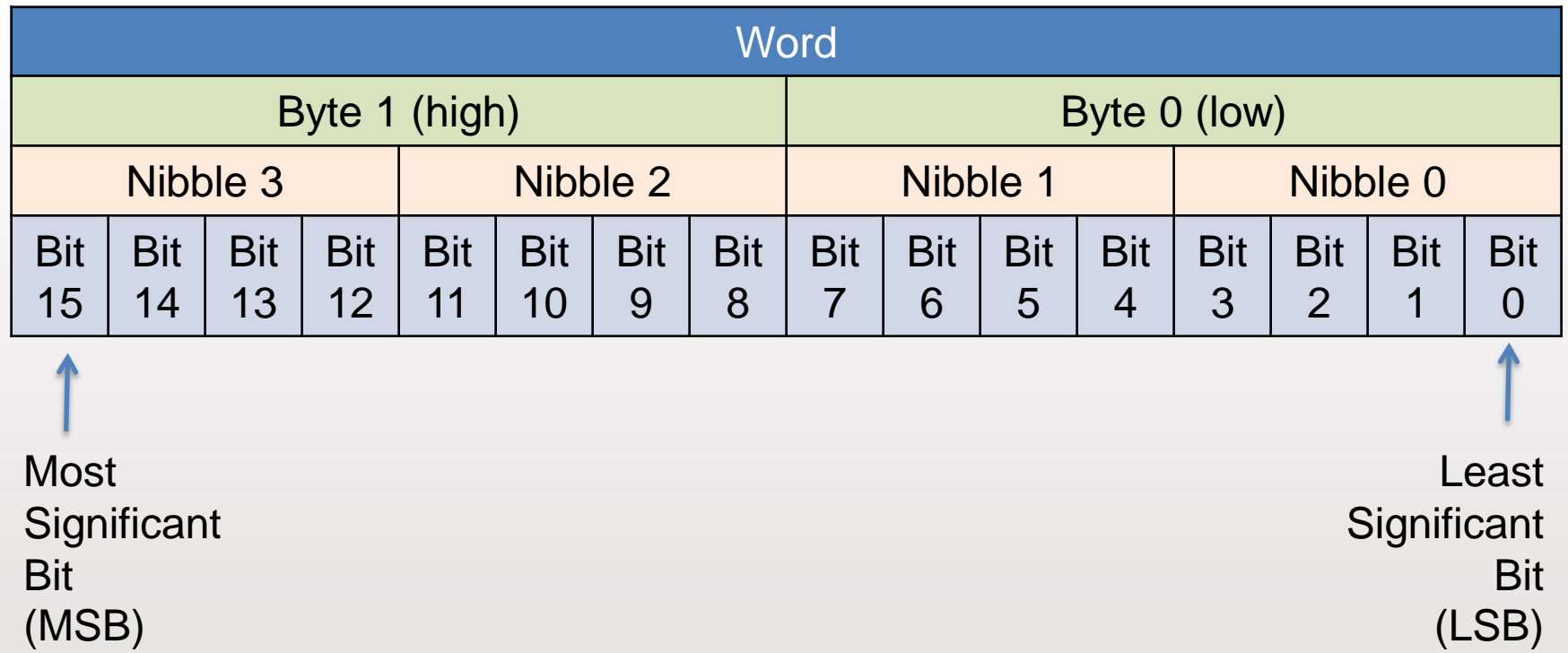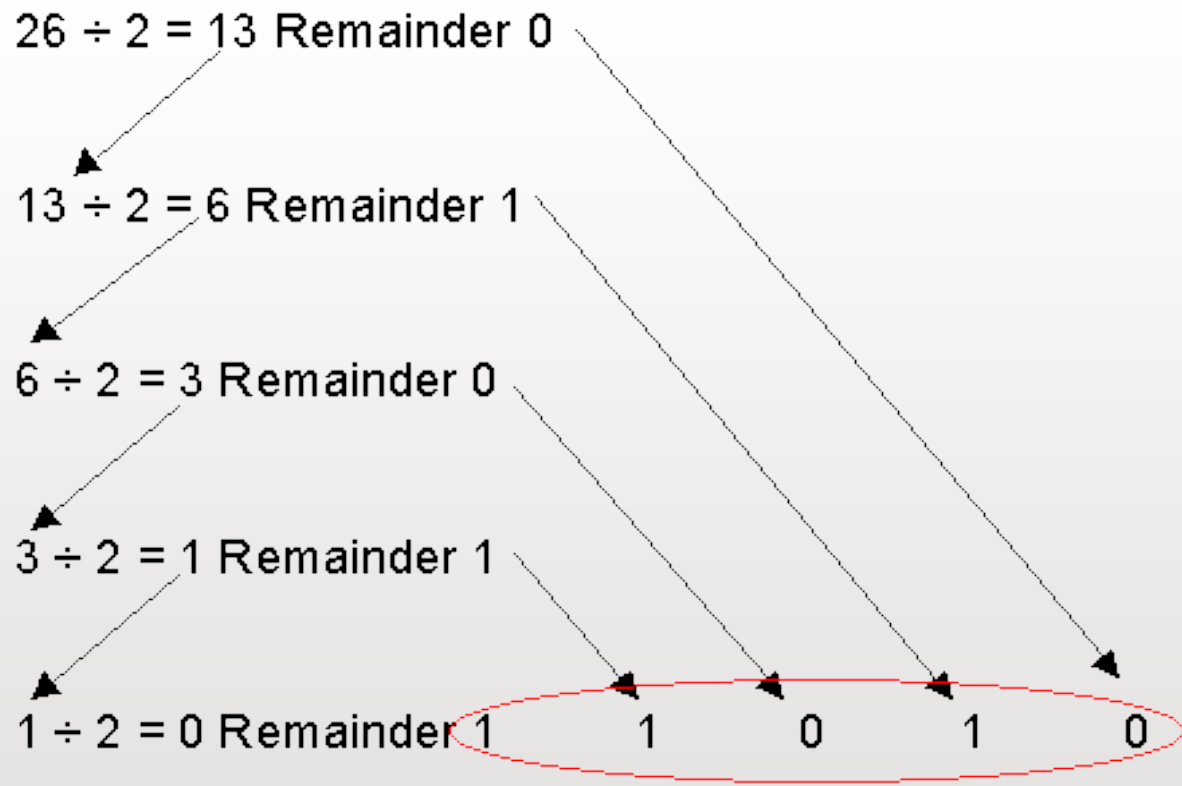
Word															
Byte 1 (high)								Byte 0 (low)							
Nibble 3				Nibble 2				Nibble 1				Nibble 0			
Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

Most Significant Bit (MSB)

Least Significant Bit (LSB)

Decimal to Binary

$26 \div 2 = 13$ Remainder 0

$13 \div 2 = 6$ Remainder 1

$6 \div 2 = 3$ Remainder 0

$3 \div 2 = 1$ Remainder 1

$1 \div 2 = 0$ Remainder 1   1   0   1   0

Binary Weights

a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0	a_{-1}	a_{-2}
1	1	1	1	1	1	1	1	1	1
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}
128	64	32	16	8	4	2	1	0.5	0.25

Octal Number System

- **To shorten long binary numbers**
  - **0-7**

Octal to Decimal

7	1	2	6	3
8^4	8^3	8^2	8^1	8^0

decimal:

$3 \times 8^0 = 3$

$6 \times 8^1 = 48$

$2 \times 8^2 = 128$

$1 \times 8^3 = 512$
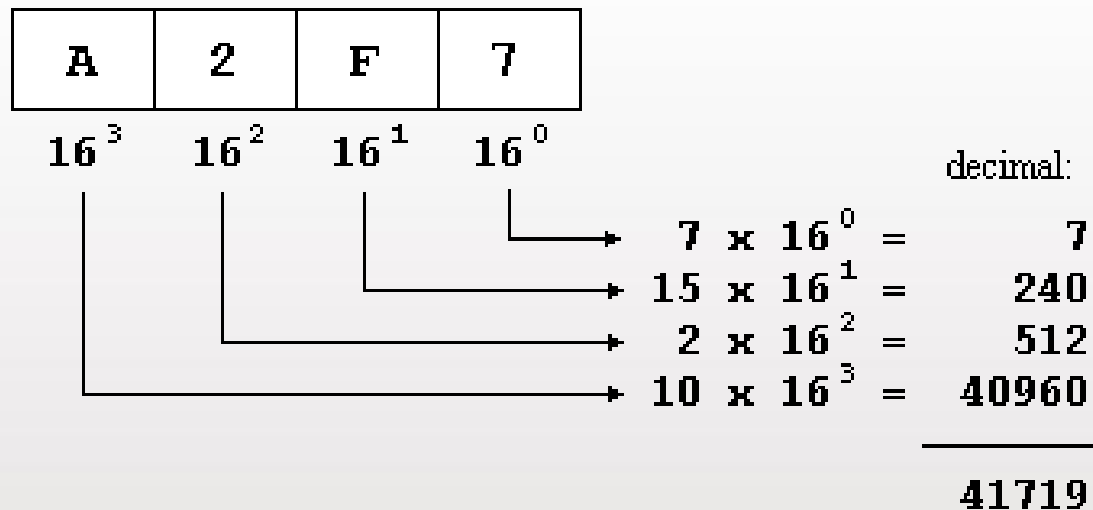
$7 \times 8^4 = 28672$

29363
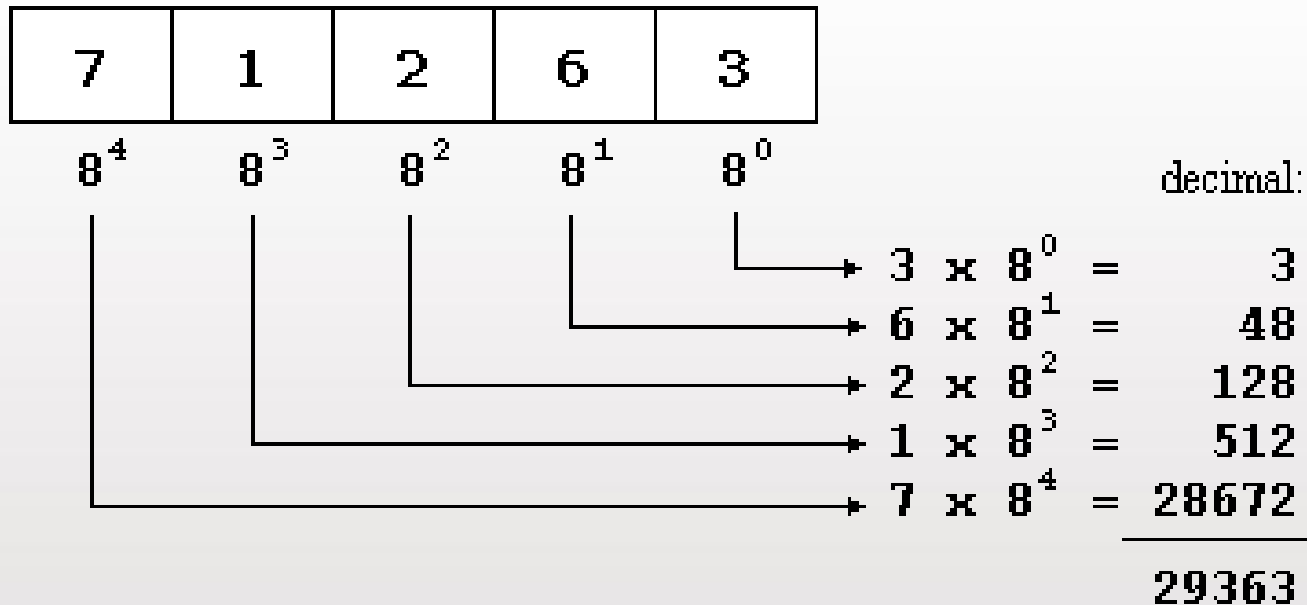
Hexadecimal Number System

- **Sometimes called hex numbers**
- **To shorten binary numbers stored in groups of 4**
  - **0-9, A-F**
- **Base-16 numbers can be written in two formats:**
  - 24_{16} **or   24h**
- **Base-16 also means that there are 16 valid numbers. Starting with zero they are:**
  - **0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F**
- **Where:**
  - **A = 10, B = 11, C = 12, D = 13, E = 14, F = 15**

Hexadecimal Weighting

A	2	F	7

16^3 $\quad$ 16^2 $\quad$ 16^1 $\quad$ 16^0

decimal:

$$7 \times 16^0 = 7$$
$$15 \times 16^1 = 240$$
$$2 \times 16^2 = 512$$
$$10 \times 16^3 = 40960$$
$$\overline{41719}$$

Binary to Hexadecimal