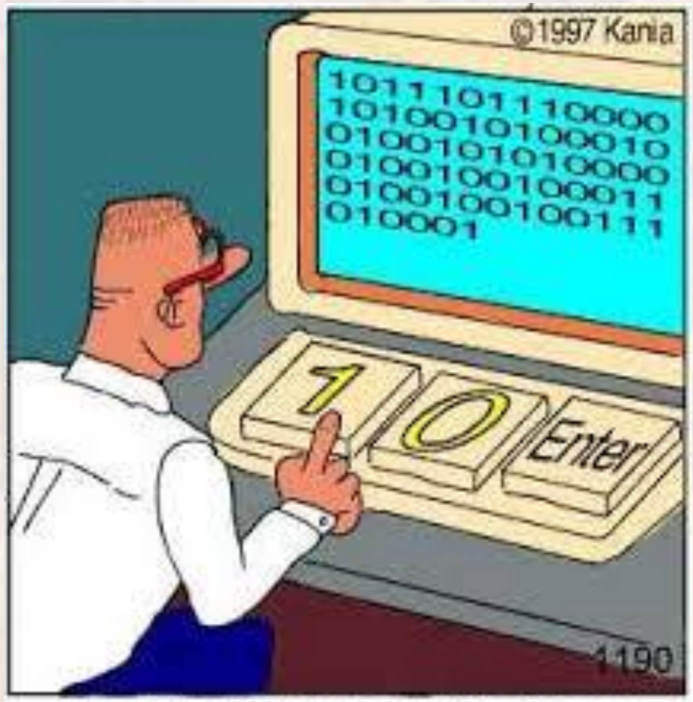
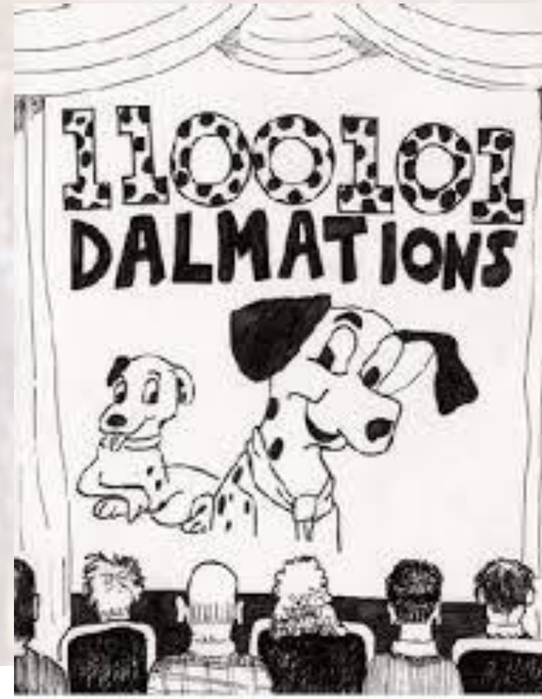


Real programmers code in binary.



Film Night at the Binary Society

Number Systems Intro

Last updated 8/20/20

Number Systems

- These slides introduce number systems and terminlogy
- Upon completion: You should be able to describe the meaning of each term and provide examples

Number Systems Intro

- Base 10 (decimal)
  - The most familiar base for most people
    - ones, tens, hundreds, thousands
    - tenths, hundredths, thousandths
  - Base 10 → 10 individual digits
    - Range of individual digit: 0 → 9
  - Each position to the left of the decimal point is 10X the previous position
  - Each position to the right of the decimal point is 1/10th the previous position

1	2	3	4	.	5	6	7
Thousands	Hundreds	Tens	Ones	decimal point	tenths	hundredths	thousandths

1	2	3	4	.	5	6	7
digit x 10^3	digit x 10^2	digit x 10^1	digit x 10^0	decimal point	digit x 10^{-1}	digit x 10^{-2}	digit x 10^{-3}

Number Systems Intro

- Base 2 (binary)

  - The most common base for digital electronics
    - ones, twos, fours, eights
    - halves, quarters, eighths

  - Base 2 → 2 individual digits
    - Range of individual digit: 0 → 1

  - Each position to the left of the binary point is 2X the previous position

  - Each position to the right of the binary point is 1/2 the previous position

1	1	0	1	.	1	0	1
Eights	Fours	Twos	Ones	binary point	Halves	Quarters	Eighths

1	1	0	1	.	1	0	1
digit x 2^3	digit x 2^2	digit x 2^1	digit x 2^0	binary point	digit x 2^{-1}	digit x 2^{-2}	digit x 2^{-3}

Number Systems Intro

- Base 16 (hexadecimal)

  - Used as a short hand for binary
    - ones, 16s, 256s, 4096s
    - 16ths, 256ths

  - Base 16 → 16 individual digits
    - Range of individual digit: 0 → 9,A→F
    - 10=A, 11=B, 12=C, 13=D, 14=E, 15=F

  - Each position to the left of the hexadecimal point is 16X the previous position

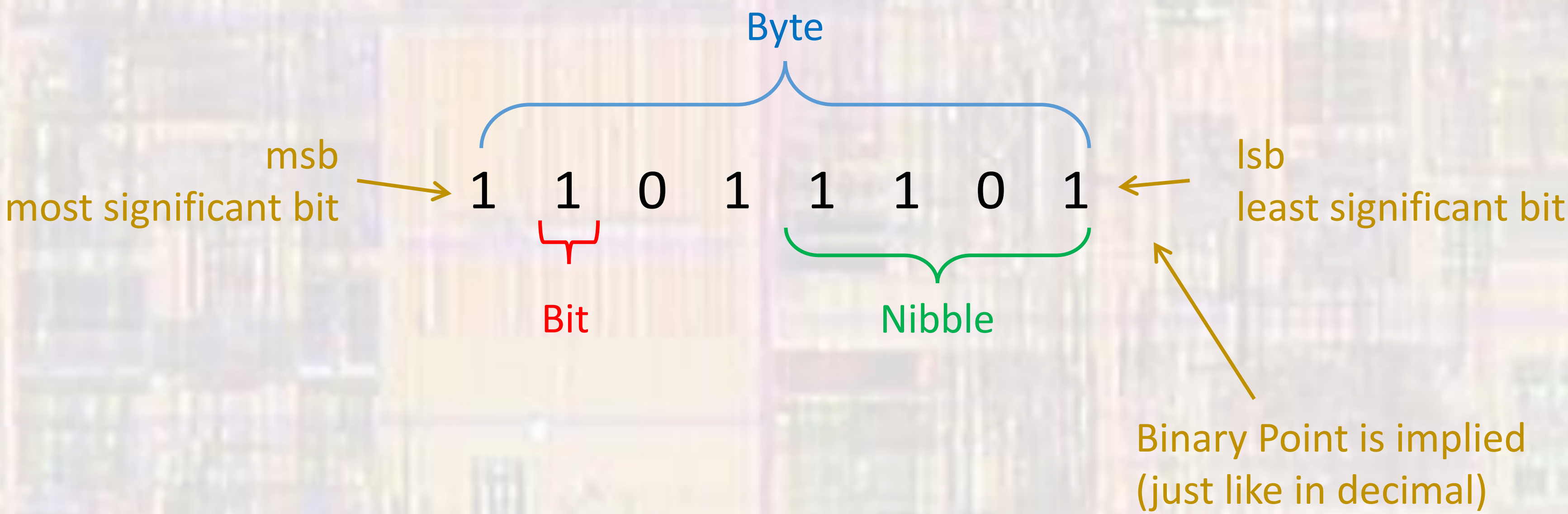
  - Each position to the right of the hexadecimal point is 1/16 the previous position

2	B	0	E	.	3	A	2
4096s	256s	16s	Ones	hexadecimal point	16ths	256ths	4096ths

2	B	0	E	.	3	A	2
digit x 16^3	digit x 16^2	digit x 16^1	digit x 16^0	hexadecimal point	digit x 16^{-1}	digit x 16^{-2}	digit x 16^{-3}

Number Systems Intro

- Binary Terminology



Number Systems Intro

- Binary Terminology

16 Bit Word

1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1

32 Bit Word

1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1

64, 128, 256, 512, 1024 Bit Words

Number Systems Intro

- Bit Values

Right to Left

Bit #	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
	1	0	1	1	1	0	1	1	1	0	0	0	1	0	0	0
Value	2,147,483,648	1,073,741,824	536,870,912	268,435,456	134,217,728	67,108,864	33,554,432	16,777,216	8,388,608	4,194,304	2,097,152	1,048,576	524,288	262,144	131,072	65,536

Bit #	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	0	1	1	0	0	1	0	0	1	1	0	0	0	1	1	1
Value	32,768	16,384	8,192	4,096	2,048	1,024	512	256	128	64	32	16	8	4	2	1

1K
1M
1G

Bit #	1	2	3	4	5	6	7	8
.	1	1	0	0	0	0	1	0
Value	0.5	0.25	0.125	0.0625	0.03125	0.015625	0.0078125	0.00390625

Left to Right

Number Systems Intro

- Exponential shorthand

  - Use of K, M, G, T is situationally dependent
    - In science and math:
      - K = $x10^3$
      - M = $x10^6$
      - G = $x10^9$
      - T = $x10^{12}$
    - In computer and digital systems:
      - K = $x2^{10}$ = x1,024
      - M = $x2^{20}$ = x1,048,576
      - G = $x2^{30}$ = x1,073,741,824
      - T = $x2^{40}$ = x1,099,511,627,776

Number Systems Intro

- More Terminology
  - Assume S is an 8 bit binary number

S = 10010110

- S[7:0] = 10010110 — 10010110
- S[3:0] = 0110 — 10010110
- S[7:6] = 10 — 10010110
- S[5] = 0 — 10010110
- S[6,3] = 00 — 10010110
- S[1] = 1 — 10010110
- S[0] = 0 — 10010110

Number Systems Intro

- Special note on binary numbers in C programming

  - Some but not all compilers allow binary numbers to be represented in C code directly

    95 → 0b01011101

  - To be safe and ensure our code is portables we will NOT use this notation.
  - Binary numbers can be represented with:
    - Their decimal equivalents 95
    - Their hexadecimal equivalents 0x5D