Chap 2: Data processing

1. Numerical system and data format
2. Data processing systems

2.1. Number Systems

Common Number Systems

System	Base	Symbols	Used by humans?	Used in computers?
Decimal	10	0, 1, … 9	Yes	No
Binary	2	0, 1	No	Yes
Octal	8	0, 1, … 7	No	No
Hexa-decimal	16	0, 1, … 9, A, B, … F	No	No

Quantities/Counting (1 of 3)

Decimal	Binary	Octal	Hexa-decimal
0	0	0	0
1	1	1	1
2	10	2	2
3	11	3	3
4	100	4	4
5	101	5	5
6	110	6	6
7	111	7	7

Quantities/Counting (2 of 3)

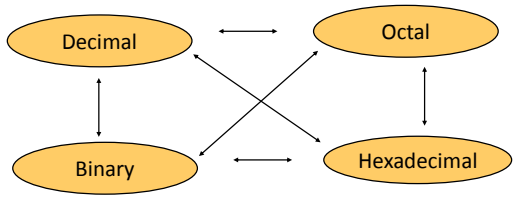
Decimal	Binary	Octal	Hexa-decimal
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

Quantities/Counting (3 of 3)

Decimal	Binary	Octal	Hexa-decimal
16	10000	20	10
17	10001	21	11
18	10010	22	12
19	10011	23	13
20	10100	24	14
21	10101	25	15
22	10110	26	16
23	10111	27	17

Conversion Among Bases

- The possibilities:

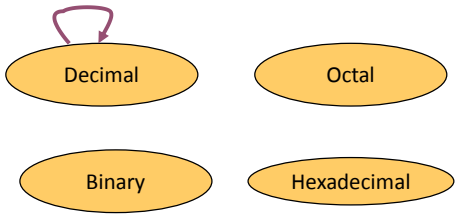


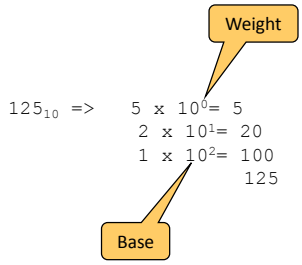
Quick Example

$$25_{10} = 11001_2 = 31_8 = 19_{16}$$

Base

Decimal to Decimal (just for fun)

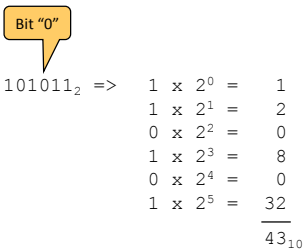




Binary to Decimal

- Technique
  - Multiply each bit by 2^n, where *n* is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

Example



Octal to Decimal

- Technique
  - Multiply each bit by 8^n, where *n* is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

Example

724_8 => $4 \times 8^0 = 4$
$2 \times 8^1 = 16$
$7 \times 8^2 = 448$
468_{10}

Hexadecimal to Decimal

- Technique
  - Multiply each bit by 16^n, where *n* is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

Example

ABC_{16} => $C \times 16^0 = 12 \times 1 = 12$
$B \times 16^1 = 11 \times 16 = 176$
$A \times 16^2 = 10 \times 256 = 2560$
2748_{10}

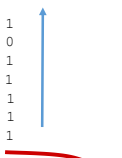
Decimal to Binary

- Technique
  - Divide by two, keep track of the remainder
  - First remainder is bit 0 (LSB, least-significant bit)
  - Second remainder is bit 1
  - Etc.

Example

$125_{10} = ?_2$

2 | 125		
2 | 62	1	
2 | 31	0	
2 | 15	1	
2 | 7	1	
2 | 3	1	
2 | 1	1	
0	1	



$125_{10} = 1111101_2$

Octal to Binary

- Technique
  - Convert each octal digit to a 3-bit equivalent binary representation

Example

$705_8 = ?_2$

7 0 5

111 000 101

$705_8 = 111000101_2$

Hexadecimal to Binary

- Technique
  - Convert each hexadecimal digit to a 4-bit equivalent binary representation

Example

$10AF_{16} = ?_2$

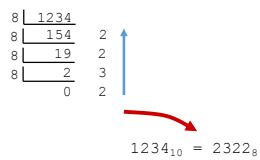
$10AF_{16} = 0001000010101111_2$

Decimal to Octal

- Technique
  - Divide by 8
  - Keep track of the remainder

Example

$1234_{10} = ?_8$



Decimal to Hexadecimal

- Technique
  - Divide by 16
  - Keep track of the remainder

Example

$1234_{10} = ?_{16}$

16	1234	
16	77	2
16	4	13 = D
	0	4

$1234_{10} = 4D2_{16}$

Binary to Octal

- Technique
  - Group bits in threes, starting on right
  - Convert to octal digits

Example

$1011010111_2 = ?_8$

1 011 010 111

1 3 2 7

$1011010111_2 = 1327_8$

Binary to Hexadecimal

- Technique
  - Group bits in fours, starting on right
  - Convert to hexadecimal digits

Example

$1010111011_2 = ?_{16}$

10 1011 1011

2 B B

$1010111011_2 = 2BB_{16}$

Octal to Hexadecimal

- Technique
  - Use binary as an intermediary

Example

$1076_8 = ?_{16}$

1 0 7 6

001 000 111 110

2 3 E

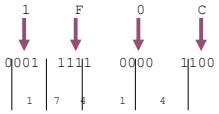
$1076_8 = 23E_{16}$

Hexadecimal to Octal

- Technique
  - Use binary as an intermediary

Example

$1F0C_{16} = ?_8$



$1F0C_{16} = 17414_8$

Exercise – Convert …

Decimal	Binary	Octal	Hexa-decimal
33			
	1110101		
		703	
			1AF

Don't use a calculator!

Exercise – Convert …

Answer

Decimal	Binary	Octal	Hexa-decimal
33	100001	41	21
117	1110101	165	75
451	111000011	703	1C3
431	110101111	657	1AF

Common Powers (1 of 2)

- Base 10

Power	Preface	Symbol	Value
10^{-12}	pico	p	.000000000001
10^{-9}	nano	n	.000000001
10^{-6}	micro	μ	.000001
10^{-3}	milli	m	.001
10^{3}	kilo	k	1000
10^{6}	mega	M	1000000
10^{9}	giga	G	1000000000
10^{12}	tera	T	1000000000000

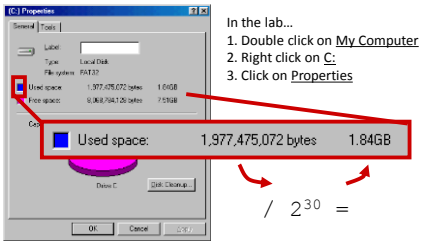
Common Powers (2 of 2)

- Base 2

Power	Preface	Symbol	Value
2^{10}	kilo	k	1024
2^{20}	mega	M	1048576
2^{30}	Giga	G	1073741824

- What is the value of "k", "M", and "G"?
- In computing, particularly w.r.t. memory, the base-2 interpretation generally applies

Example



In the lab…
1. Double click on My Computer
2. Right click on C:
3. Click on Properties

/ 2^{30} =

Exercise – Free Space

- Determine the "free space" on all drives on a machine in the lab

Drive	Free space	
	Bytes	GB
A:		
C:		
D:		
E:		
etc.		

Review – multiplying powers

- For common bases, add powers

$$a^b \times a^c = a^{b+c}$$

$$2^6 \times 2^{10} = 2^{16} = 65,536$$

or…

$$2^6 \times 2^{10} = 64 \times 2^{10} = 64k$$

Binary Addition (1 of 2)

- Two 1-bit values

A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	10

"two"

Binary Addition (2 of 2)

- Two *n*-bit values
  - Add individual bits
  - Propagate carries
  - E.g.,

```
  1   1
  10101      21
+ 11001    + 25
-------    ----
 101110      46
```

Multiplication (1 of 3)

- Decimal (just for fun)

```
   35
x 105
  175
 000
 35
----
3675
```

Multiplication (2 of 3)

- Binary, two 1-bit values

A	B	A × B
0	0	0
0	1	0
1	0	0
1	1	1

Multiplication (3 of 3)

- Binary, two *n*-bit values
  - As with decimal values
  - E.g.,

```
    1110
  x 1011
    1110
   1110
  0000
 1110
10011010
```

Fractions

- Decimal to decimal (just for fun)

```
3.14 =>     4 x 10^-2 = 0.04
            1 x 10^-1 = 0.1
            3 x 10^0  = 3
                        3.14
```

pp. 46-50

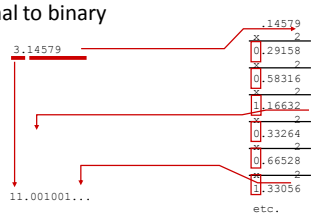
Fractions

- Binary to decimal

```
10.1011 =>      1 x 2^-4 = 0.0625
                1 x 2^-3 = 0.125
                0 x 2^-2 = 0.0
                1 x 2^-1 = 0.5
                0 x 2^0  = 0.0
                1 x 2^1  = 2.0
                           2.6875
```

Fractions

- Decimal to binary



Exercise – Convert ...

Decimal	Binary	Octal	Hexa-decimal
29.8			
	101.1101		
		3.07	
			C.82

Don't use a calculator!

Skip answer Answer

Exercise – Convert ...

Answer

Decimal	Binary	Octal	Hexa-decimal
29.8	11101.110011…	35.63…	1D.CC…
5.8125	101.1101	5.64	5.D
3.109375	11.000111	3.07	3.1C
12.5078125	1100.10000010	14.404	C.82

Thank you