Chapter 1
Data Representation (Part 1)

Data Representation

- There are two basic ways of representing information, **analog** and **digital**.
- They are distinguished by the nature of the values that they allow information variables to assume.

Analog vs. Digital

Analog quantities

- can vary over a continuous range of values.
- Examples: voltage, room thermostat

Digital quantities

- represented by symbols called digits.
- Examples: digital watch

Analog and Digital Systems

Analog System

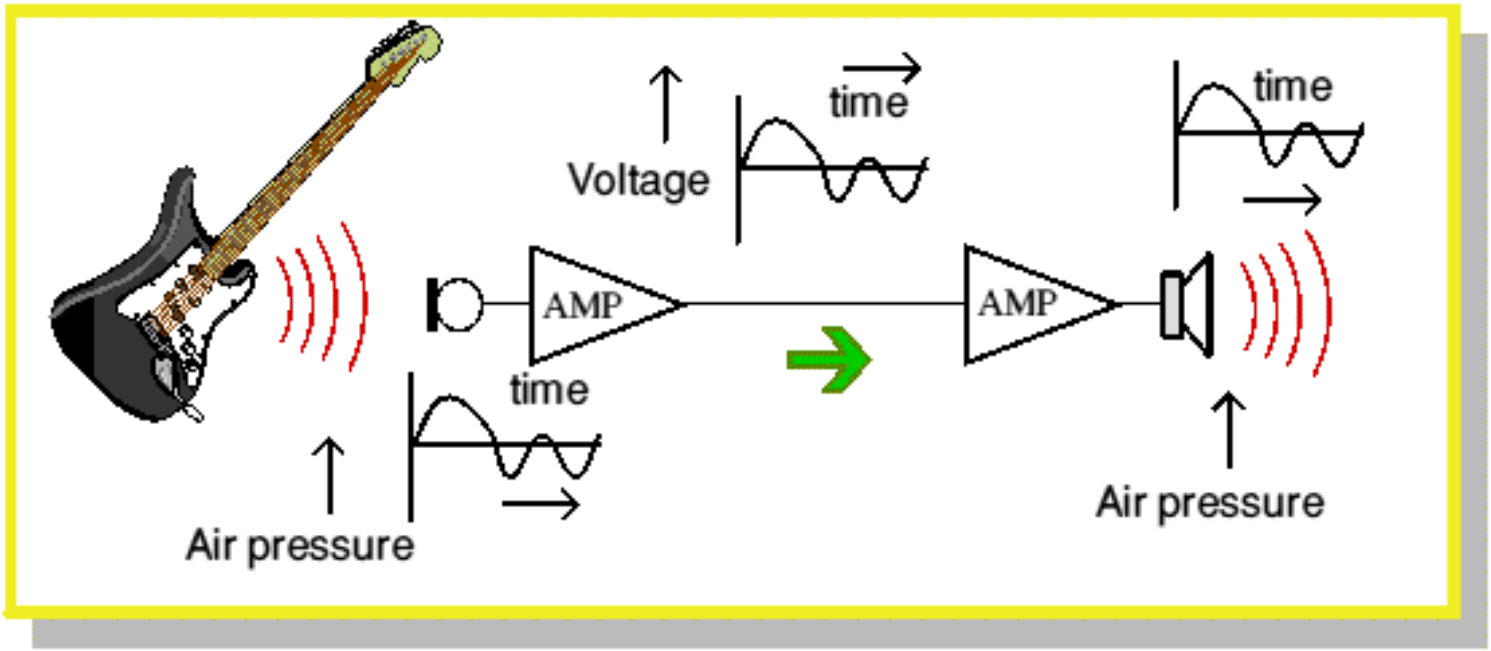
- contains devices that manipulate physical quantities that are represented in continuous range of values.
- Examples: audio amplifiers, automobile odometer

Digital quantities

- is a combination of devices designed to manipulate physical quantities that are represented in discrete values.
- Examples: digital computers, digital audio/video equipment

Example – **Analog System**

- *A simple guitar system*



Example – **Digital Systems**

- Wireless Devices

- Smart Watch

- Game Consoles

Advantages of Digital Techniques

- Digital system design is easier
- Information storage is easy
- Greater precision and accuracy
- Programmability
- Less susceptible to noise
- Digital circuitry can be fabricated on IC chips

Limitation of Digital Techniques

- There is one major drawback when using digital techniques:

The real world is mainly analog.

Limitation of Digital Techniques

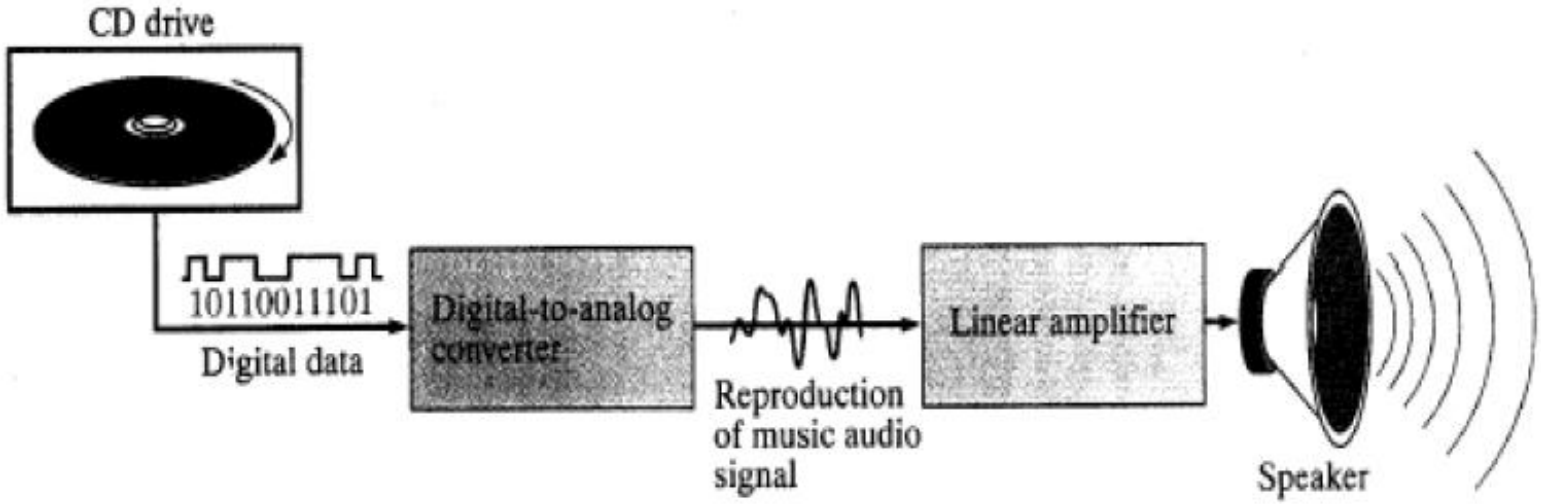
- There is one major drawback when using digital techniques:

The real world is mainly analog.

- *Hybrid systems* – both digital and analog techniques employed within the same system.

Example – **Hybrid System**

- CD Player



Digital Number Systems

- Many number systems are in use in digital technology.
- The most common are the *decimal*, *binary*, *octal*, and *hexadecimal* systems.

Number Systems

Number System	Base	Coefficients
Decimal	10	0 - 9
Binary	2	0 , 1
Octal	8	0 - 7
Hexadecimal	16	0 – 9, A - F

Base Conversion

- From any *base-r* to Decimal
- From Decimal to any *base-r*
- From Binary to either Octal or Hexadecimal
- From either Octal or Hexadecimal to Binary

Conversion: *Base-r* to *Decimal*

Procedure

- **Step 1:**

  Multiply each coefficient with the corresponding power of r.

- **Step 2:**

  Get the sum.

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2$ = _____ 10

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2$ = _____ 10

= (0×2^3) +

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2$ = _____ 10

= $(0 \times 2^3) + (1 \times 2^2) +$

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2 =$ _____ 10

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) +$

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2 =$ _____ 10

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) +$

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2 =$ _____ $_{10}$

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) + (1 \times 2^{-1}) +$

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2 =$ _____ $_{10}$

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) +$
$(1 \times 2^{-1}) + (0 \times 2^{-2}) +$

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2 =$ _____ 10

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) +$
$(1 \times 2^{-1}) + (0 \times 2^{-2}) + (1 \times 2^{-3})$

Conversion: *Base-r* to *Decimal*

Examples:

1. $(0111.101)_2 =$ _____ 10

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) + (1 \times 2^{-1}) + (0 \times 2^{-2}) + (1 \times 2^{-3})$

$= 0 + 4 + 2 + 1 + 0.5 + 0 + 0.125$

Conversion: *Base-r* to *Decimal*

Example (Binary-to-Decimal) :

1. $(0111.101)_2 =$ _____ $_{10}$

$= (0 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) + (1 \times 2^{-1}) + (0 \times 2^{-2}) + (1 \times 2^{-3})$

$= 0 + 4 + 2 + 1 + 0.5 + 0 + 0.125$

$= (7.625)_{10}$

Conversion: *Base-r* to *Decimal*

Example (Octal-to-Decimal) :

1. $(515.4)_8 =$ _____ 10

$= (5 \times 8^2) + (1 \times 8^1) + (5 \times 8^0) + (4 \times 8^{-1})$

Conversion: *Base-r* to *Decimal*

Example (Octal-to-Decimal) :

1. $(515.4)_8 =$ _____ 10

$= (5 \times 8^2) + (1 \times 8^1) + (5 \times 8^0) + (4 \times 8^{-1})$

$= 320 + 8 + 5 + 0.5$

Conversion: *Base-r* to *Decimal*

Example (Octal-to-Decimal) :

1. $(515.4)_8 =$ _____ $_{10}$

$= (5 \times 8^2) + (1 \times 8^1) + (5 \times 8^0) + (4 \times 8^{-1})$

$= 320 + 8 + 5 + 0.5$

$= (333.5)_{10}$

Binary to Decimal

Examples

1. $(11011100)_2$ = _____ 10

Binary to Decimal

Examples

1. $(11011100)_2$ = _____ 10

128	64	32	16	8	4	2	1
1	1	0	1	1	1	0	0

Binary to Decimal

Examples

1. $(11011100)_2 = (220)_{10}$

128	64	32	16	8	4	2	1
1	1	0	1	1	1	0	0

Binary to Decimal

Examples

1. $(11011100)_2 = (220)_{10}$

128	64	32	16	8	4	2	1
1	1	0	1	1	1	0	0

2. $(010101)_2 =$ _____ $_{10}$

Binary to Decimal

Examples

1. $(11011100)_2 = (220)_{10}$

128	64	32	16	8	4	2	1
1	1	0	1	1	1	0	0

2. $(010101)_2 =$ _____ $_{10}$

32	16	8	4	2	1
0	1	0	1	0	1

Binary to Decimal

Examples

1. $(11011100)_2 = (220)_{10}$

128	64	32	16	8	4	2	1
1	1	0	1	1	1	0	0

2. $(010101)_2 = (21)_{10}$

32	16	8	4	2	1
0	1	0	1	0	1

Conversion: *Decimal* to *Base-r*

Procedure

Step 1:

Separate integer from fraction.

Step 2:

Convert integer to base-r

Step 3:

Convert fraction to base-r

Integer to base-r

- Divide integer by r
- Accumulate remainders

Fraction to base-r

- Multiply fraction by r
- Accumulate integers

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem 1

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem 1

20 / 2 = 10 rem 0

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem	1
20 / 2 = 10 rem	0
10 / 2 = 5 rem	0

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem	1
20 / 2 = 10 rem	0
10 / 2 = 5 rem	0
5 / 2 = 2 rem	1

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem	1
20 / 2 = 10 rem	0
10 / 2 = 5 rem	0
5 / 2 = 2 rem	1
2 / 2 = 1 rem	0

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem	1
20 / 2 = 10 rem	0
10 / 2 = 5 rem	0
5 / 2 = 2 rem	1
2 / 2 = 1 rem	0
1 / 2 = 0 rem	1

Decimal to Binary

Examples

1. $(41.6875)_{10}$ = _____$_2$

Step 1:

Integer = 41

Fraction = 0.6875

Step 2:

41 / 2 = 20 rem 1

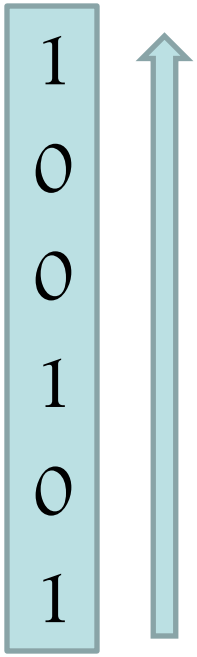
20 / 2 = 10 rem 0

10 / 2 = 5 rem 0

5 / 2 = 2 rem 1

2 / 2 = 1 rem 0

1 / 2 = 0 rem 1



Decimal to Binary

Step 3:

0.6875 x 2 = 1.3750 1

Decimal to Binary

Step 3:

0.6875 x 2 = 1.3750 1

0.3750 x 2 = 0.7500 0

Decimal to Binary

Step 3:

0.6875 x 2 = 1.3750 1

0.3750 x 2 = 0.7500 0

0.7500 x 2 = 1.5000 1

Decimal to Binary

Step 3:

0.6875 x 2 = 1.3750 1

0.3750 x 2 = 0.7500 0

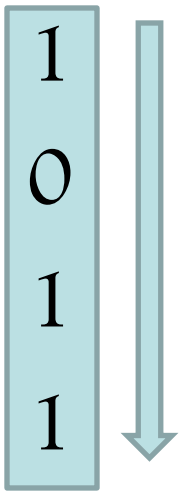
0.7500 x 2 = 1.5000 1

0.5000 x 2 = 1.0000 1

Decimal to Binary

Step 3:

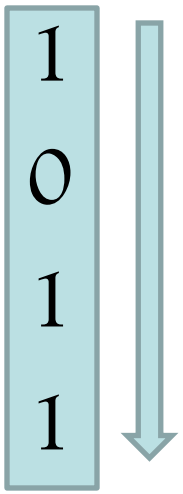
0.6875 x 2 = 1.3750	1
0.3750 x 2 = 0.7500	0
0.7500 x 2 = 1.5000	1
0.5000 x 2 = 1.0000	1



Decimal to Binary

Step 3:

0.6875 x 2 = 1.3750	1
0.3750 x 2 = 0.7500	0
0.7500 x 2 = 1.5000	1
0.5000 x 2 = 1.0000	1



Thus: $(41.6875)_{10} = (101001.1011)_2$

Decimal to Octal

Examples

2. $(143.44)_{10}$ = _____$_8$

Step 1:

Integer = 143

Fraction = 0.44

Decimal to Octal

Examples

2. $(143.44)_{10}$ = _____$_8$

Step 1:

Integer = 143

Fraction = 0.44

Step 2:

143 / 8 = 17 rem 7

Decimal to Octal

Examples

2. $(143.44)_{10}$ = _____$_8$

Step 1:

Integer = 143

Fraction = 0.44

Step 2:

143 / 8 = 17 rem 7

17 / 8 = 2 rem 1

Decimal to Octal

Examples

2. $(143.44)_{10}$ = _____$_8$

Step 1:

Integer = 143

Fraction = 0.44

Step 2:

143 / 8 = 17 rem 7

17 / 8 = 2 rem 1

2 / 8 = 0 rem 2

Decimal to Octal

Examples

2. $(143.44)_{10}$ = _____$_8$

Step 1:

Integer = 143

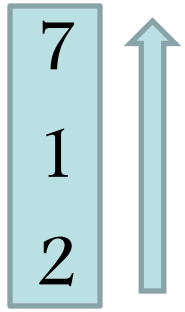
Fraction = 0.44

Step 2:

143 / 8 = 17 rem 7

17 / 8 = 2 rem 1

2 / 8 = 0 rem 2



Decimal to Octal

Step 3:

0.44 x 8 = 3.52 3

Decimal to Octal

Step 3:

0.44 x 8 = 3.52 3

0.52 x 8 = 4.16 4

Decimal to Octal

Step 3:

0.44 x 8 = 3.52	3
0.52 x 8 = 4.16	4
0.16 x 8 = 1.28	1

Decimal to Octal

Step 3:

0.44 x 8 = 3.52	3
0.52 x 8 = 4.16	4
0.16 x 8 = 1.28	1
0.28 x 8 = 2.24	2

Decimal to Octal

Step 3:

0.44 x 8 = 3.52	3
0.52 x 8 = 4.16	4
0.16 x 8 = 1.28	1
0.28 x 8 = 2.24	2
0.24 x 8 = 1.92	1

Decimal to Octal

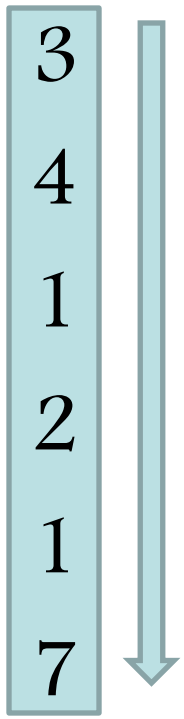
Step 3:

0.44 x 8 = 3.52	3
0.52 x 8 = 4.16	4
0.16 x 8 = 1.28	1
0.28 x 8 = 2.24	2
0.24 x 8 = 1.92	1
0.92 x 8 = 7.36	7

Decimal to Octal

Step 3:

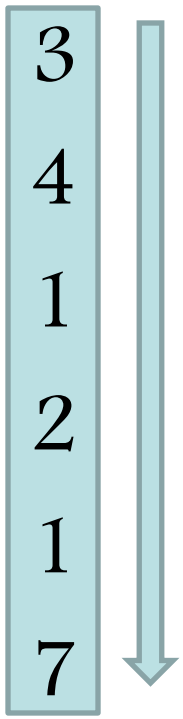
0.44 x 8 = 3.52	3
0.52 x 8 = 4.16	4
0.16 x 8 = 1.28	1
0.28 x 8 = 2.24	2
0.24 x 8 = 1.92	1
0.92 x 8 = 7.36	7



Decimal to Octal

Step 3:

0.44 x 8 = 3.52	3
0.52 x 8 = 4.16	4
0.16 x 8 = 1.28	1
0.28 x 8 = 2.24	2
0.24 x 8 = 1.92	1
0.92 x 8 = 7.36	7



Thus: $(143.44)_{10} = (217.341217)_{8}$

Decimal to Binary

Examples

1. $(130)_{10}$ = _____$_2$

128	64	32	16	8	4	2	1
1							

Decimal to Binary

Examples

1. $(130)_{10}$ = _____$_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	

Decimal to Binary

Examples

1. $(130)_{10}$ = _____$_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1						

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1	1					

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1	1	1				

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1	1	1	1			

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1	1	1	1	0		

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1	1	1	1	0	1	

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} =$ _____$_2$

64	32	16	8	4	2	1
1	1	1	1	0	1	1

Decimal to Binary

Examples

1. $(130)_{10} = (10000010)_2$

128	64	32	16	8	4	2	1
1	0	0	0	0	0	1	0

2. $(123)_{10} = (1111011)_2$

64	32	16	8	4	2	1
1	1	1	1	0	1	1