Course contents

Design with Hardware Description Language: Structural and behavioural Verilog				
Combinational logic circuits Encoder, decoder, multiplexer			**Sequential logic circuits** Counter, register, finite state machine	
Digital circuits				**Flip-flops**
Number systems and codes	**Logic gates**	**Boolean algebra**	**Digital arithmetic**	**Boolean expression simplification**

Summary

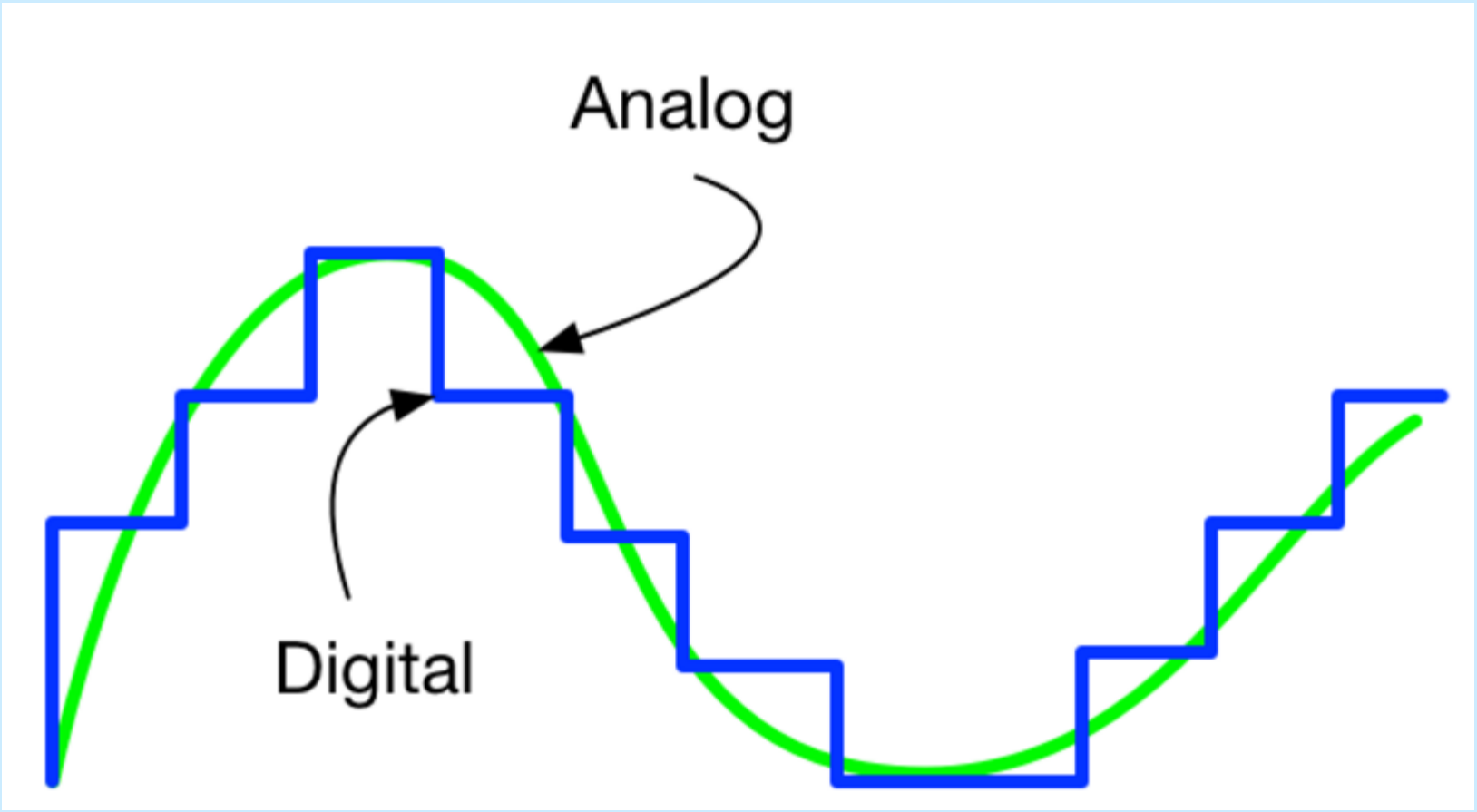
on

Introduction,
Number systems & Codes

Key concepts

1. Digital vs Analog
2. Serial vs Parallel
3. Number bases: 2, 8, 10, 16
4. Codes: BCD, ASCII, Gray
5. Parity method for error detection

Analog / digital

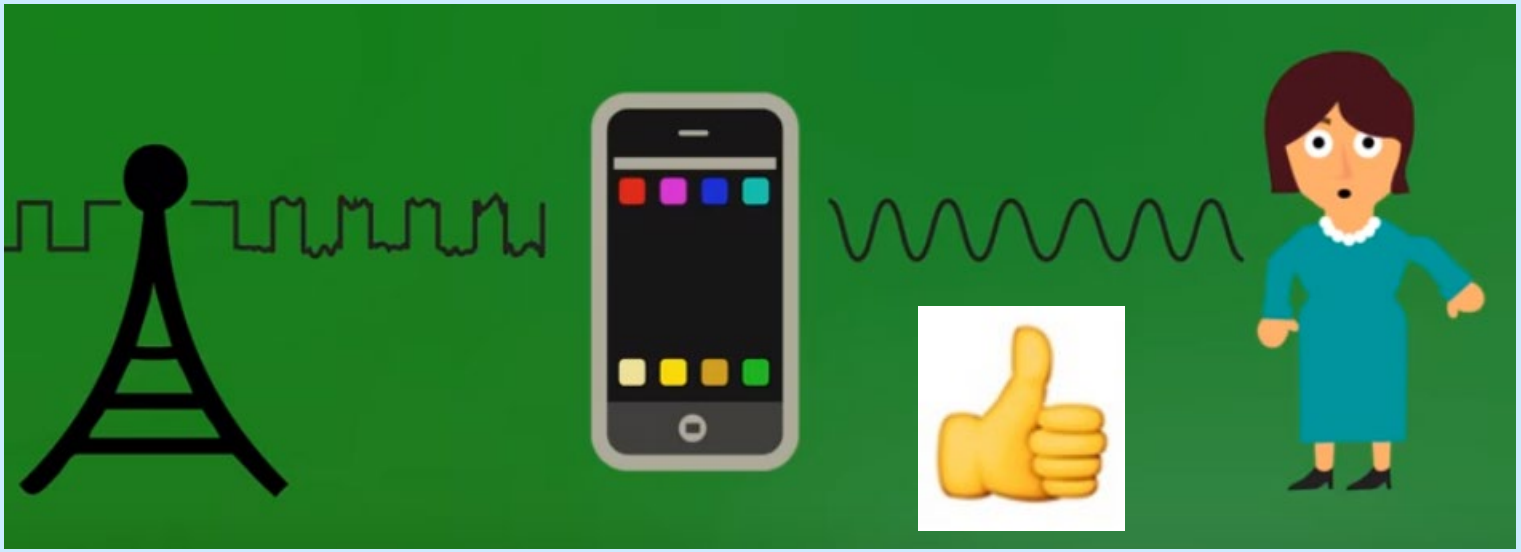


http://www.technodabbler.com/analog-music-in-a-digital-world/

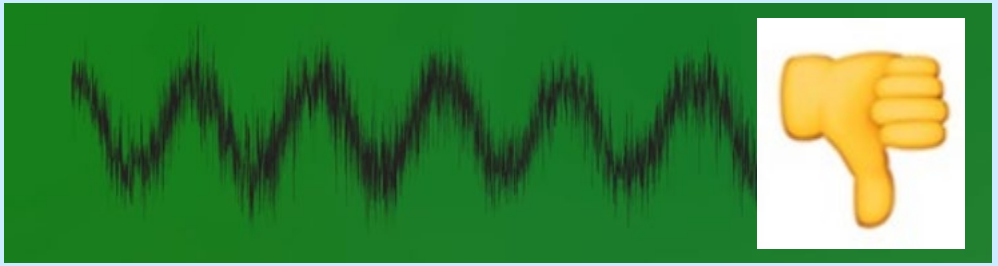
Digital vs Analog – an illustration

https://www.youtube.com/watch?v=XCu6L4kQF3k

Digital vs Analog (cont)

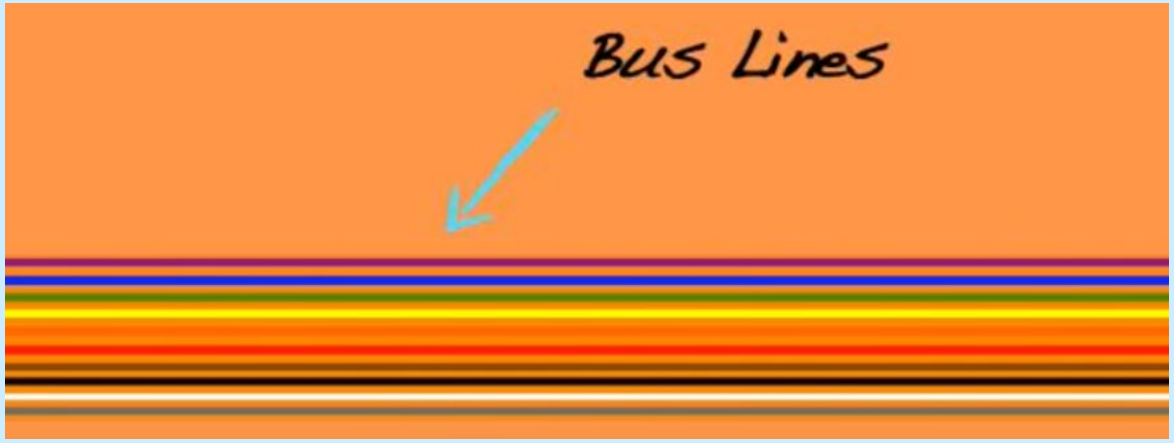


Contrast with purely analog



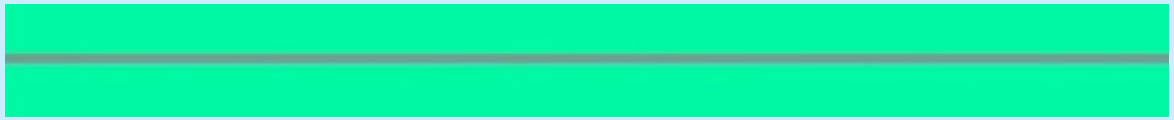
https://www.youtube.com/watch?v=XCu6L4kQF3k

Serial vs Parallel data transmission



Speed

versus

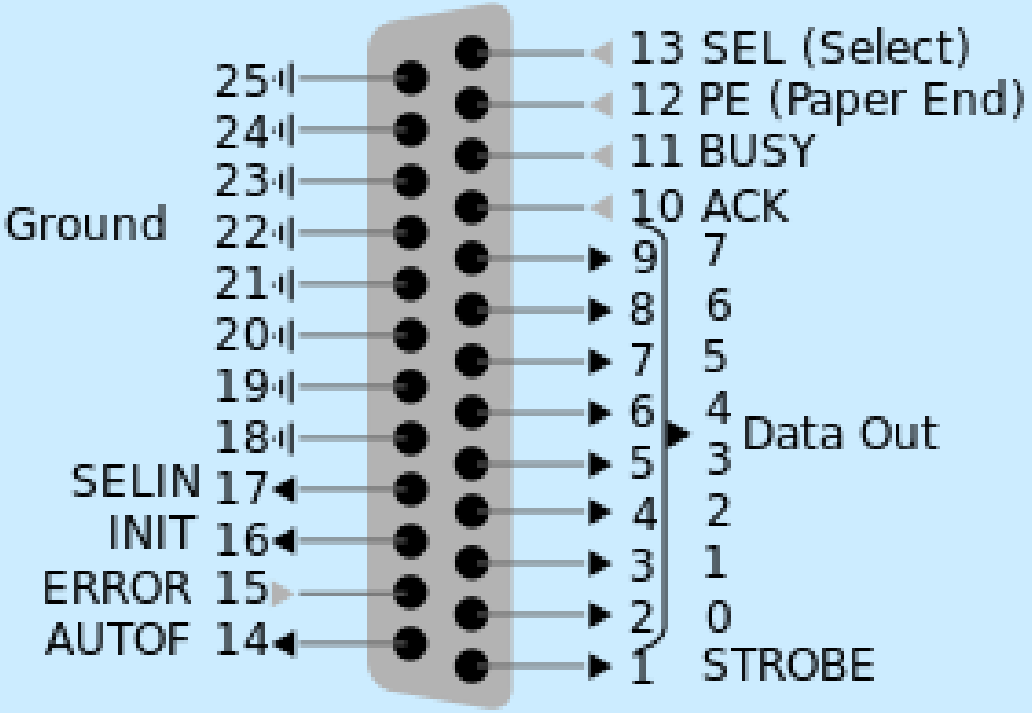


cost

https://www.youtube.com/watch?v=cBZUckBCy-U

Parallel data interface example

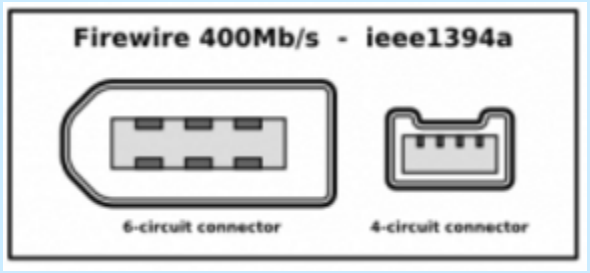
Traditional Printer port



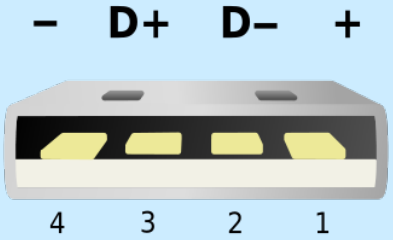
Serial data interface examples

RS232

Ethernet



Firewire



USB

Which number below has the largest value?

A. 24_8

B. 20_{16}

C. 22_{10}

Number Bases: 2, 8, 16

Binary: **1 0 1 0 1 0 1 1 0 0 0 1 1 1**

Octal: ? 0 1 0 1 0 1 0 1 1 0 0 0 1 1 1

2 5 3 0 7

Group 3 bits starting from LSB
Pad MSB with 0's if necessary

Verify with http://coderstoolbox.net/number/

Number Bases: 2, 8, 16

Binary: **1 0 1 0 1 0 1 1 0 0 0 1 1 1**

Hexadecimal: ?

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

2 A C 7

Group 4 bits starting from LSB
Pad MSB with 0's if necessary

Number conversion examples

- **Convert from base N to decimal**
- **Multiply by weights and Add**

e.g. 1001.0011 (base 2)

$1001_2 = 1(2\text{^}3) + 1(2\text{^}0) = 8 + 1 = 9_{10}$

$0.0011_2 = 1(2\text{^}-3) + 1(2\text{^}-4) = 0.1875_{10}$

Thus $1001.0011_2 = 9.1875_{10}$

Convert from base N to decimal

e.g. 100 (base 8)

= 1(8^2) + 0 + 0 = 64_{10}

e.g. FEED (hex)

= 15(16^3) +14(16^2) + 14(16) + 13

= 65261_{10}

Number conversion examples

- **Convert from decimal to base N**
- **Repeat division by N**
- **Examples:**

Convert decimal 32536 to base 8
32536/8 = 4067 r 0
4067/8 = 508 r 3
508/8 = 63 r 4
63/8 = 7 r 7
Thus $32536_{10} = 77430_8$

Convert from decimal to base 2

Convert decimal 898 to base 2

898/2 = 449 r 0
449/2 = 224 r 1
224/2 = 112 r 0
112/2 = 56 r 0
…… etc.

Tedious!

Thus 898_{10} = 11 1000 0010 $_2$

Base-16 as short form for base-2

- Alternatively, convert to base **16** first
- e.g. 898_{10} to base 2
- 898/**16** = 56 r 2
- 56/**16** = 3 r 8

2 (hex) = 0010 (bin)
8 (hex) = 1000 (bin)
3 (hex) = 0011 (bin)

Thus 898_{10} = **3**x16^2 + **8**x16 + **2** (dec)
= 3 8 2 (hex)
= 0011 1000 0010 $_2$

Worked example

What is X?

Given that

$$\frac{3EA_{16} - 156_{7}}{X_{8}} = 49_{12}$$

Codes: BCD, ASCII, Gray

BCD: replaces <u>each</u> decimal digit (0 to 9 only) with 4 bits

Decimal	BCD 8 4 2 1
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1

e.g.
105 -> 0001 0000 0101
Not 110 1001

974 -> 1001 0111 0100
Not 11 1100 1110

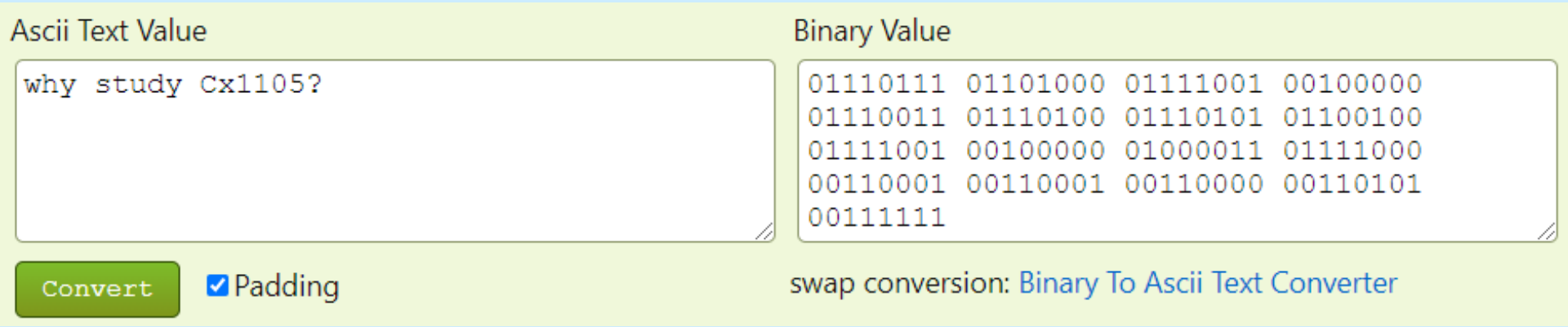
Not to be confused with straight binary

http://www.miniwebtool.com/decimal-to-bcd-converter/

ASCII

- **ASCII: 7 bits to represent each alphanumeric character**

  (a-z, A-Z, 0-9, punctuation marks etc.)



http://www.binaryhexconverter.com/ascii-text-to-binary-converter

Gray code

1 bit change at a time when moving through the code words in sequence

Example:

Decimal	Binary	Gray
7	0 1 1 1	0 1 0 0
8	1 0 0 0	**1** 1 0 0
9	1 0 0 1	1 1 0 **1**

http://www.miniwebtool.com/binary-to-gray-code-converter/

Is this a sequence of Gray codes?
010 -> 110 -> 100 -> 000 and repeats

A. Yes

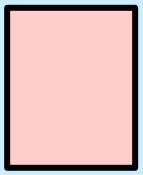
B. No

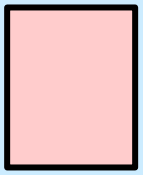
C. Not sure

Odd and even parity

Example, ASCII code for character “A” is

1 0 0 0 0 0 1

<u>odd</u> parity: transmit  **1 0 0 0 0 0 1**

<u>even</u> parity: transmit  **1 0 0 0 0 0 1**

Limitation: Can only detect 1 bit error

http://www.electronicshub.org/parity-generator-and-parity-check/#parity_generator_and_checker

End of summary

on

Introduction, Number systems & Codes