6004 Spring 1998: L01

6.004: Computation Structures
(Exploring the Innards of a Computer System)

Digital Abstraction and Logic

http://cag-www.lcs.mit.edu/6.004

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The 6.004 Staff

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6.004 Staff - 2

	Recitation		Instructor	TA
1	WF at 10AM	26-210	*Luis Sarmenta*	*John Wang*
2	WF at 11AM	26-210	*Luis Sarmenta*	*John Wang*
4	WF at 11AM	34-303	*Gill Pratt*	*Marcie Black*
7	WF at 12PM	34-303	*Gill Pratt*	*Marcie Black*
8	WF at 1PM	26-310	*Dennis Freeman*	*Mike Sy*
5	WF at 2PM	26-314	*Dennis Freeman*	*Mike Sy*
3	WF at 12PM	26-210	CANCELLED	
6	WF at 1PM	34-302	CANCELLED	

LAB TA: *Adrian Danieli*

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6.004 Logistics

- **Textbook: “Computation Structures” by Ward and Halstead**
- **Grading:**
  - 10 Problem sets: 100 points
  - 2 Quizzes: 200 points
  - 1 Final: 200 points
  - 5 Laboratories and Design Contest: ?? points
    - » Lab grades used in threshold cases.
    - » Minimum performance required to pass the course.

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6.004 Laboratory

- You will go through a sequence of laboratory assignments that culminate in the design of a computer
  - Laboratory located in 34-501
  - Open 24 hours, 7 days a week
  - No lab kits unlike previous terms
  - You will use a software environment, and a language called Curl, to simulate everything from simple logic circuits to (eventually) the detailed operation of a processor

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What is 6.004 About?

Stock answer: Structures that perform computations!

We will focus on digital computers

Today's lecture:

- What is computation?
- Why digital computation rather than analog?

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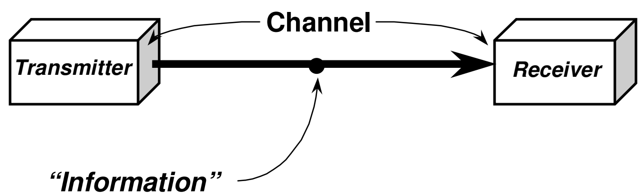
What is Computation?

Reliable** transmission, processing and storage of **information



Reliability $\rightarrow$ robustness in the presence of noise

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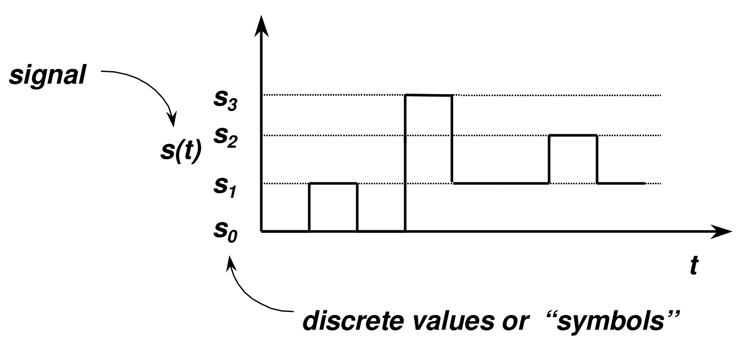
Representation of Information

Represent information as discrete values of a continuous signal that varies as a function of time, position or other coordinates



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How Much Information?

- Let *q* be the number of distinct symbols
- Define the baud rate *B* as the number of symbols per second, or number of value transitions per second
- Define the bit rate as $\log_2(q) \times B$

Example:

$q = 8 \quad B = 1000 \Rightarrow \log_2(8) \times 1000 =$ ***3000 bits per second***

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Increasing Information Rate

- Increase baud rate
- Increase number of symbols
- Add channels

Increasing baud rate?

Fundamental limitation (Nyquist)

Maximum baud rate $\leq$ $2W$

where W is the channel bandwidth

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Increasing Information Rate - II

Increasing the number of symbols

How many discrete voltages between 0V and 5V? Answer: _______

Can we increase the number of symbols to get arbitrary high information rates? Answer: _____

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Representing Images

- **Representation of each point *(x, y)* on a greyscale picture:**
  - **Voltage of a signal with *q = 100***
  - **0 volts: BLACK**
  - **1 volt: WHITE**
  - **0.28 volts: 28% grey**
- **Representation of picture:**
  - **Scan points in a prescribed order to generate a voltage waveform *V(x, y)***

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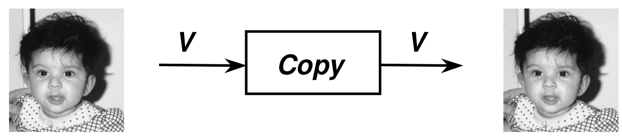
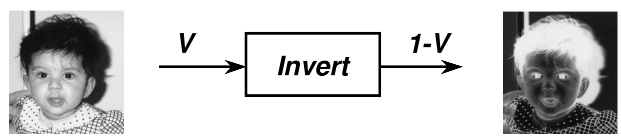
Information Processing

- **Copying**



- **Inversion**



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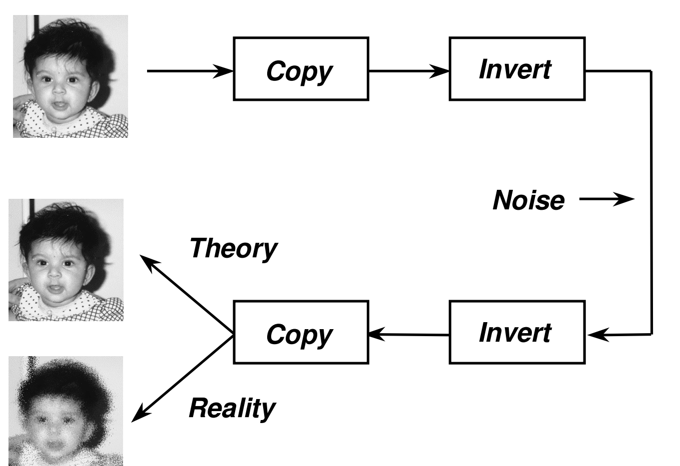
Information Processing Systems



Noise of **<u>10mV</u>** ***causes image corruptions***

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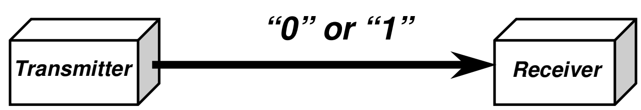
The Digital Deal

- Reduce the information content per signal drastically
- In return get a guarantee of the amount of information reliably processed, namely noise immunity

q = 2 ***Binary-valued signal or bit***



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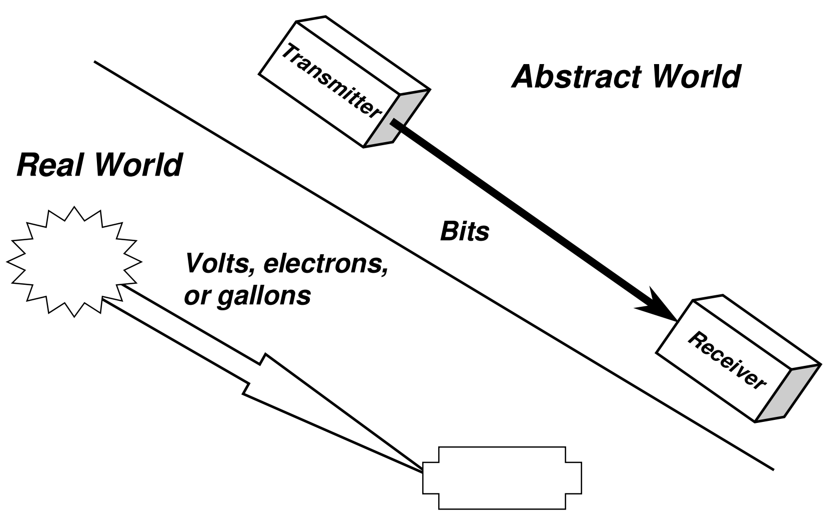
The Digital Abstraction



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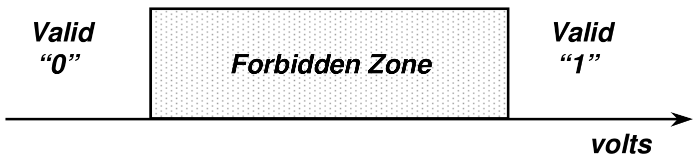
Voltages and Digital Values

- **Do not mistake "0" for "1", or vice versa**
  - **In a 0 volt to 1 volt system, obviously noise of magnitude 1 volt will corrupt information**
- **Maximize noise immunity by appropriately choosing mapping of voltage to digital values**
  - **Outlaw "close calls" and define <u>valid voltage levels</u>**



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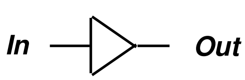
Abstraction: Combinational Device

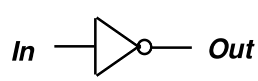
- **Functional specification defined on {0, 1}, relating each combination of input values to a value at each output**

Buffer



In	*Out*
0	*0*
1	*1*

Inverter



In	*Out*
0	*1*
1	*0*

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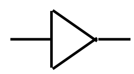
Abstraction: Combinational Device - II

- **Every combinational device must guarantee that <u>valid inputs generate valid outputs</u>**

Termed the static discipline

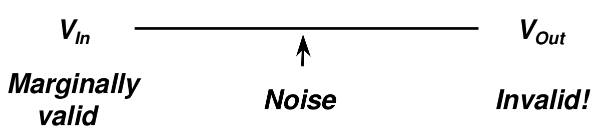
In  ***Out***

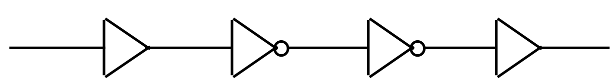
In	Out
[0.0V, 0.3V]	**[0.0V, 0.3V]**
[0.7V, 1.0V]	**[0.7V, 1.0V]**

- **Every <u>acyclic circuit</u> whose components are combinational devices is itself a combinational device**

Combinational Circuit

- **Does a wire obey the static discipline?**

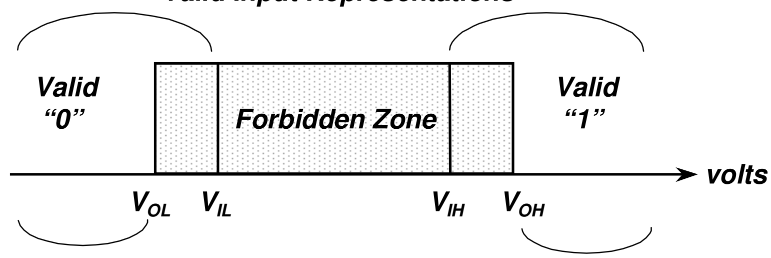




A combinational device must <u>restore</u> marginally valid signals

Static Discipline

Valid Input Representations



Valid Output Representations

Need tighter validity constraints on outputs than on inputs!

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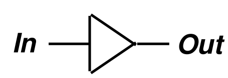
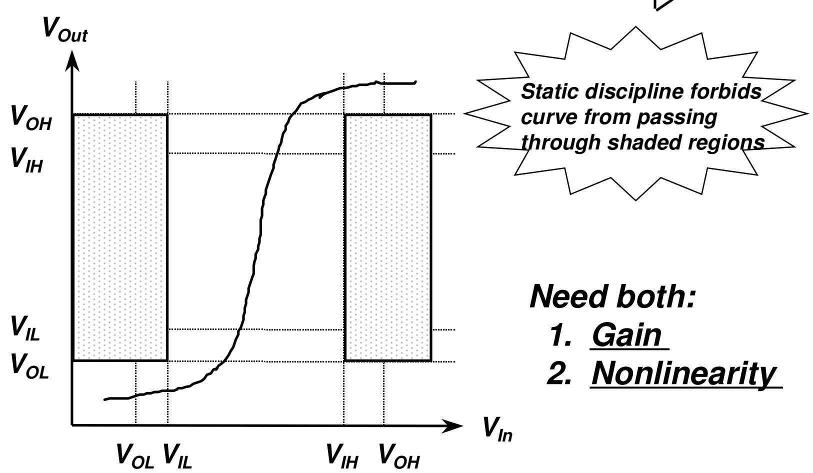
Restoring Logic

Static Voltage Transfer Curve for Buffer





Need both:

1. ***Gain***
2. ***Nonlinearity***

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