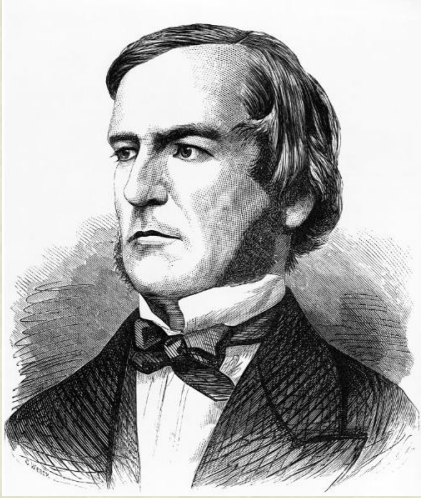
Fundamentos de Sistemas Digitais

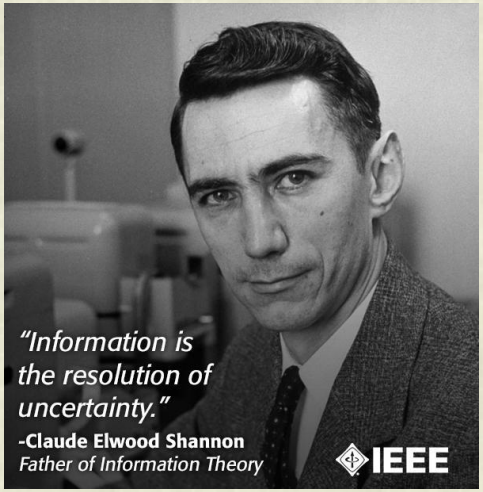
De Boole ao Circuito Integrado: uma revisão dos níveis de abstração

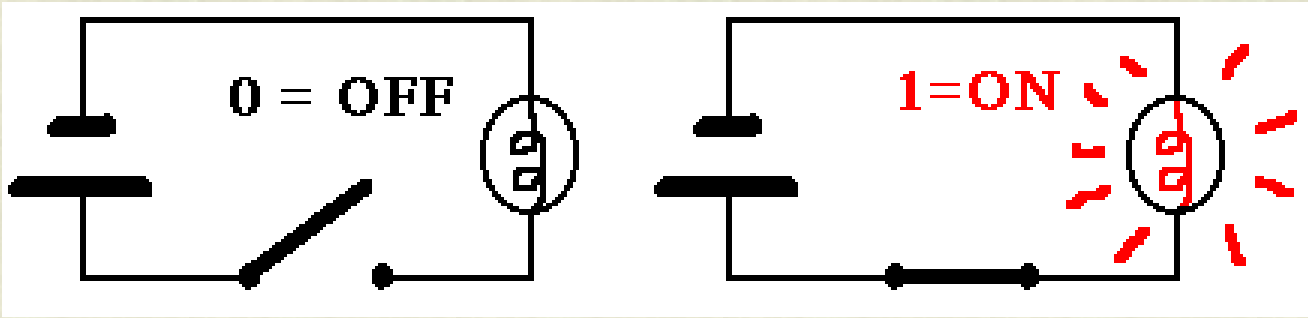
prof. Dr. Alexandre M. Amory

Uma Breve História



- **George Boole:**
  ***The mathematical analysis of logic* (1848)**
  - Recebeu várias melhorias
  - Sem aplicação prática até ….
- **Claude Shannon:**
  ***A Symbolic Analysis of Relay and Switching Circuits* (1937)**
  Aplicação de álgebra de Boole na análise de circuitos de relés
  - O pai da telecom





https://en.wikipedia.org/wiki/Claude_Shannon

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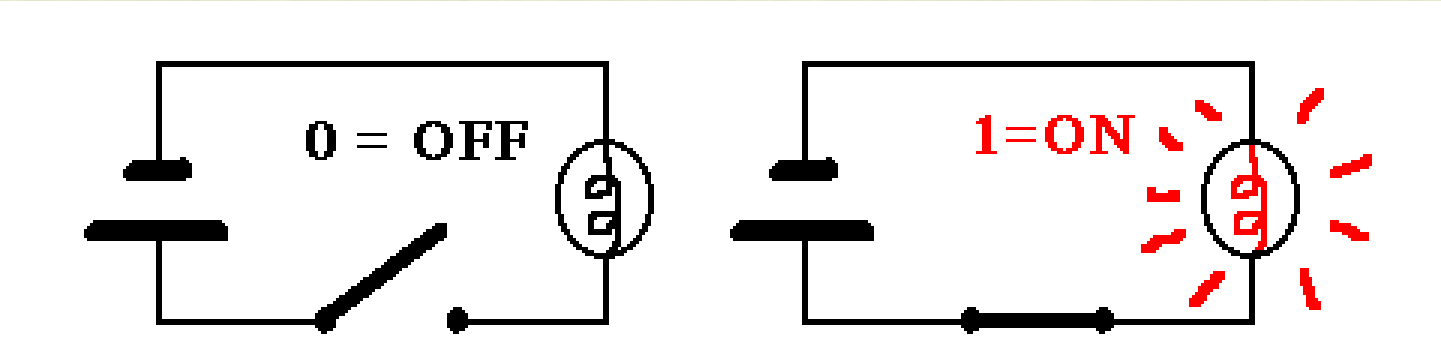
Claude Shannon at wikipedia

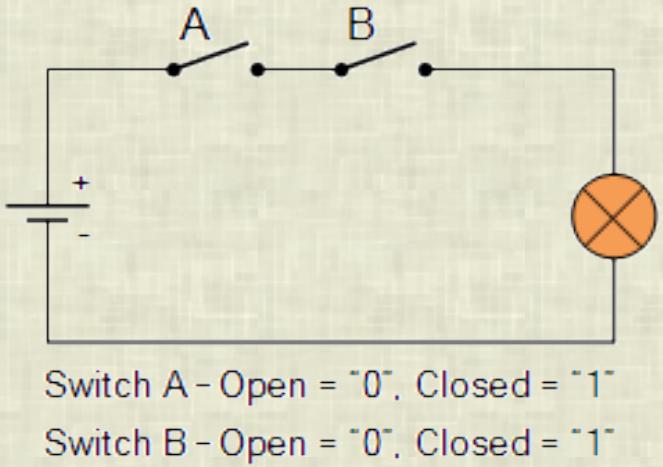
- **“In this work, Shannon proved that Boolean algebra and binary arithmetic could be used to simplify the arrangement of the electromechanical relays that were used then in telephone call routing switches. Next, he expanded this concept; proving that it would be possible to use arrangements of relays to solve problems in Boolean algebra.**

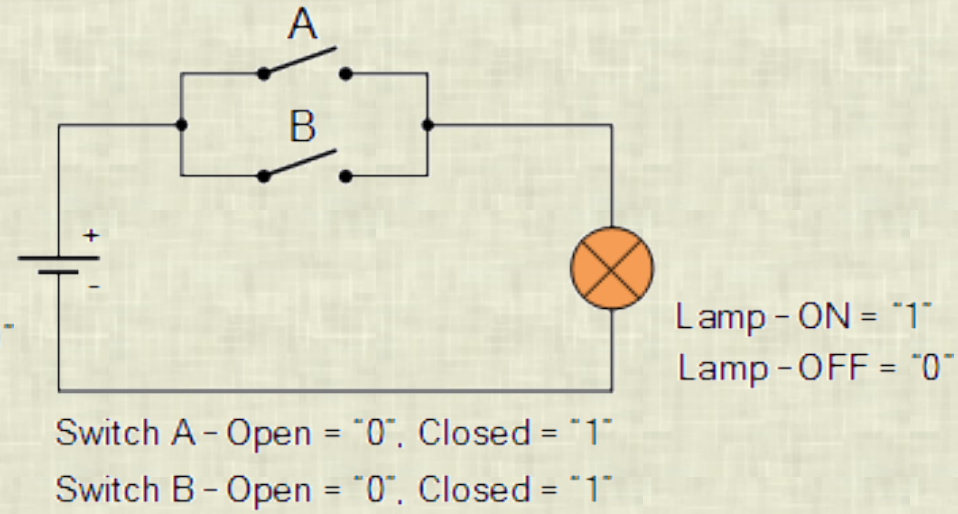
- **Using this property of electrical switches to implement logic is the fundamental concept that underlies all electronic digital computers. Shannon's work became the foundation of digital circuit design;”**

telephone call routing switches

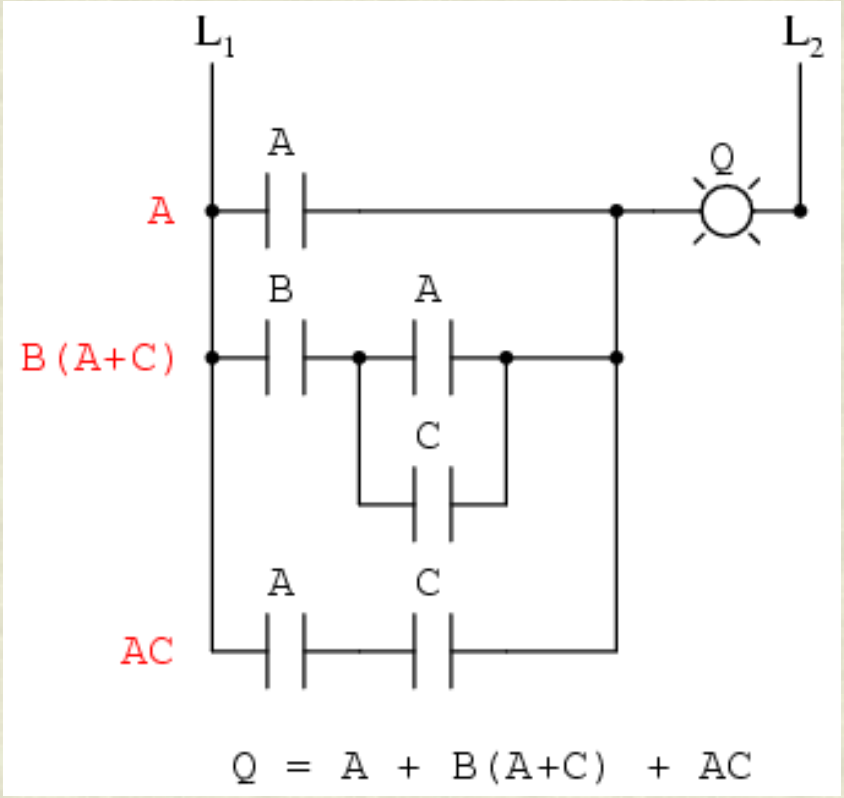
Lógica de Boole Aplicada

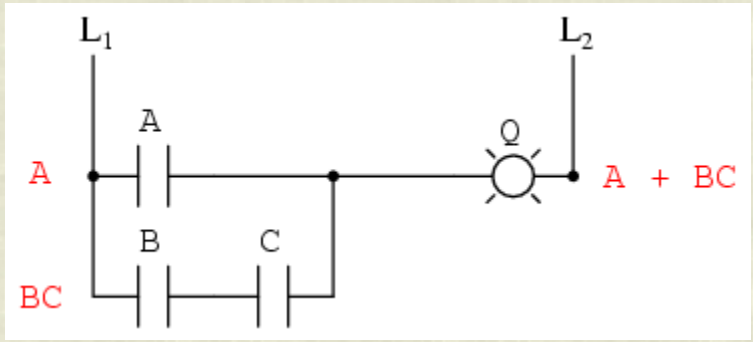






Simplicação de Chaves



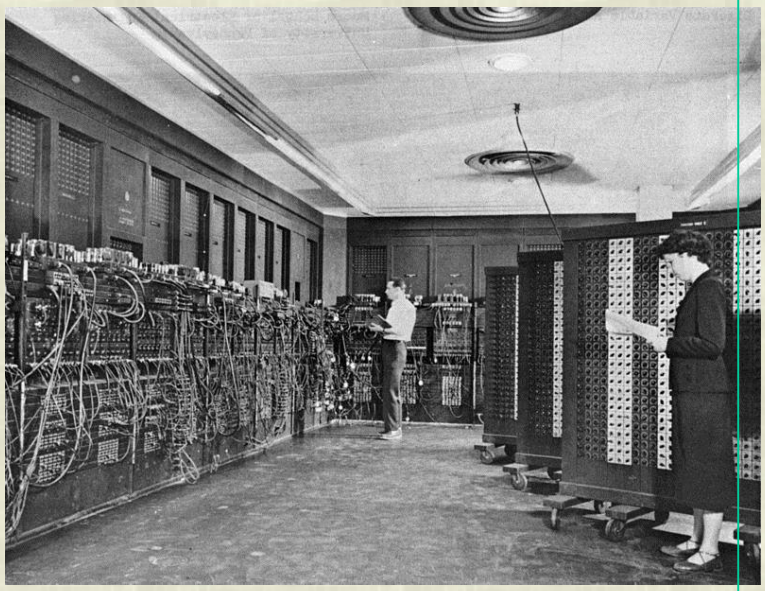


ABSTRAÇÃO !!!

Aplicação em problemas do dia-a-dia

Aplicações

- **Otimização das rede de chave de telefones**
- **Máquinas automáticas**
  - Tecnologia baseada em relé
- **Problema do relé: lentidão**
  - Soluções baseadas em relé
  - Mov. de partes mecânicas → Lento !!!
- **Solução: Válvula (1946 até +- 70')**
  - Construção do ENIAC
  - ENIAC contained 17,468 vacuum tubes, 7200 crystal diodes, 1500 relays, 70,000 resistors, 10,000 capacitors and approximately 5,000,000 hand-soldered joints. It weighed more than 30 tons, was roughly 2.4m × 0.9m × 30m in size, occupied 1800 ft2 (167m2) and consumed 150 kW of electricity
  - A multiplication of a 10- by 10-digit multiplication took 14 cycles, or 2800 microseconds—a rate of 357 per second

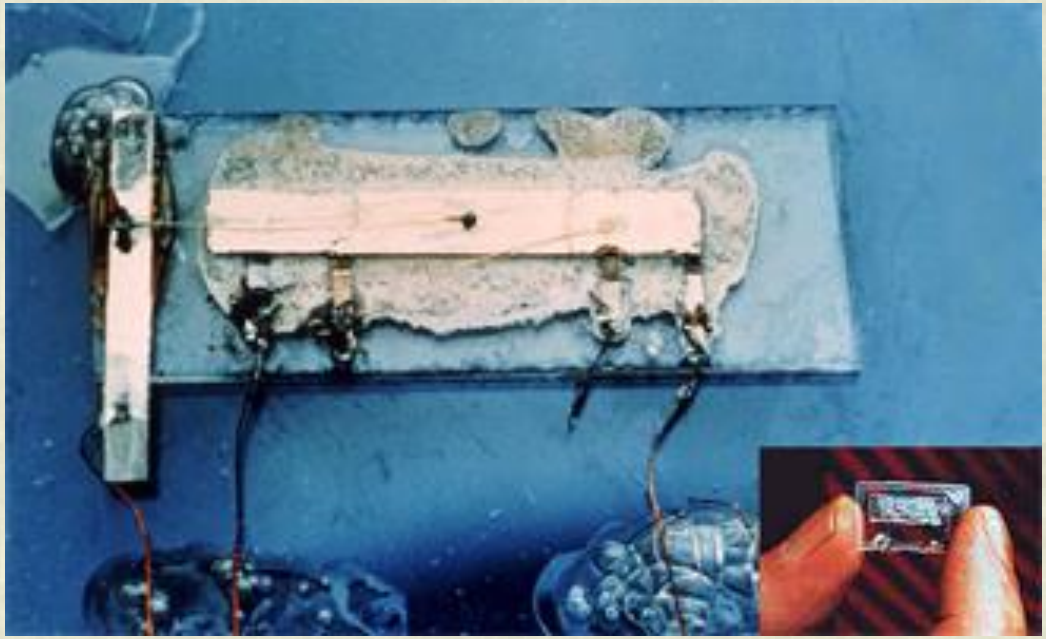


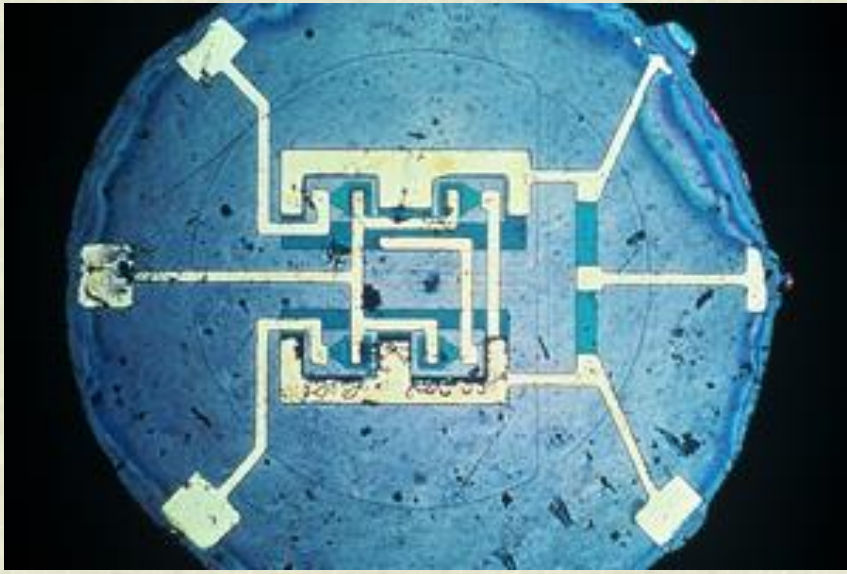
Aplicações

- **Problema da Válvula: confiabilidade**
  - "Several tubes burned out almost every day, leaving it nonfunctional about half the time."
- **Problema da Válvula: bugs nos relés !!!!!**

Aplicações

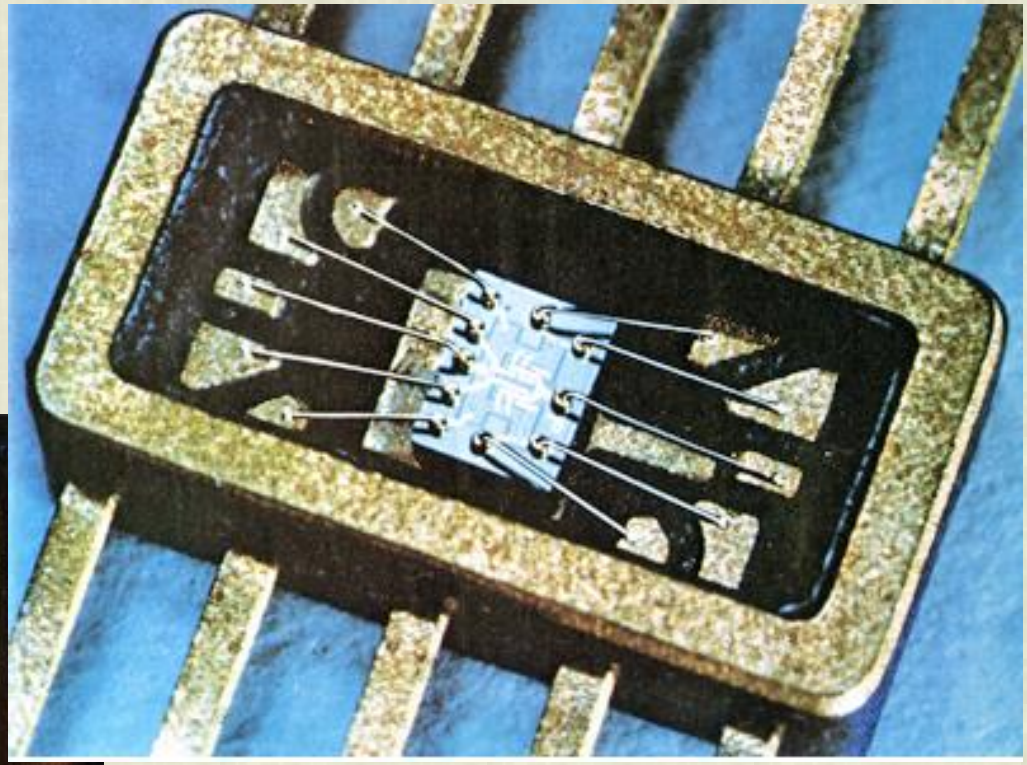
- **Solução: transistor discretos (1947 até atualmente)**
  - Vantagens: menores, mais rápidos, confiáveis

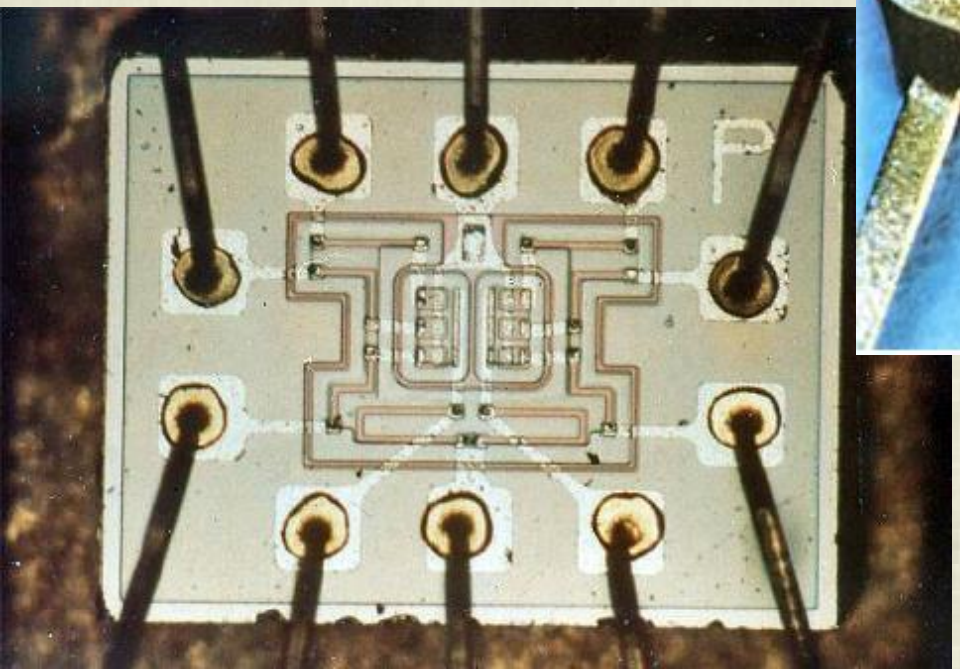




Aplicações

- **1o CI: uma porta NOR**

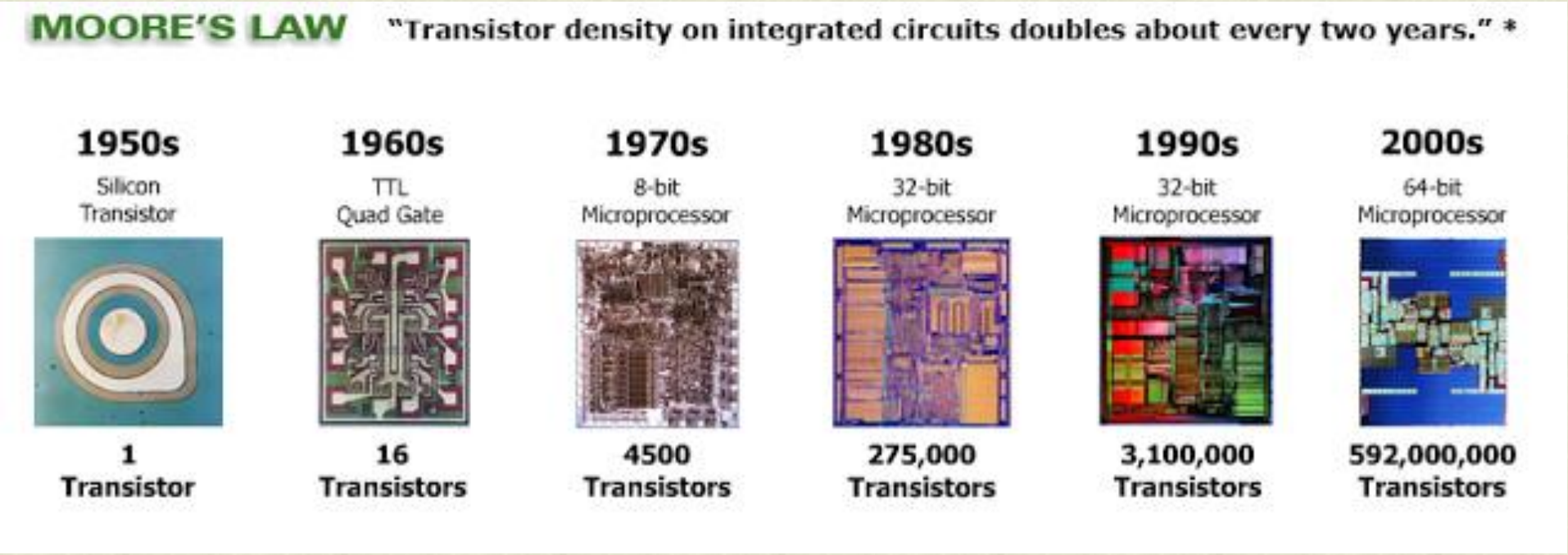




https://en.wikipedia.org/wiki/Invention_of_the_integrated_circuit

Aplicações

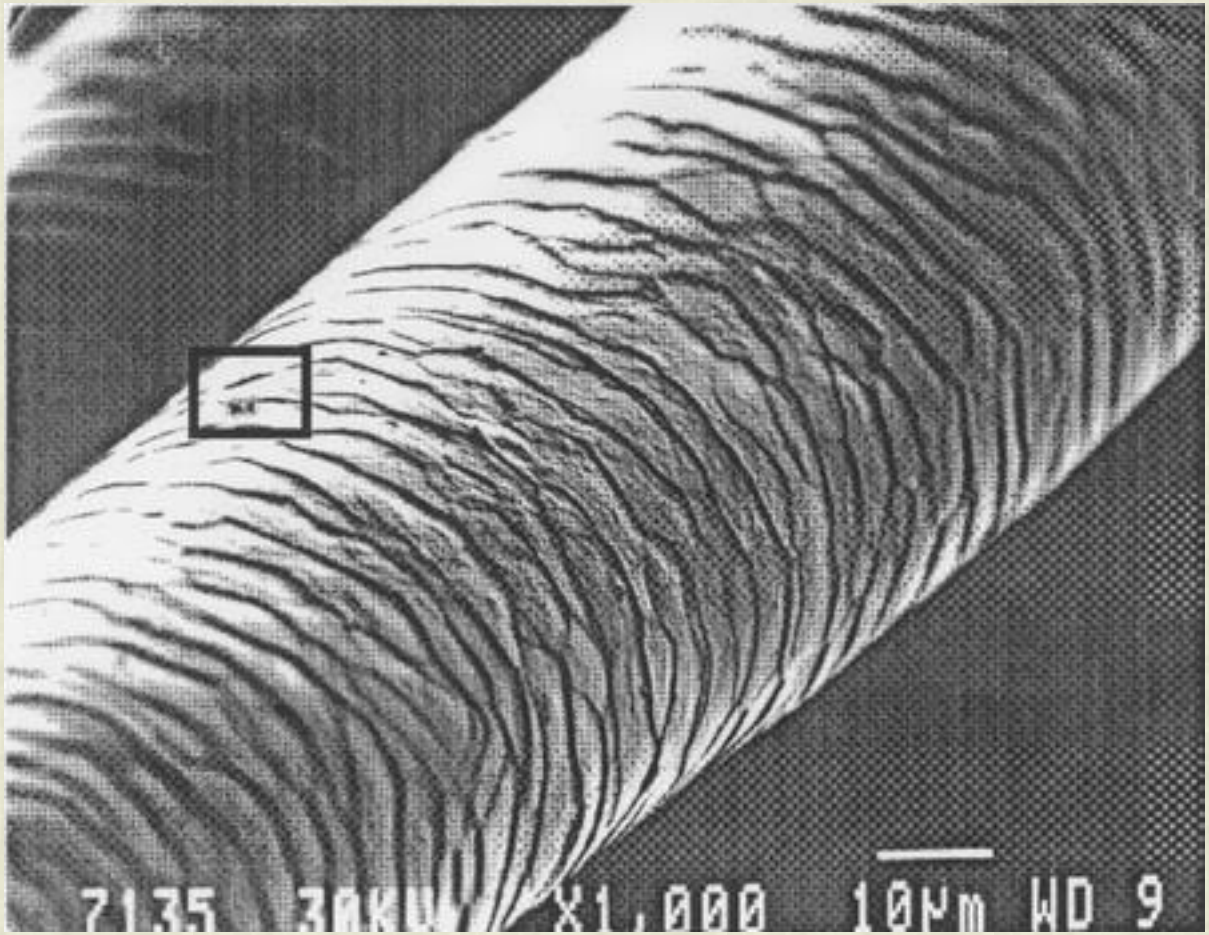
- **Circuito Integrado (CI): 1958**



Hoje em dia: +- 1.5Bilhões de transistors (22nm)

http://electronicsbyexamples.blogspot.com.br/2013/03/milestones-in-digital-electronics.html

How Small is small ???



http://www.latenightim.com/internet-marketing-electrons-and-the-meaning-of-life/

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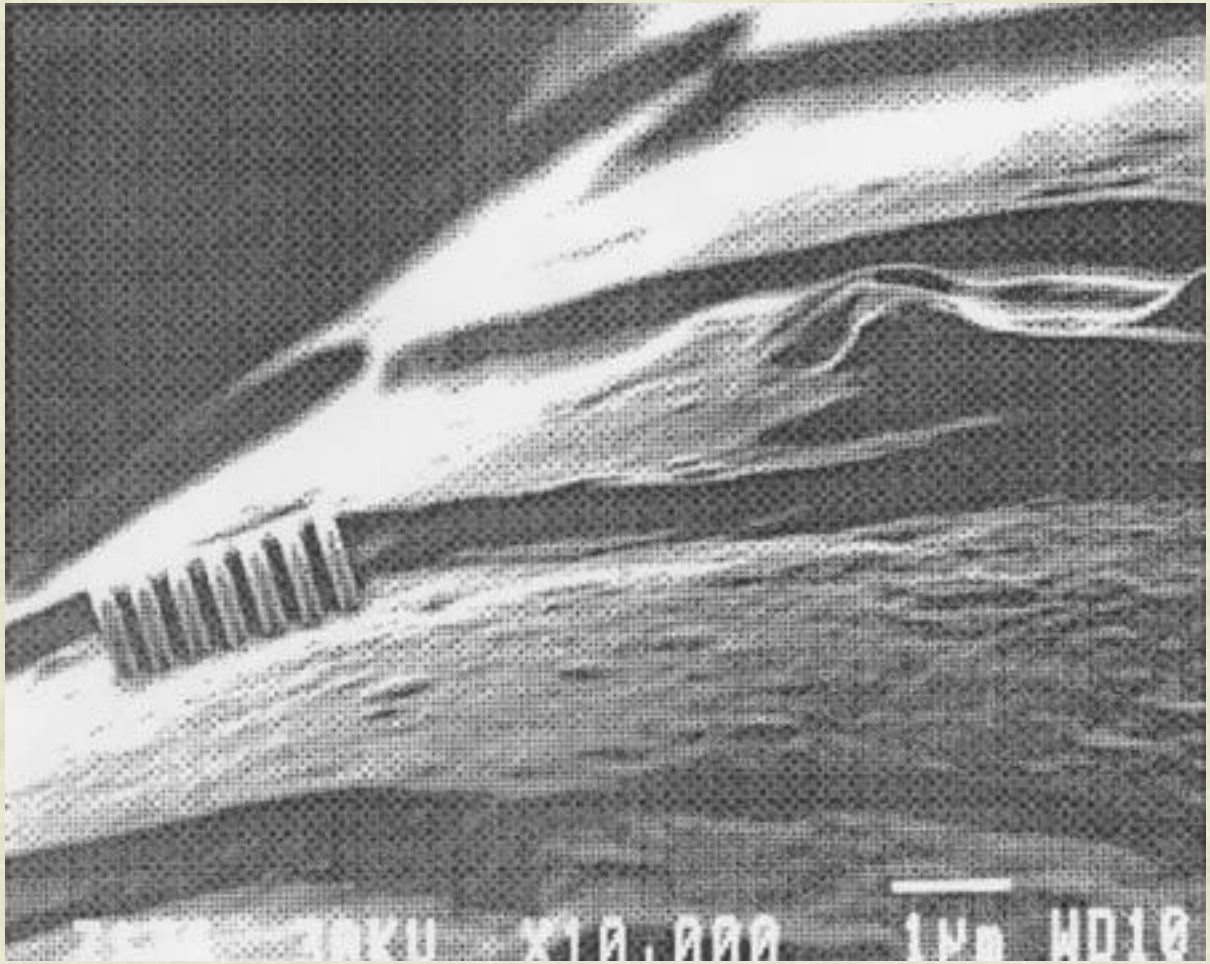

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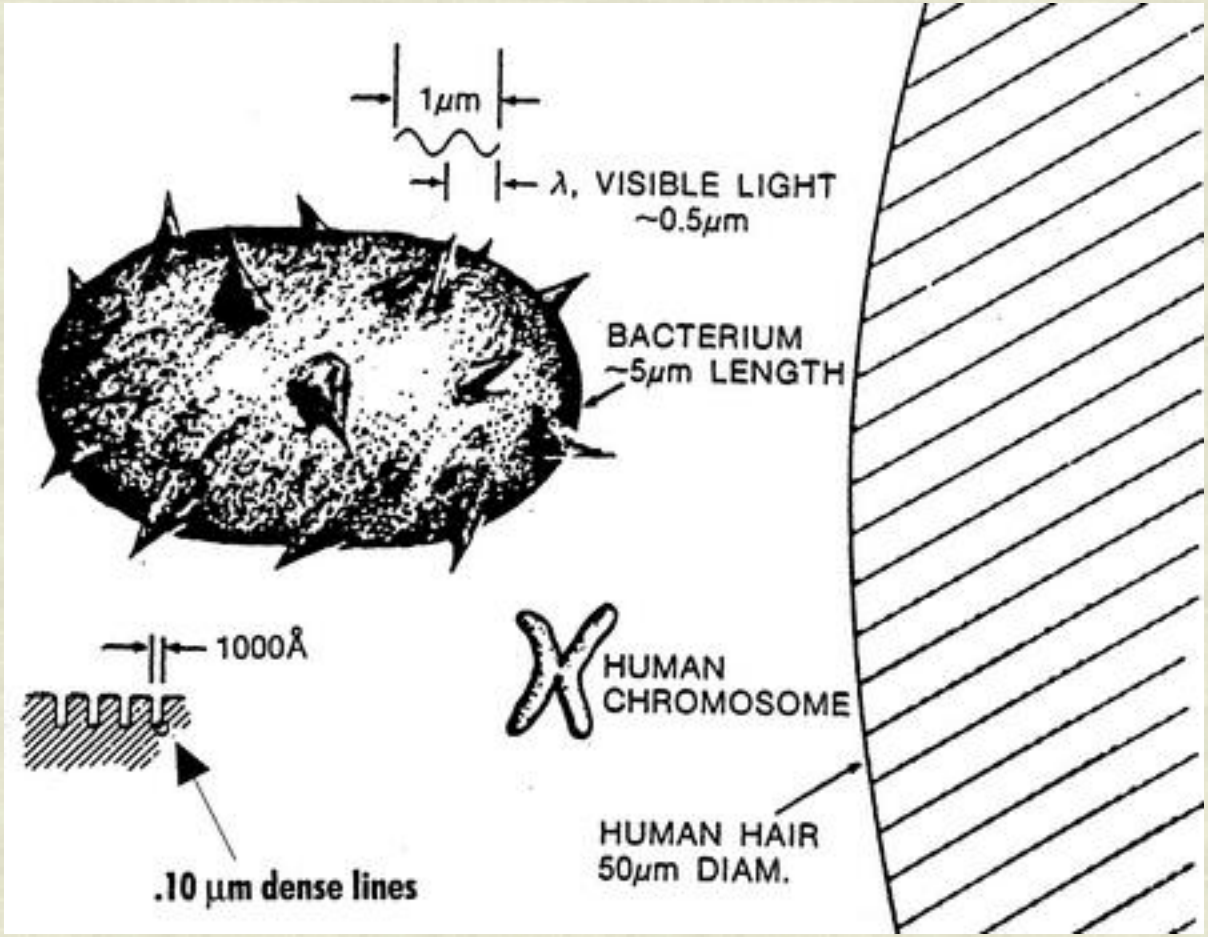

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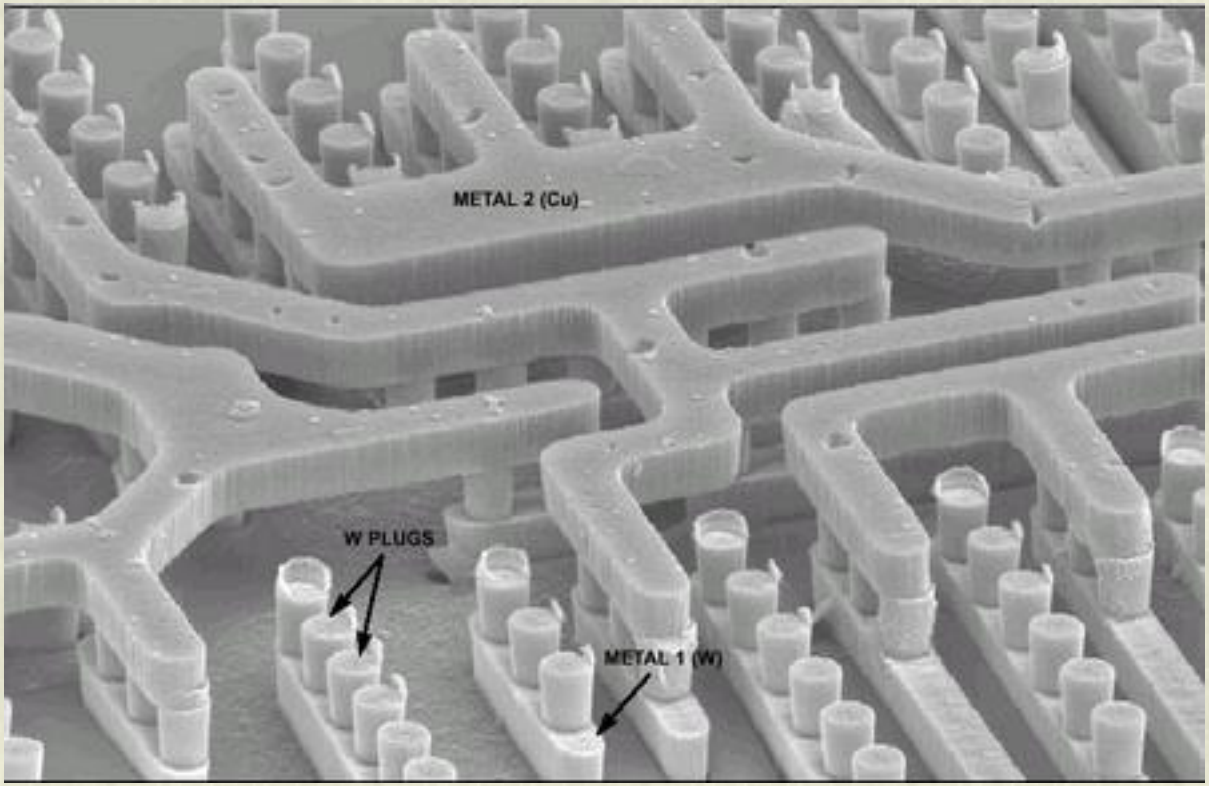

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Fundamentos de Sistemas Digitais

Diferentes Níveis de Abstração

prof. Dr. Alexandre M. Amory

Projeto de CI

- **Trabalhar com transistores é complicado**
  - Imagina com 1.5 Bilhões deles !!!
- **Solução:**
  - MUITOS níveis de abstração !!!
- **Níveis de abstração típicos:**
  - 1o : máscara de layout (baixa abstração)
  - 2o: diagrama de transistores
  - 3o: portas lógicas
  - 4o: blocos / funções lógicos
  - 5o: nível de registradores (alta abstração)
  - ….

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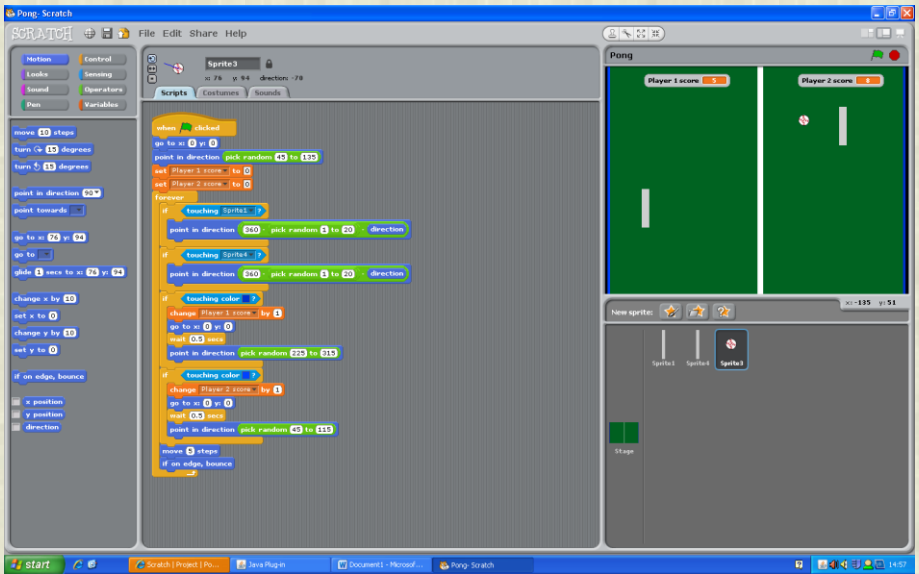
Abstração: Jogo PONG – Atari - 1972



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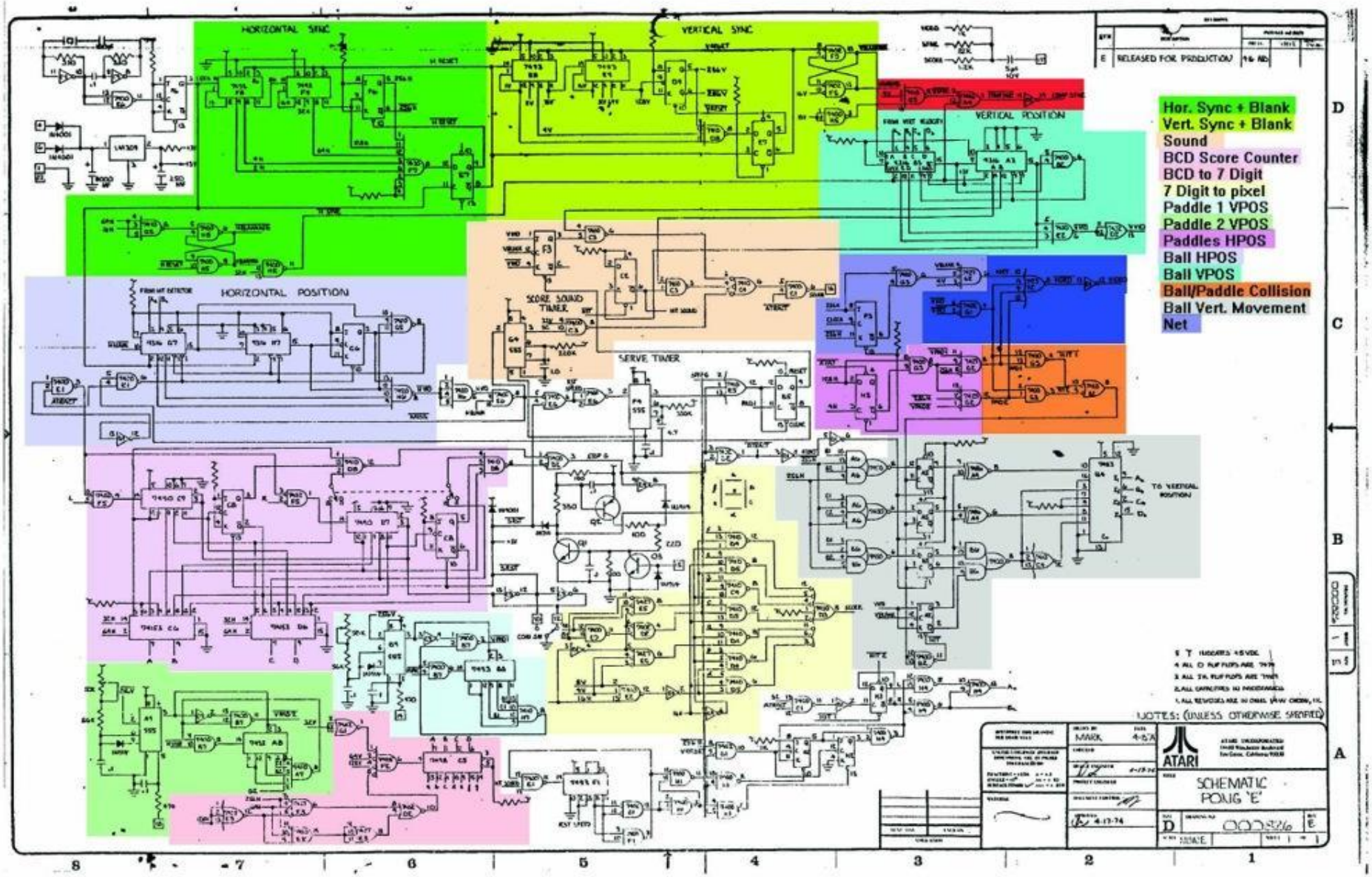
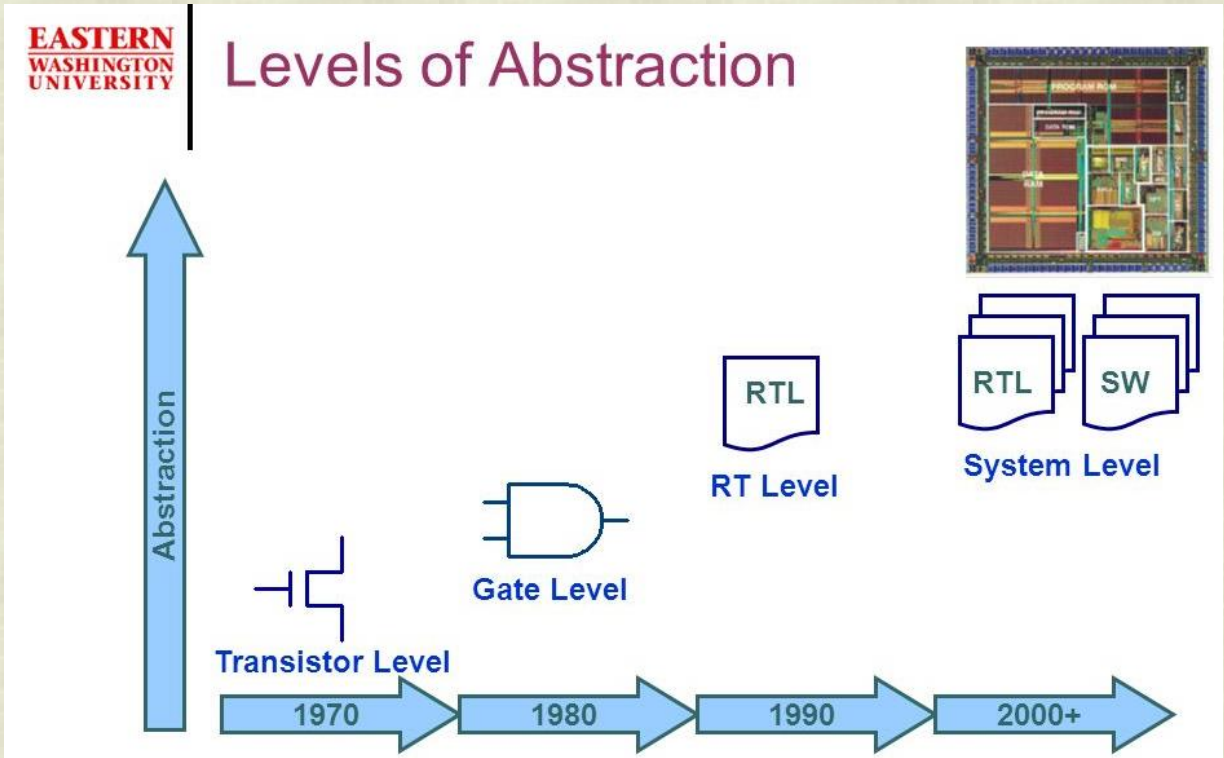


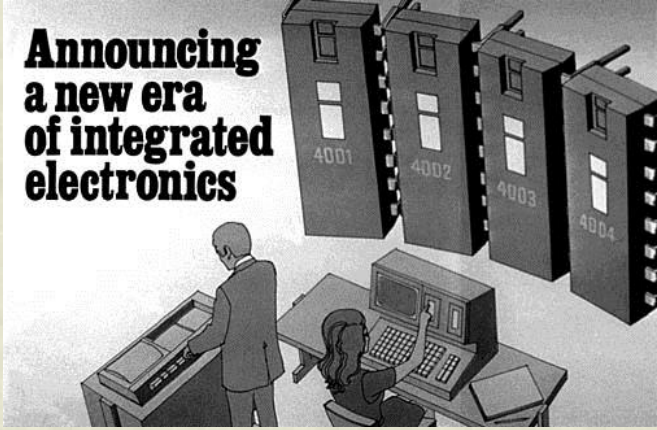
Níveis de Abstração e Camadas Atuais

Application Software	Programs
Operating Systems	Device Drivers
Architecture	Instructions Registers
Micro-architecture	Datapaths Controllers
Logic	Adders Memories
Digital Circuits	AND gates NOT gates
Analog Circuits	Amplifiers Filters
Devices	Transistors Diodes
Physics	Electrons

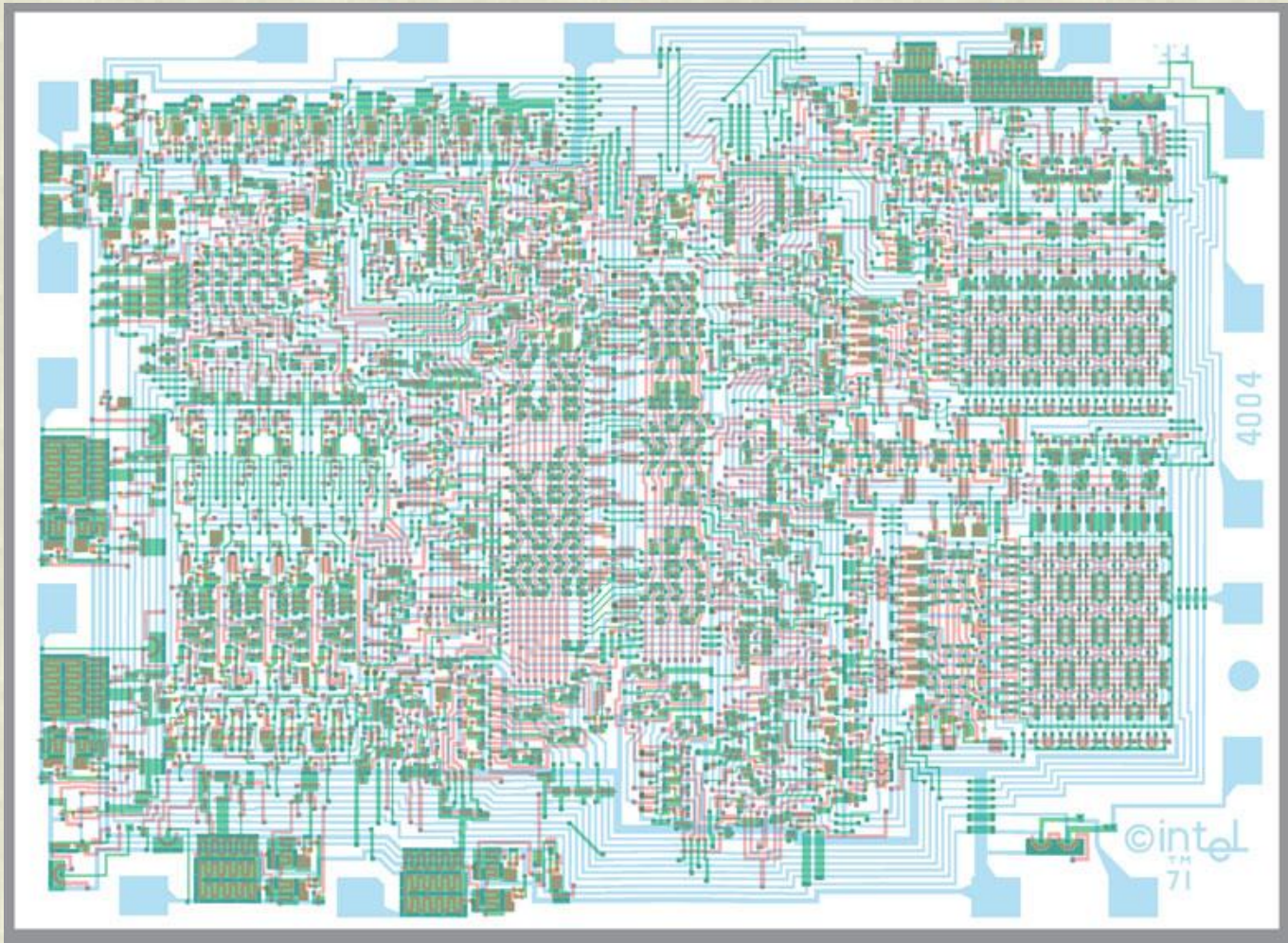
Figure 1.1 Levels of abstraction for electronic computing system



processador 4004 - Intel



From late 1971
Max. CPU clock rate: 740 kHz
Min. feature size: 10µm
Instruction set 4-bit
+- 2,300 transistors



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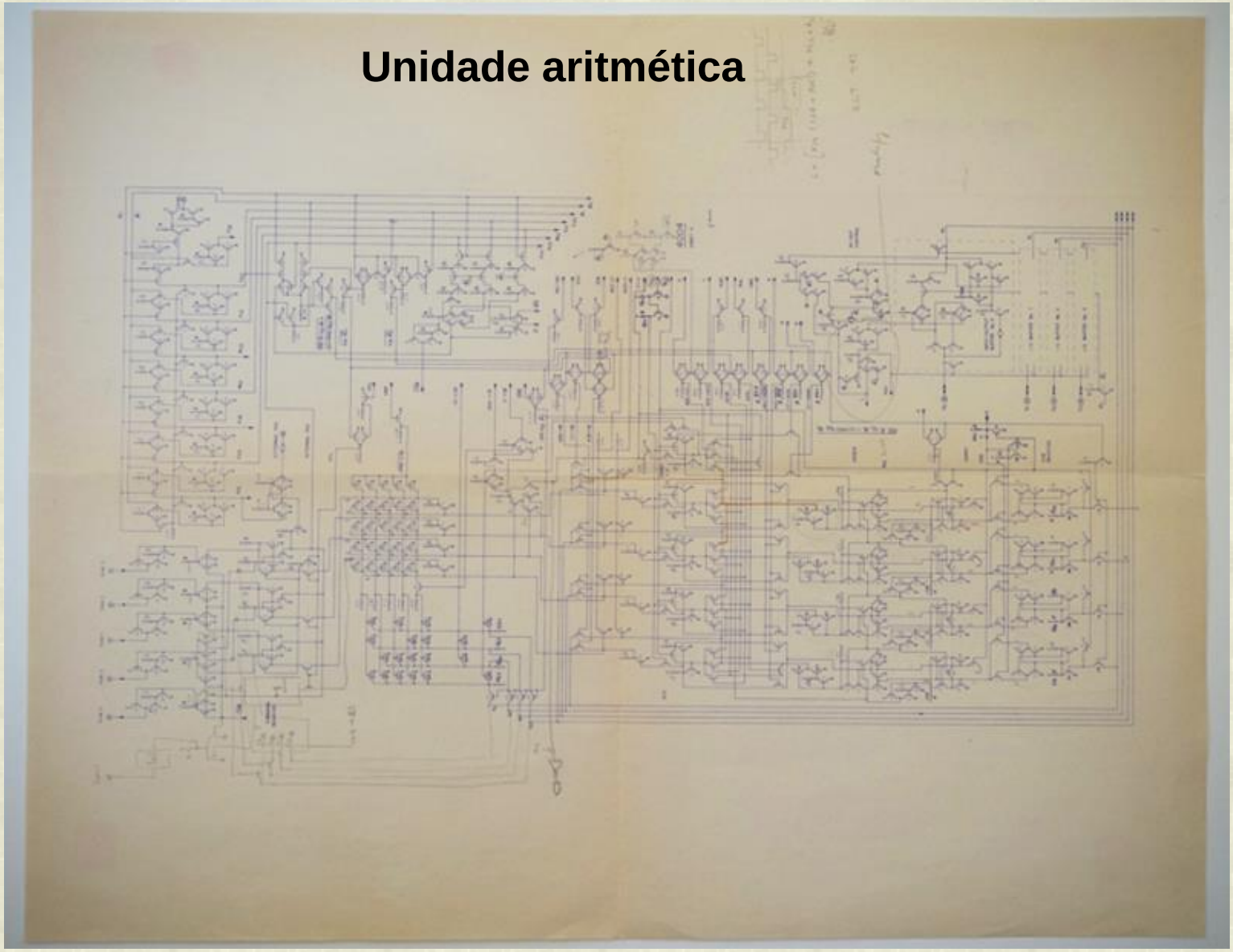

Projetistas

Necessidade de Abstração e Automação!!!

http://www.computerhistory.org/revolution/digital-logic/12/287

Nível de Transistores

Níveis de abstração típicos:

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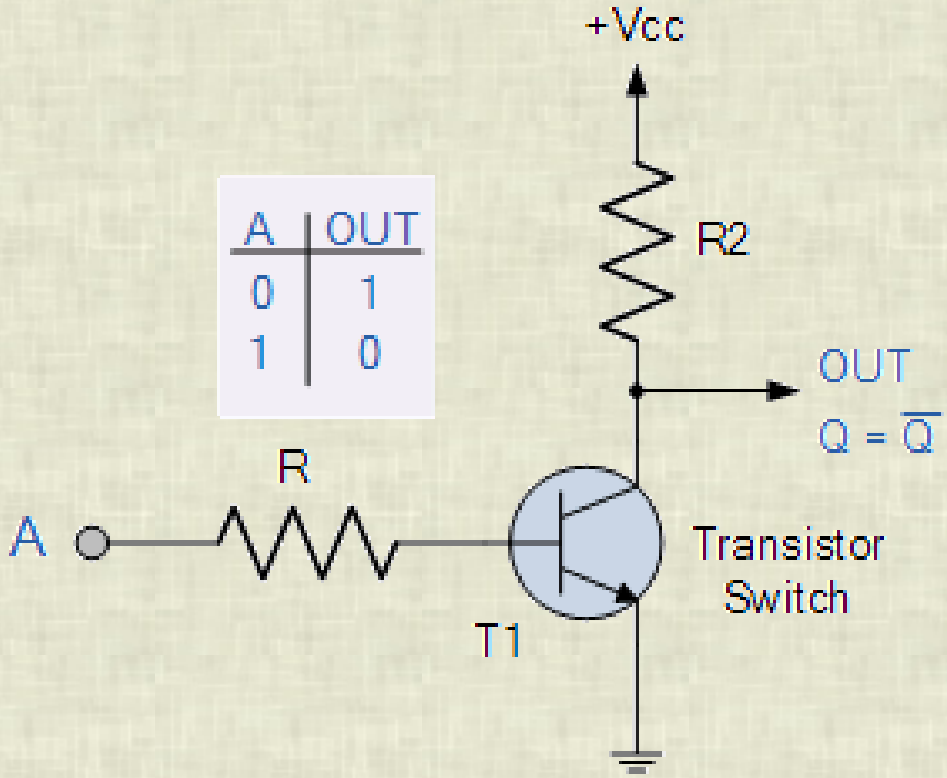
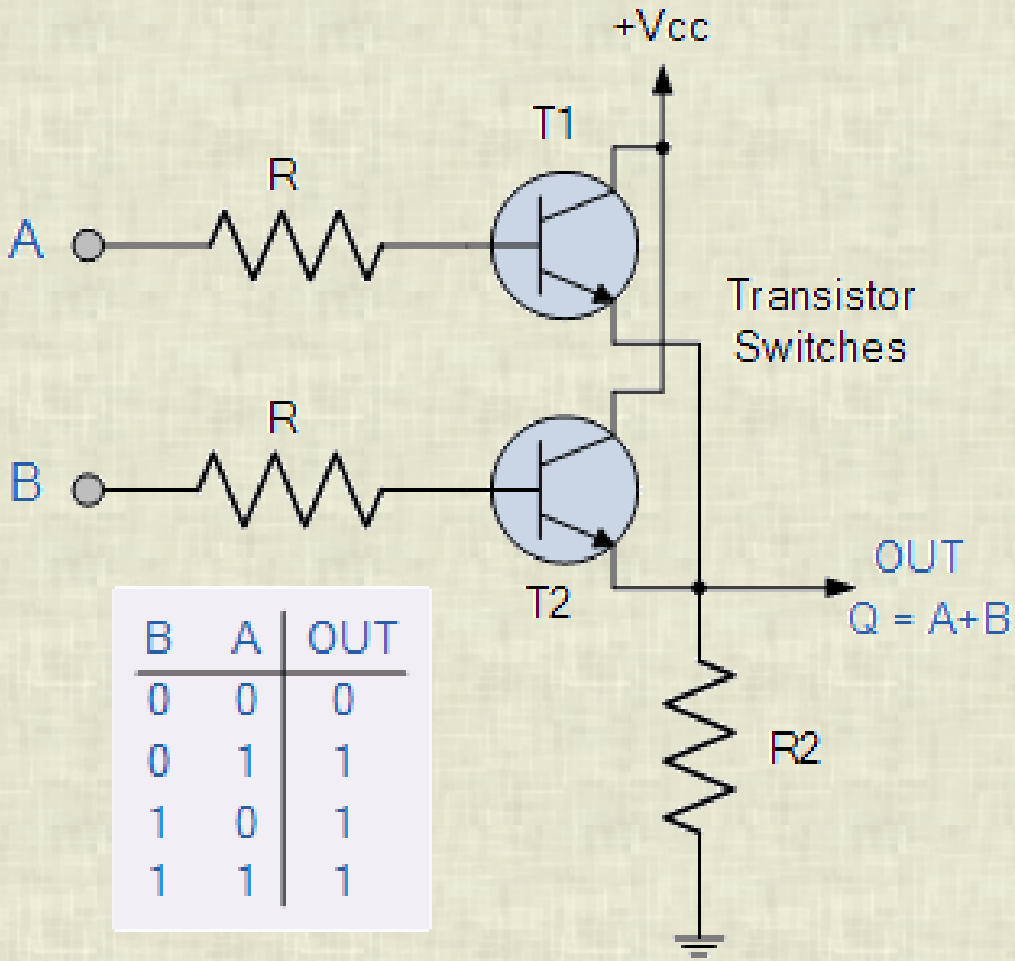


Youtube - How Transistors Work - https://goo.gl/GxdtrF

http://www.electronics-tutorials.ws/category/logic

Nível de Transistores

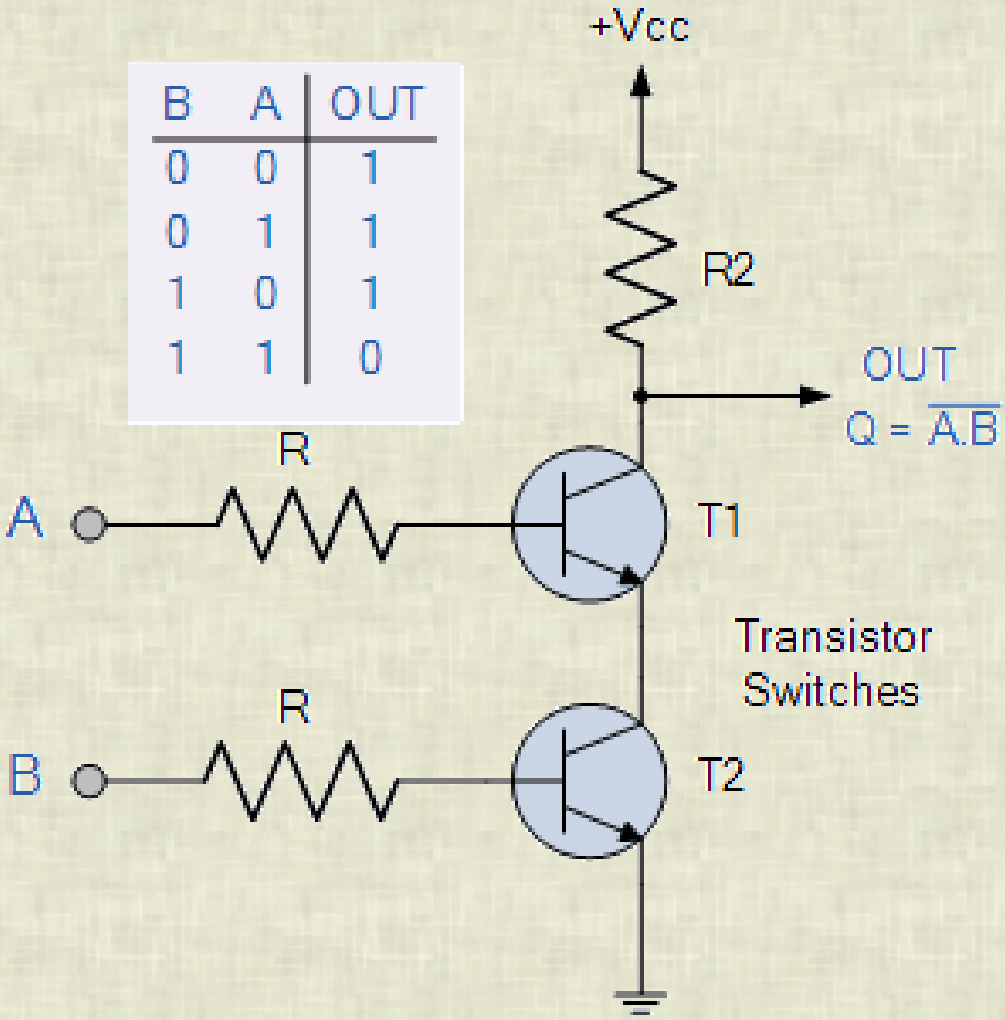


B	A	OUT
0	0	0
0	1	1
1	0	1
1	1	1

http://www.electronics-tutorials.ws/category/logic

Nível de Transistores

B	A	OUT
0	0	1
0	1	1
1	0	1
1	1	0



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Nível de Layout

Níveis de abstração típicos:

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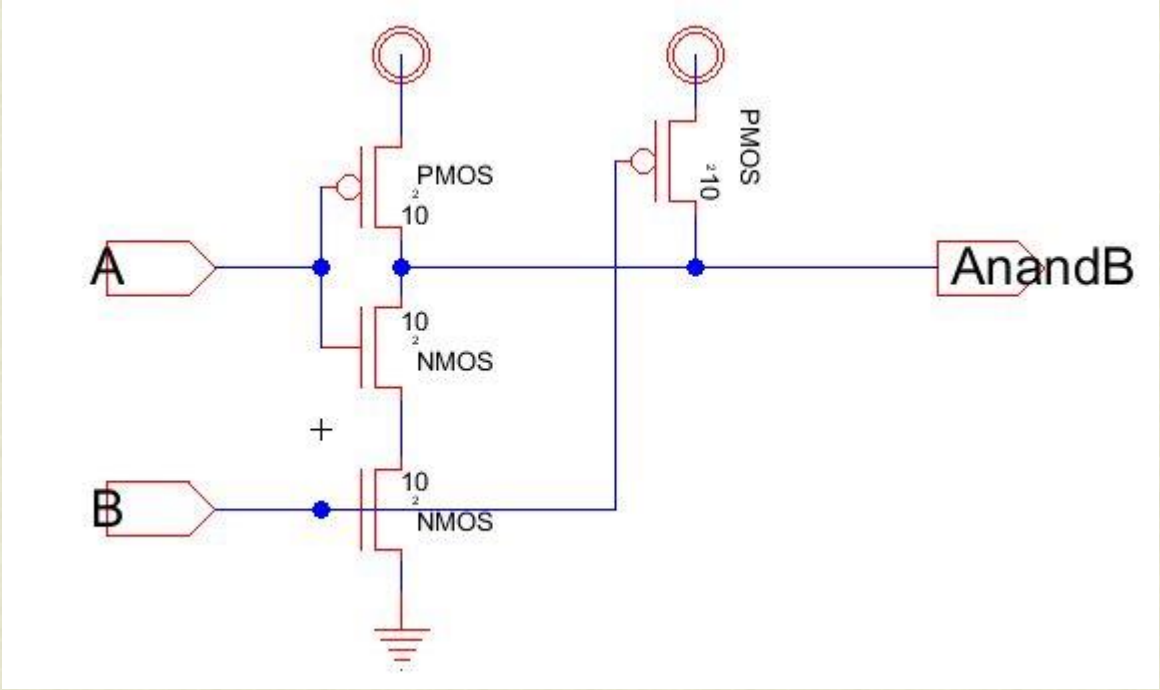

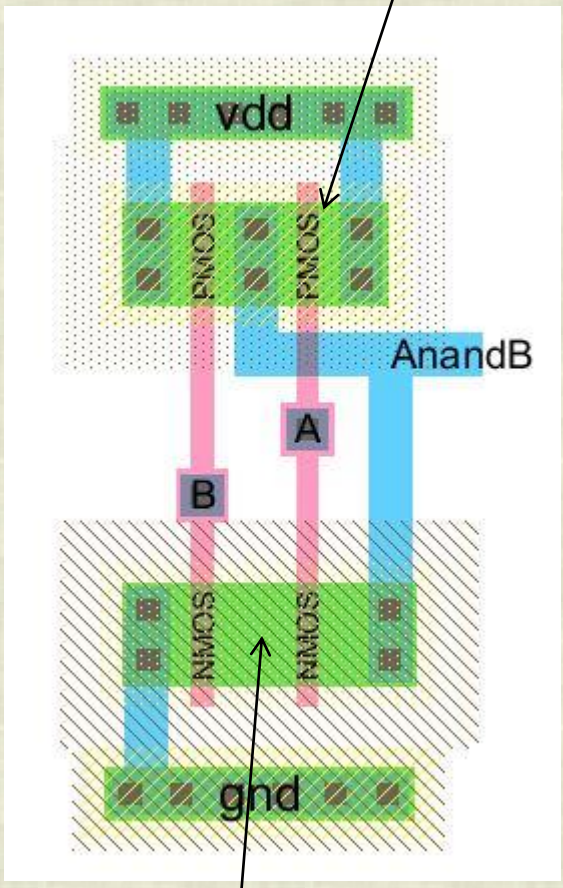

http://goo.gl/oqpP9J

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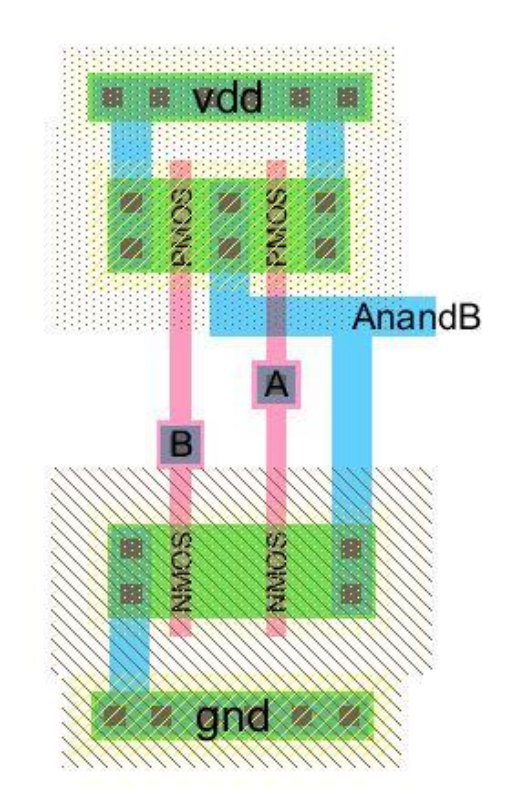

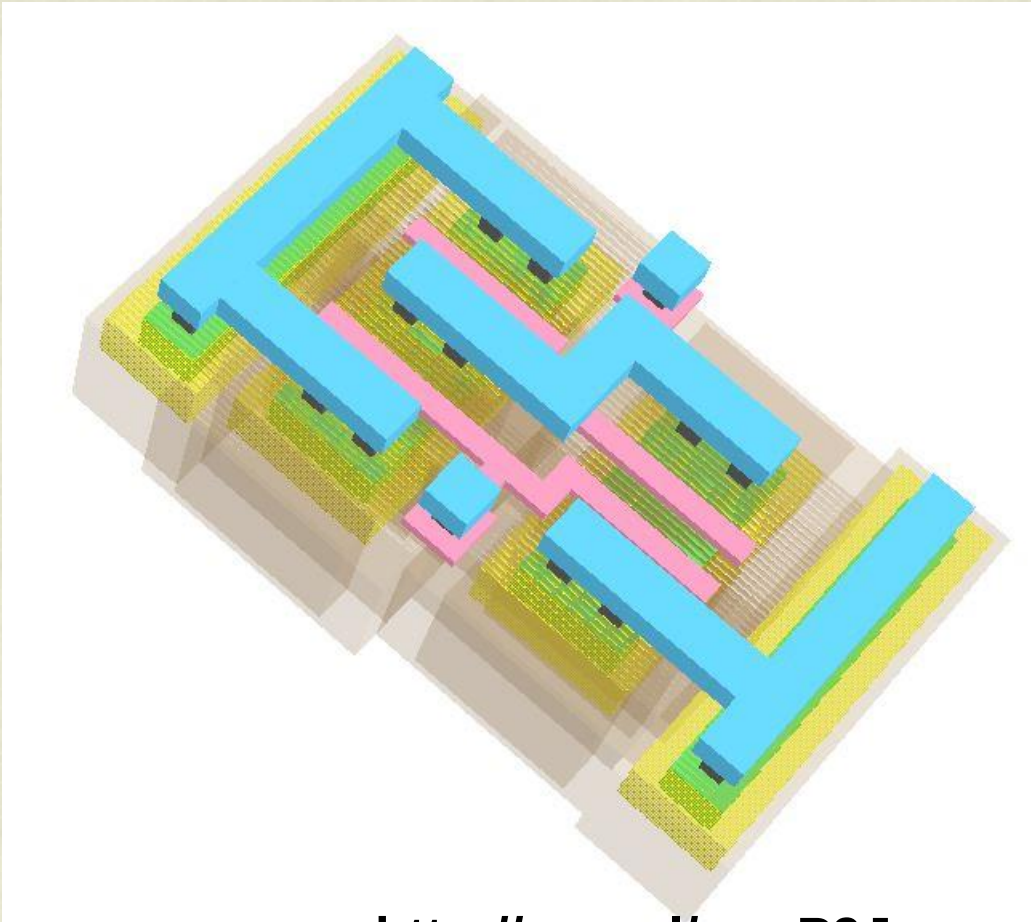

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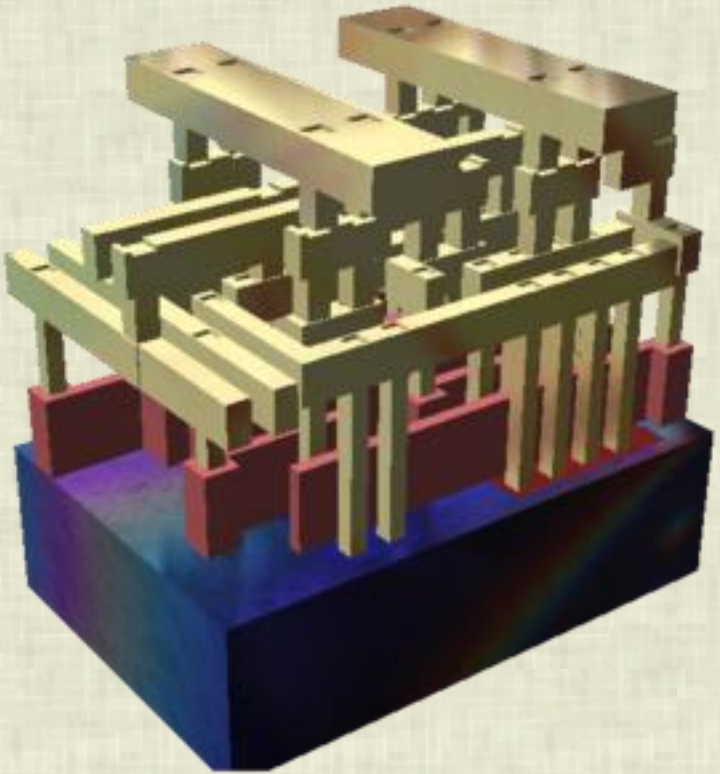

Porta Lógica: NOT

Níveis de abstração típicos:

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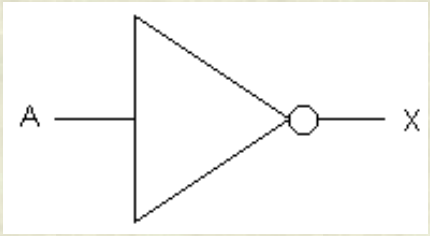
5o: nível de registradores

- Função Booleana

$X = \overline{A}$ **X = A′**

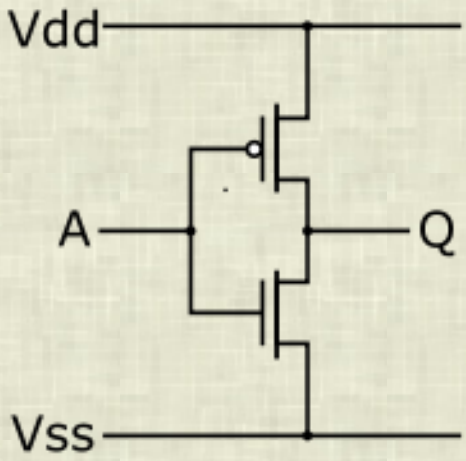
- Representação gráfica



- Tabela Verdade

A	X
0	1
1	0

- Transistores



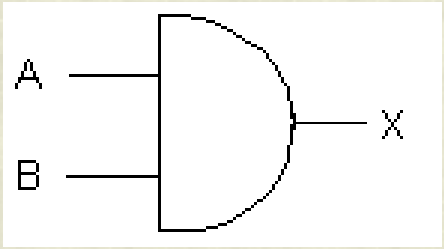
Porta Lógica E (AND)

- Função Booleana

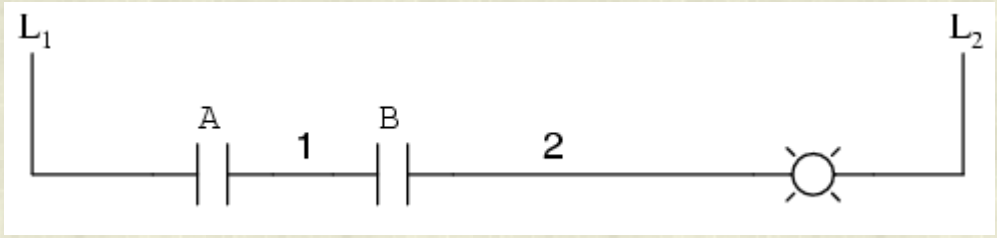
$X = A \cdot B$

* **X = A ∧ B**

- Representação gráfica



- Representação e chaves



- Tabela Verdade

A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

* livro do Gregg

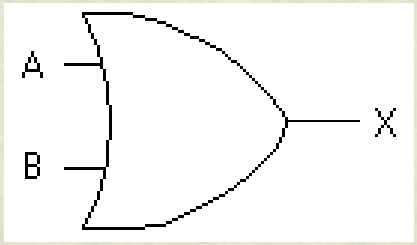
Porta Lógica OU (OR)

- Função Booleana

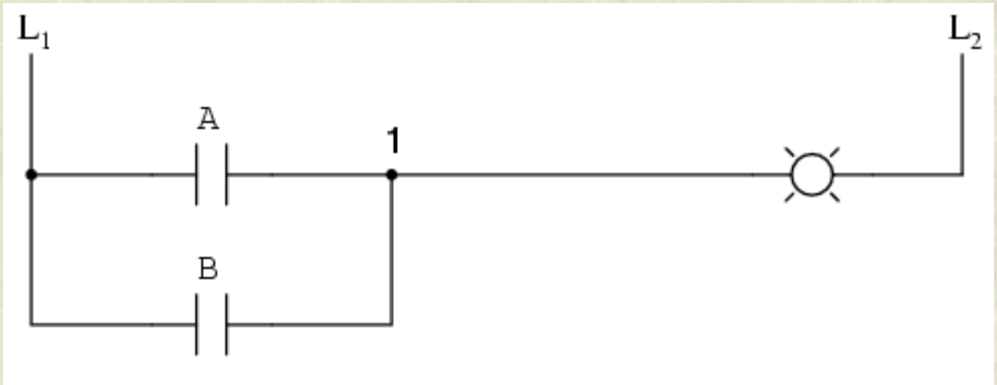
$$X = A + B$$

$$X = A \vee B$$

- Representação gráfica



- Representação e chaves



- Tabela Verdade

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

- Transistores

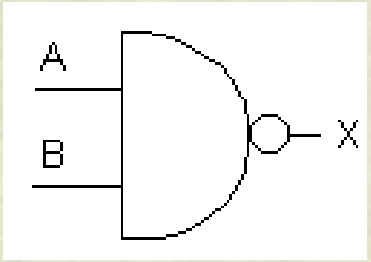
Porta NÃO E (NAND)

- Função Booleana

$$X = \overline{A \cdot B}$$

X=(A.B)'

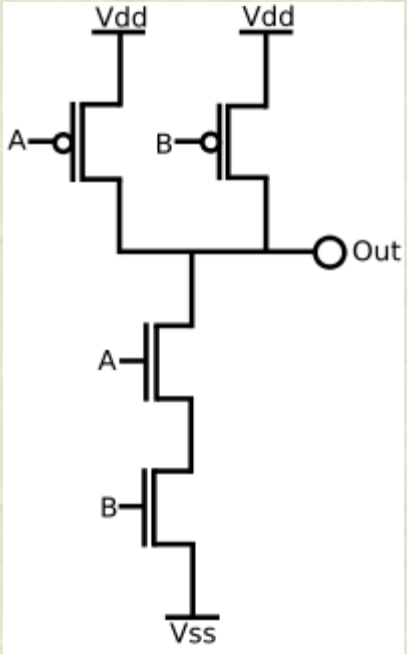
- Representação gráfica



- Tabela Verdade

A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

- Transistores



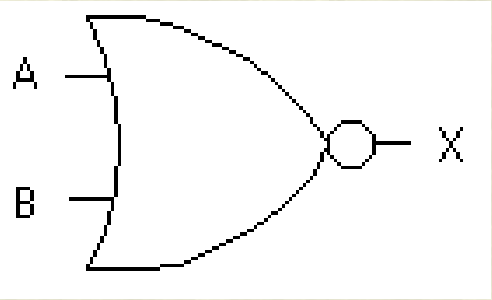
Porta NÃO OU (NOR)

- Função Booleana

$$X = \overline{A + B}$$

X=(A+B)'

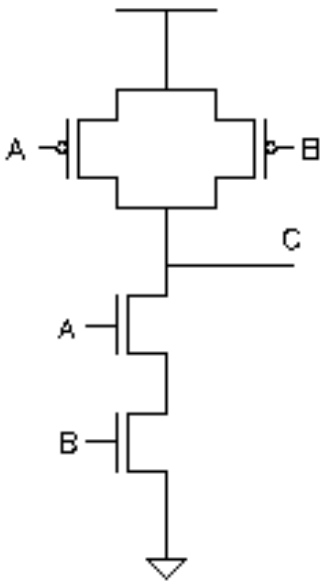
- Representação gráfica



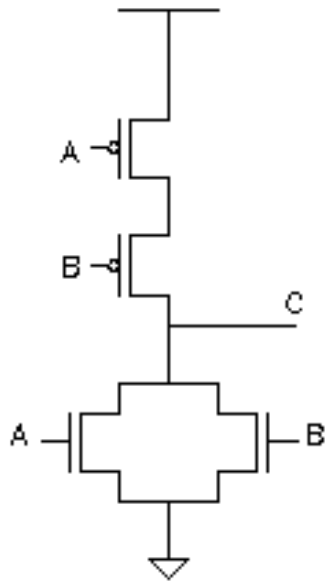
- Tabela Verdade

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

- Transistores



NAND



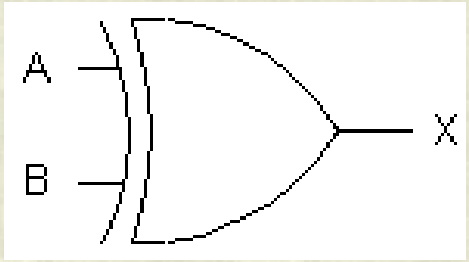
NOR

Porta OU Exclusivo (XOR)

- **Função Booleana**

$$X = A \oplus B$$

- **Representação gráfica**



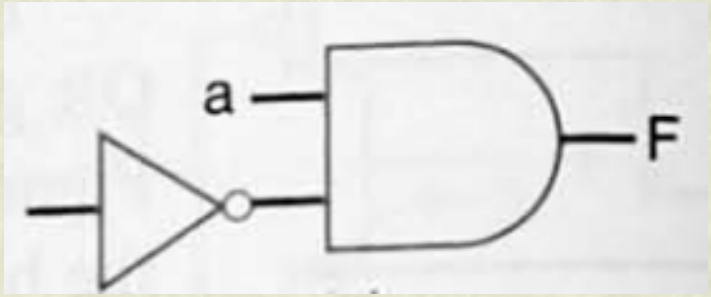
- **Tabela Verdade**

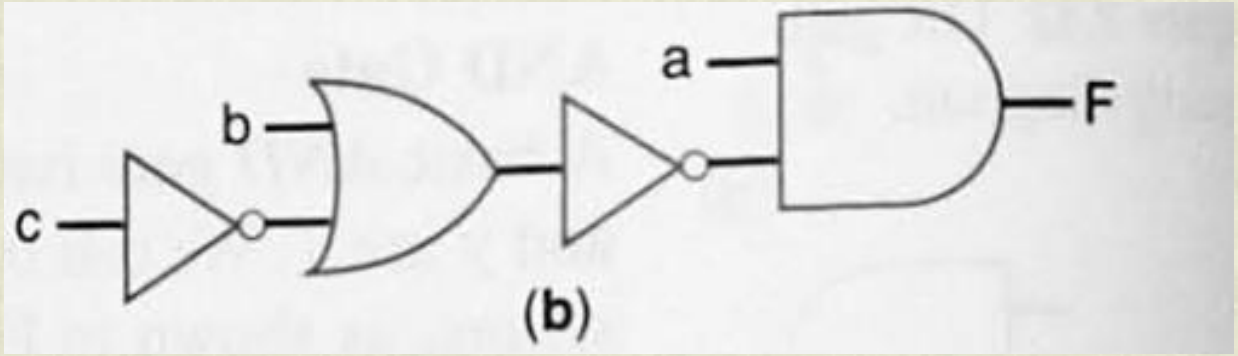
A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Equação Booleana → Portas Lógicas

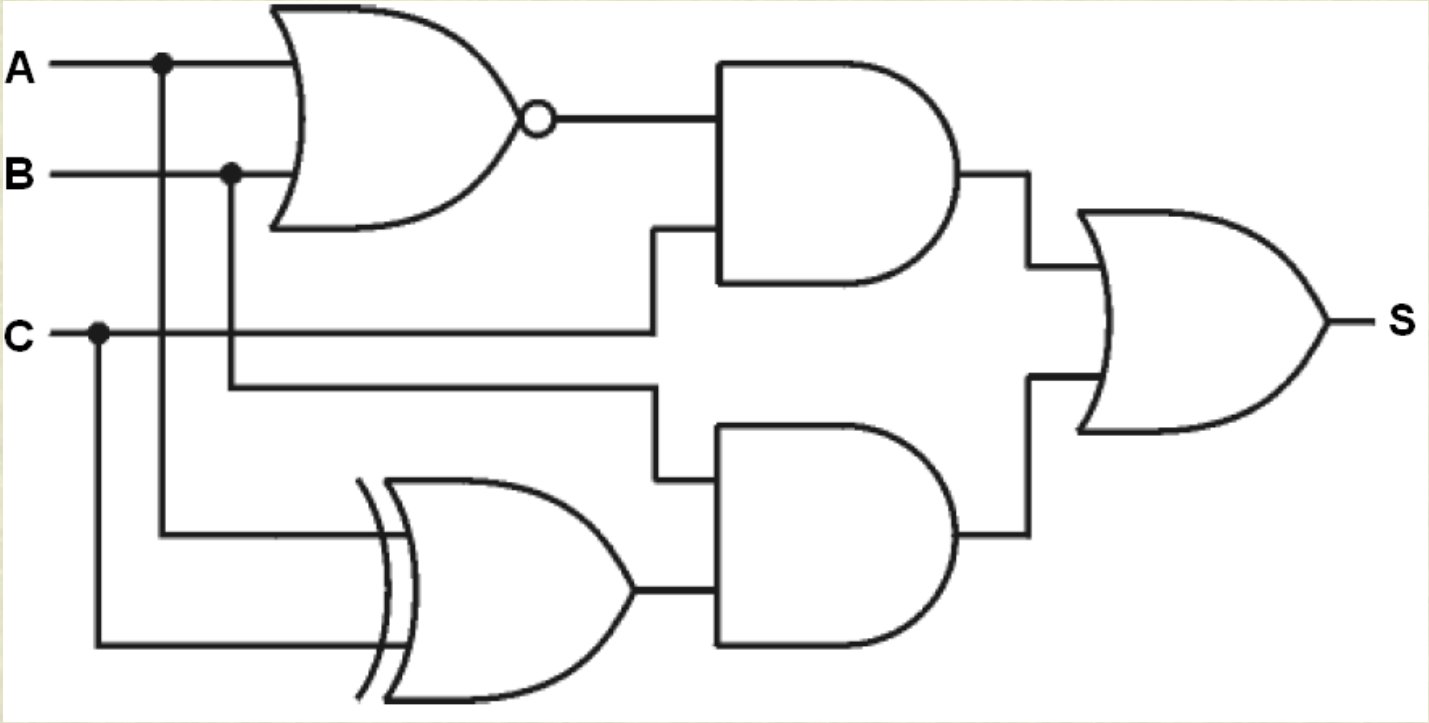
F = a AND NOT(b OR NOT (c))

F = a . (b +(c)')'

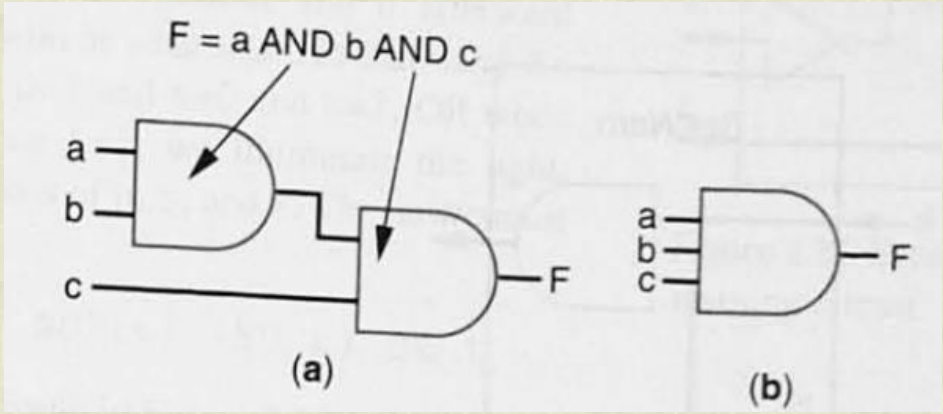




Portas lógicas → Equação Booleana



Equação Booleana → Portas Lógicas → Transistores



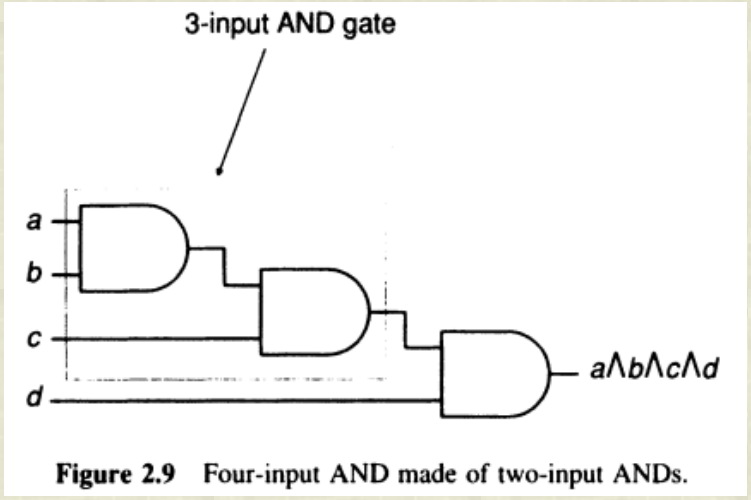
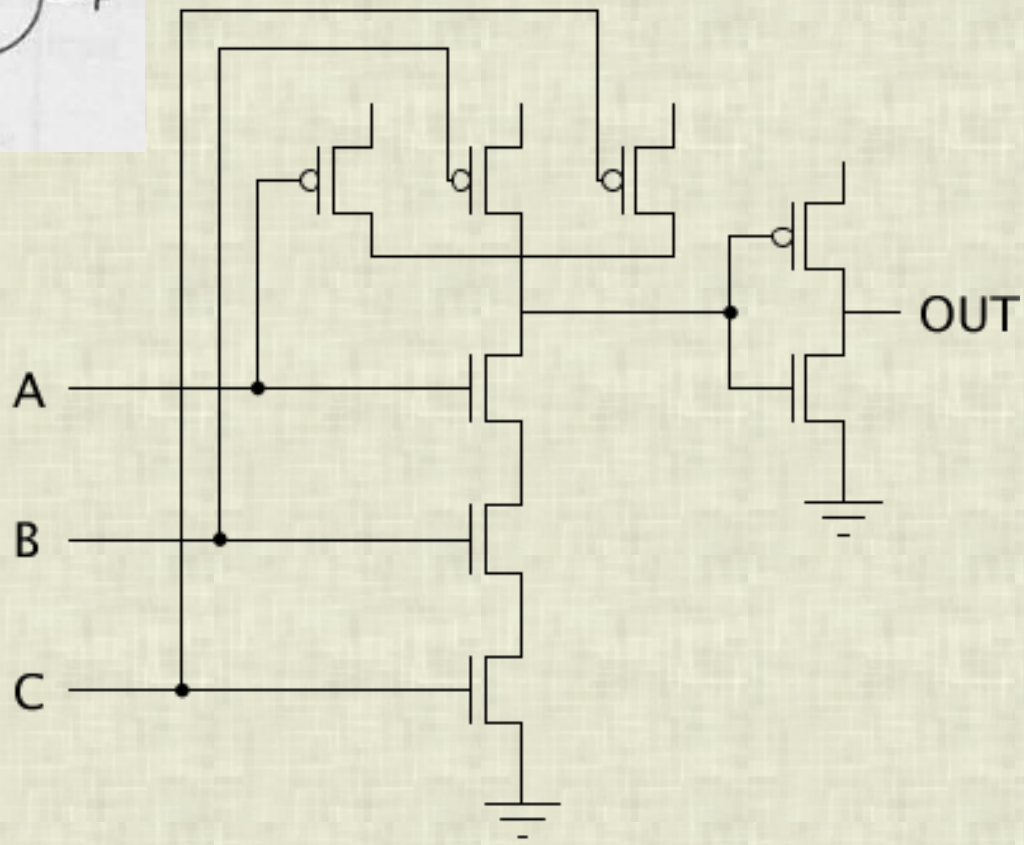
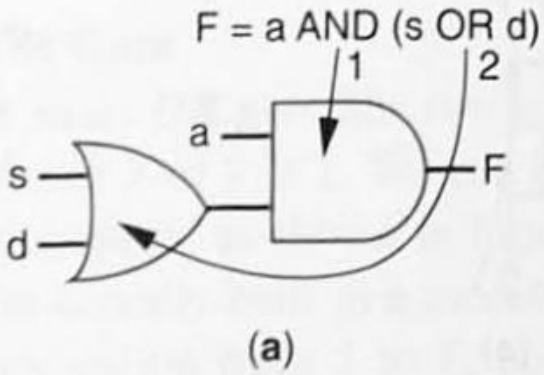


Figure 2.9 Four-input AND made of two-input ANDs.



E com 4 entradas ?

Equação Booleana → Portas Lógicas



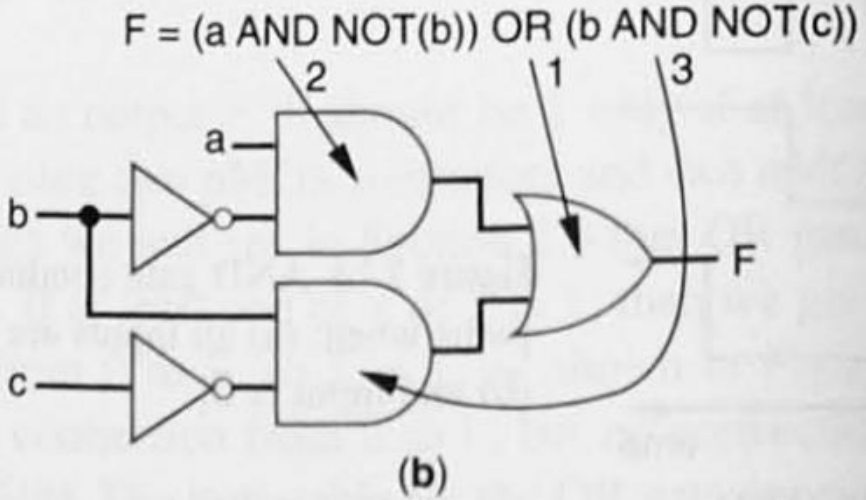
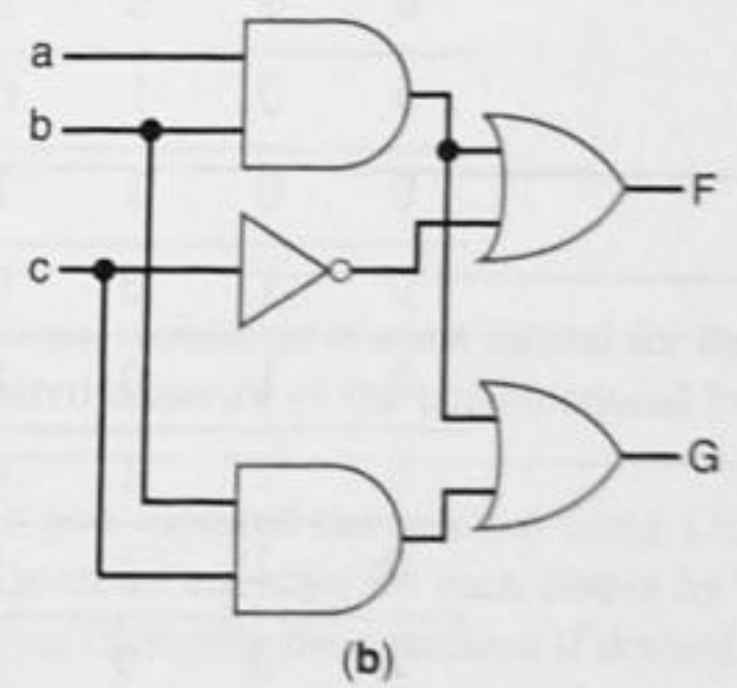


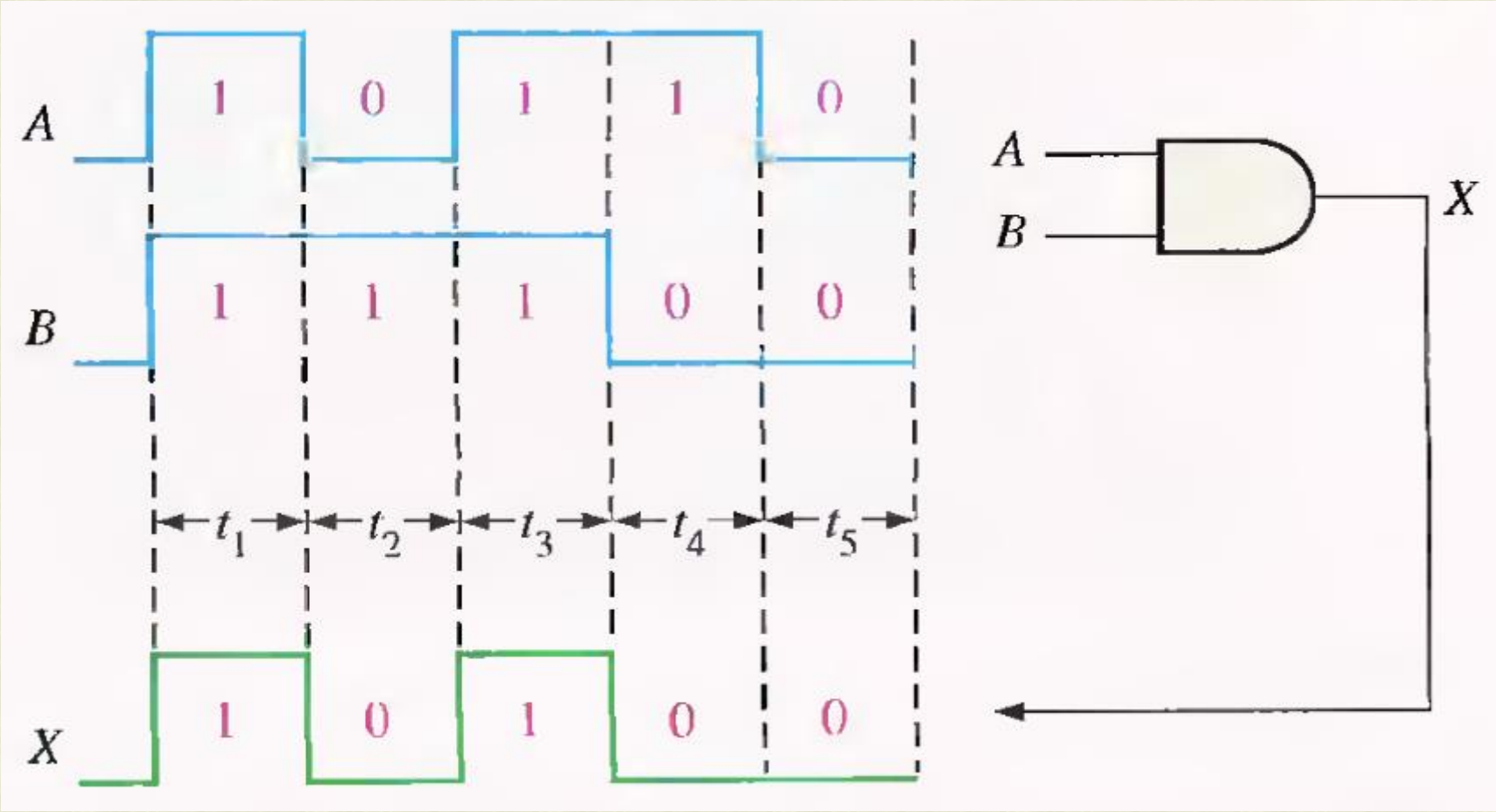
Figure 2.16 Examples of converting Boolean equations to circuits.

Equação Booleana → Portas Lógicas

F = ab + c’
G = ab + bc

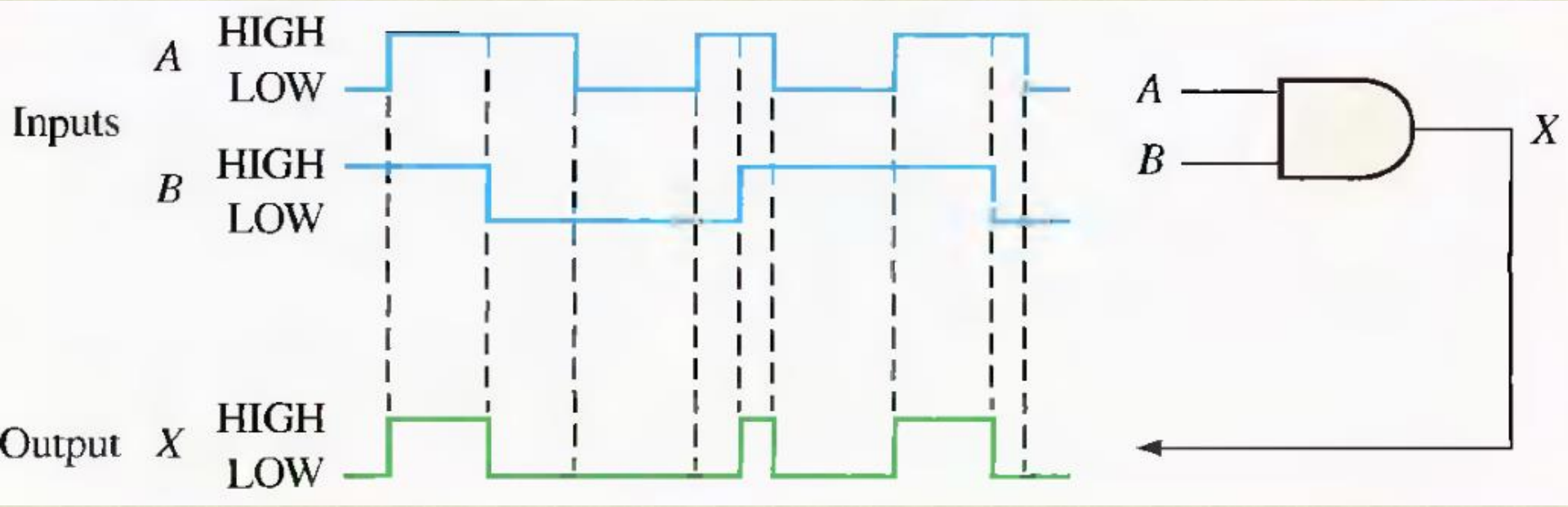


Portas Lógicas → Forma de Onda



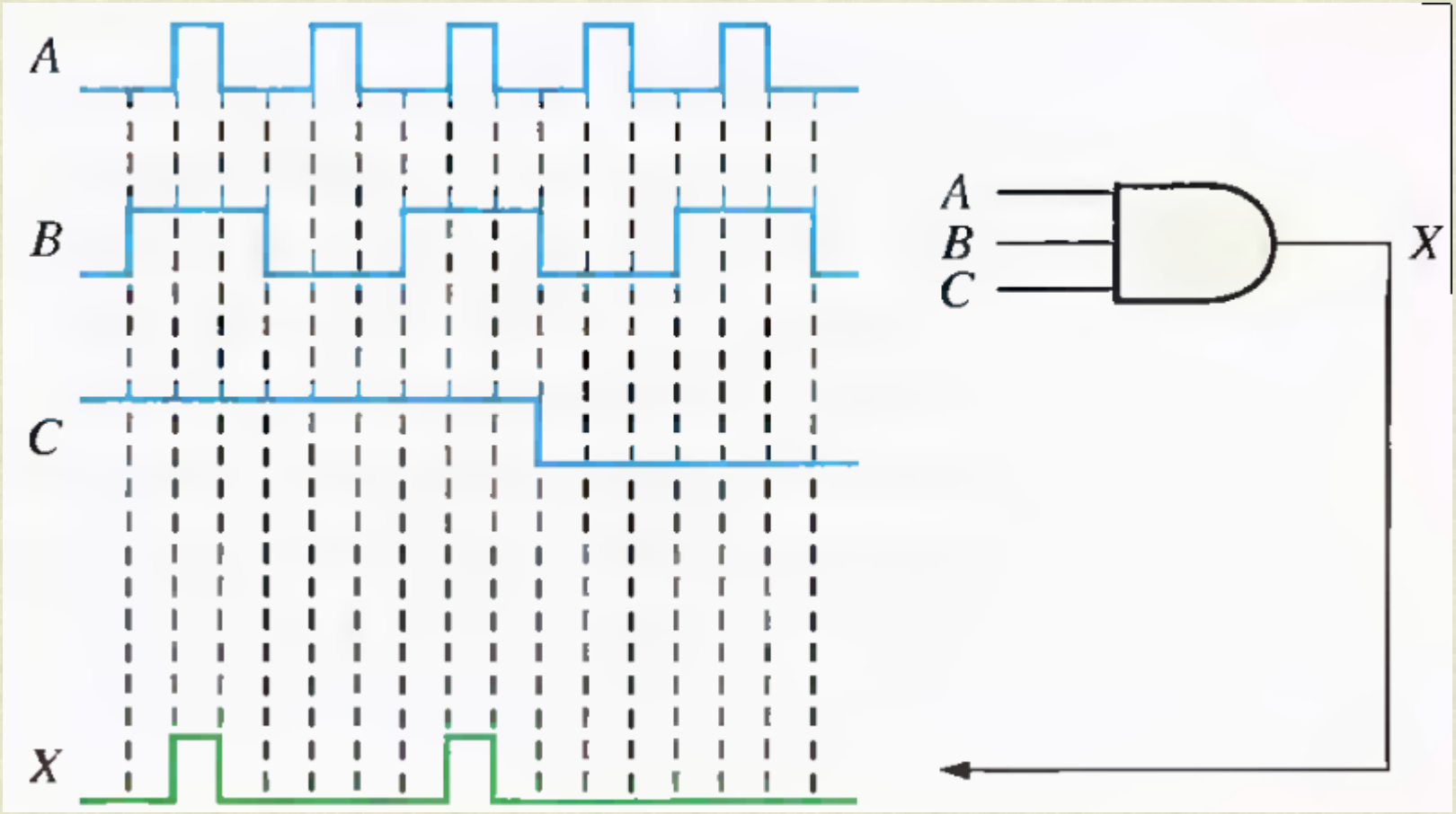
*** Floyd, cap 3**

Portas Lógicas → Forma de Onda



*** Floyd, cap 3**

Portas Lógicas → Forma de Onda



*** Floyd, cap 3**

Portas Lógicas → Forma de Onda

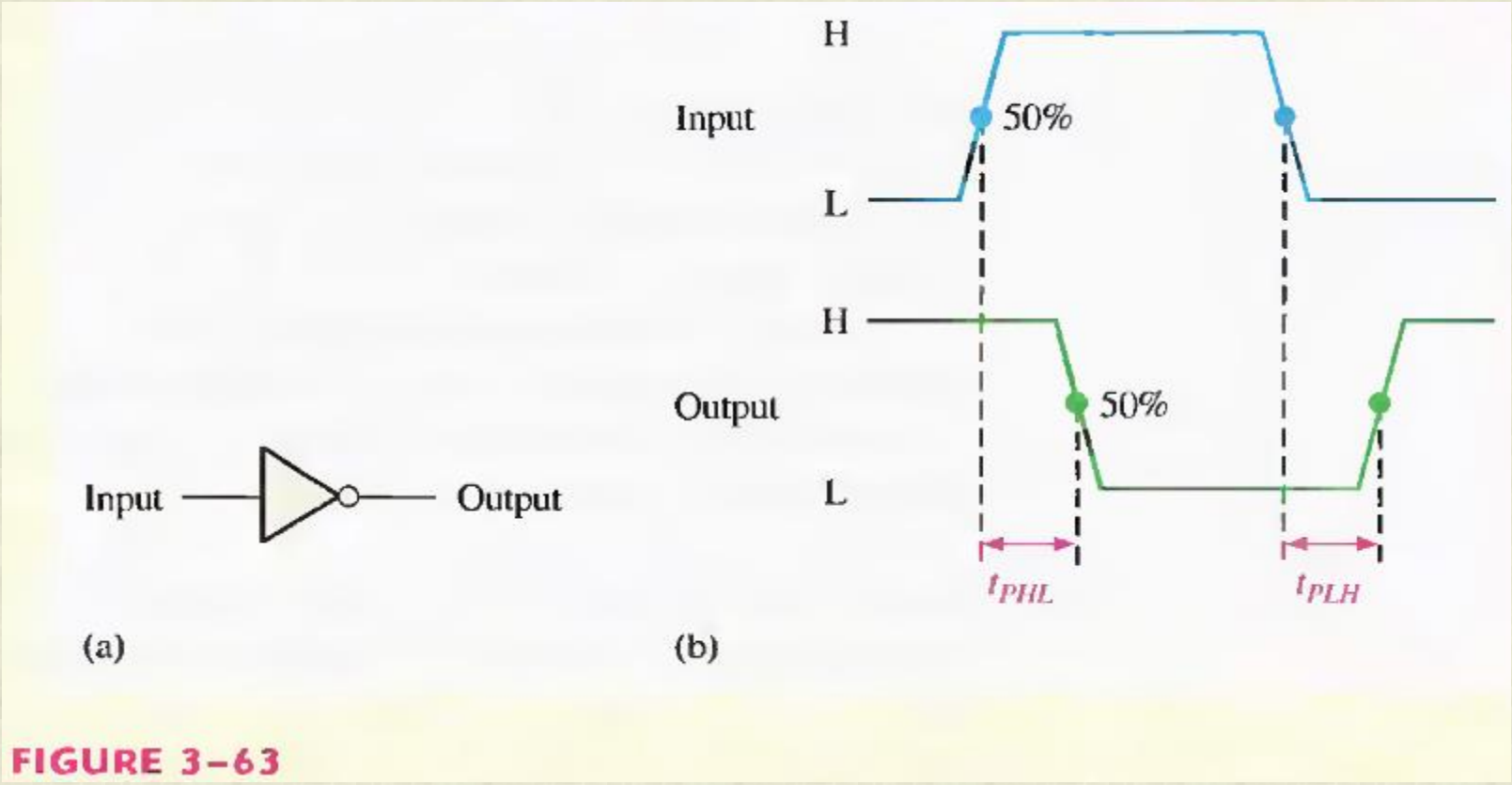


FIGURE 3–63

* Floyd, cap 3

Atividades p Próxima Aula

- **Exercício**
  - Operações lógicas com chaves, portas, expressões (pdf disponível)
  - Formas de onda (Floyd, cap 3, pag 186-197)
  - Transformar expressões/equações em circuitos
    - Final da Seção 2.2 livro do Gregg
- **Atividade p Próxima Aula**
  - Entregar no ínicio da aula
  - Escrito à mão !!!!
  - Pelo menos 10 exercícios sendo de tipos e complexidades diferentes
- **resumir capítulo 9 do livro**
  - J. Daghlian. Lógica e Álgebra de Boole.
-