Estudo de estratégias para otimização de circuitos digitais

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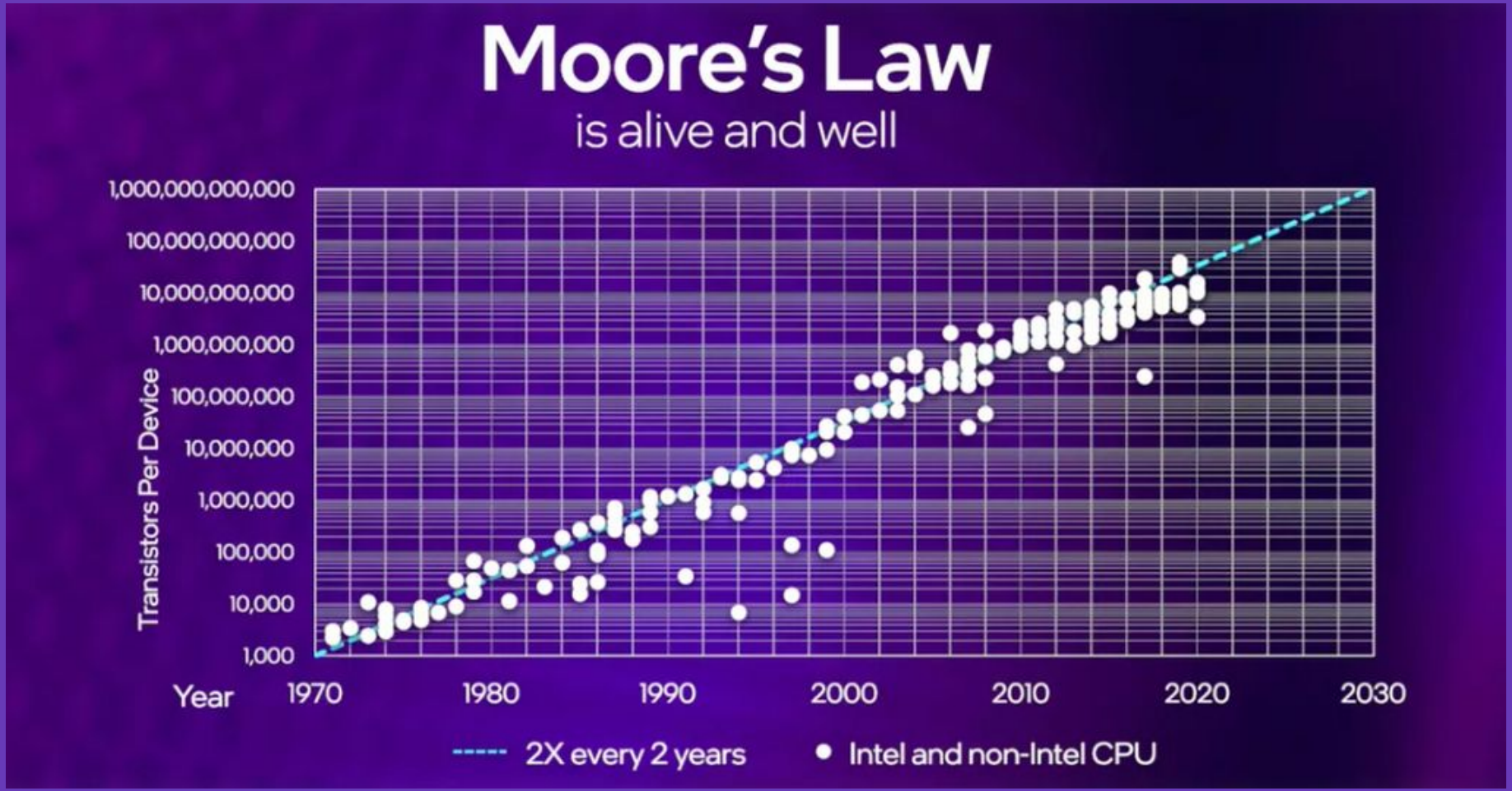
Sumário


INTEL® CORE™ i5
i5-9400F
SRF6M 2.90GHZ
X903D350 e4
DDR4 8000ST
HDMI
USB1

“The complexity for minimum component costs has increased at a rate of roughly, **a factor of two per year**”

Eletronic Magazine de 19 de abril de 1965

Gordon Moore



Trecho da apresentação de Pat Gelsinger, CEO da Intel, no IntelON em 30 de outubro de 2021

Performance per Watt Is the New Moore's Law

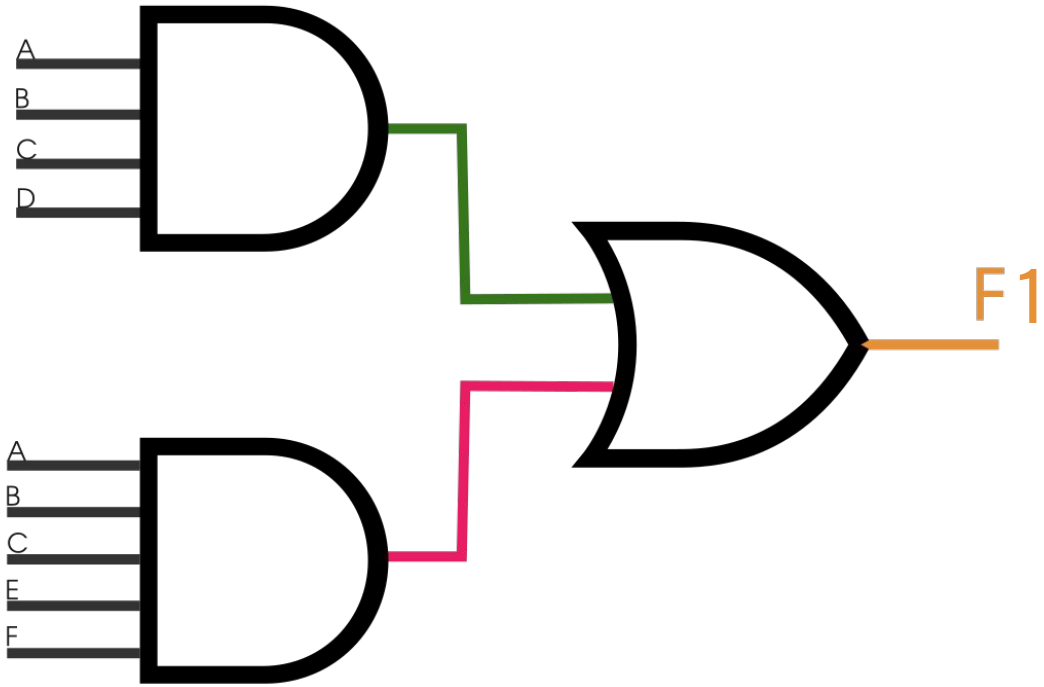
The need to decarbonize compute for the sake of our planet means the technology roadmap can no longer prioritize processing power, says Rob Aitken

Posted on 12th July 2021
By Rob Aitken, Fellow & Director of Technology, Arm

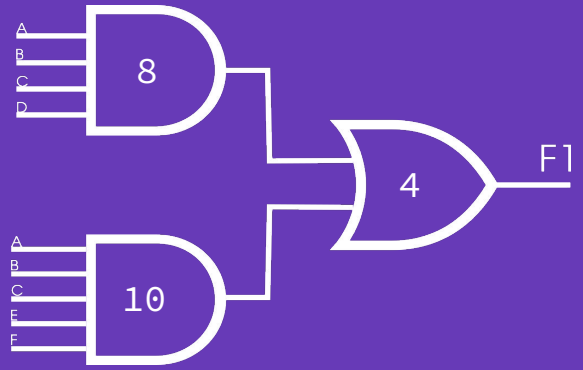
Opinion Sustainability

Reading Time: 7 mins

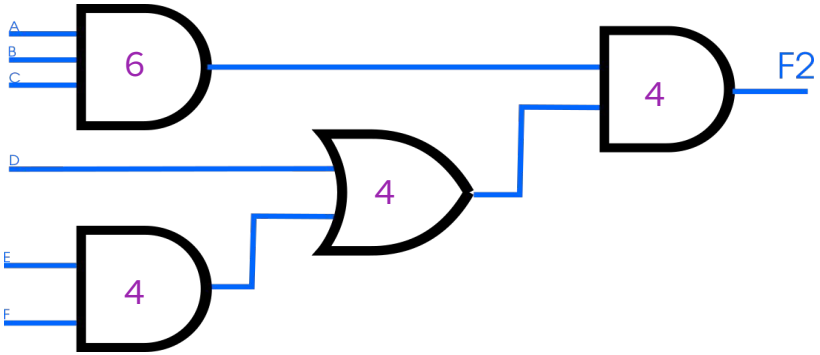

Velocidade
Tamanho
Energia



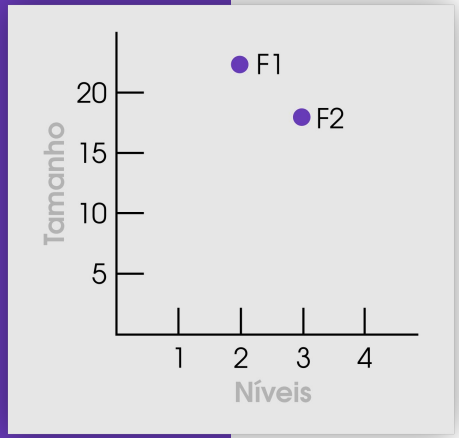
$$F1 = (A \wedge B \wedge C \wedge D) \vee (A \wedge B \wedge C \wedge E \wedge F)$$



22 TRANSISTORES
2 NÍVEIS



18 TRANSISTORES
3 NÍVEIS

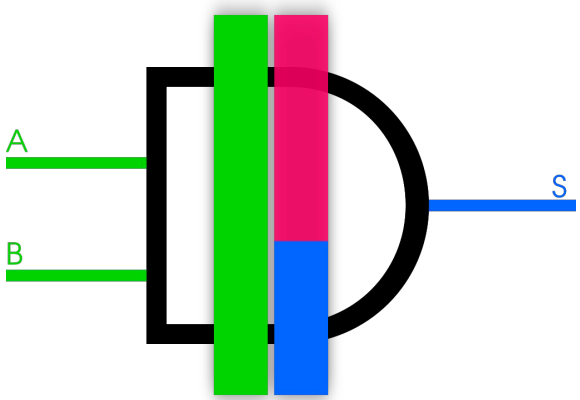


E a energia?

Rolf Landauer

A **perda de informação** em um circuito irreversível torna-se **entropia**, que é associada à quantidade de **energia** perdida em forma de **calor**

Conforme Landauer(1961)



Entropia dos estados iniciais

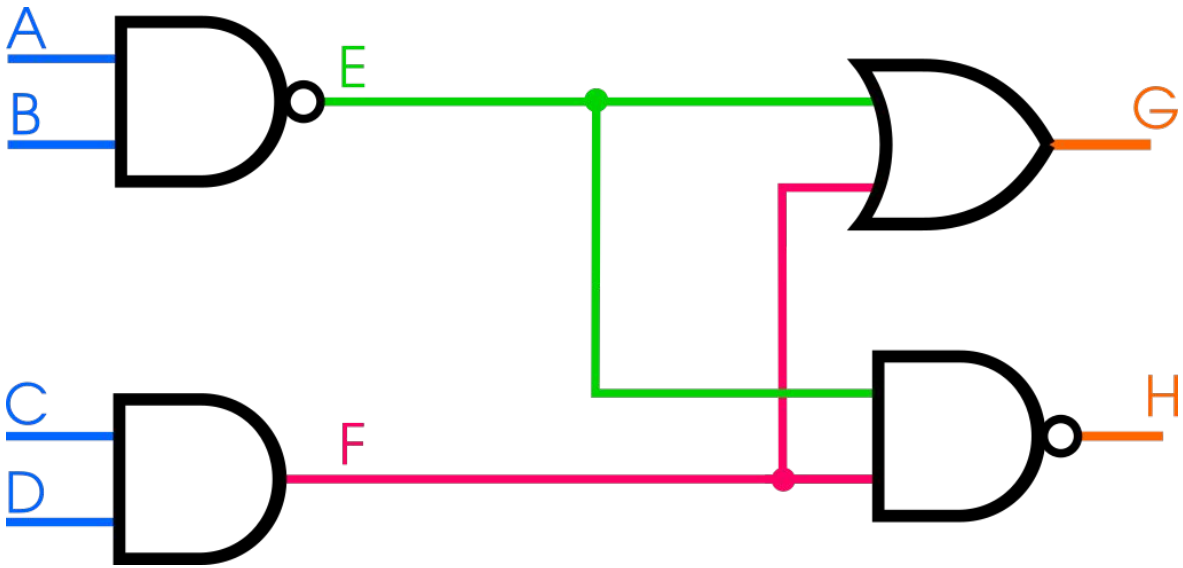
Entropia do estado final

Perdas

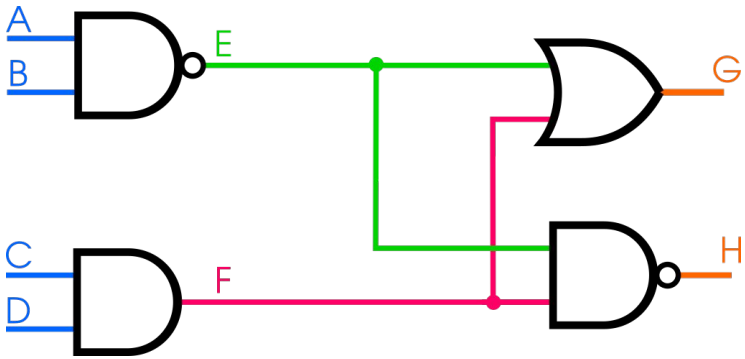
As entropias serão do tipo **S k_BT Joules**

em que k_B é a constante de Boltzmann e

T é a temperatura do meio


A
B
E
G
C
D
F
H

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



Probabilidades

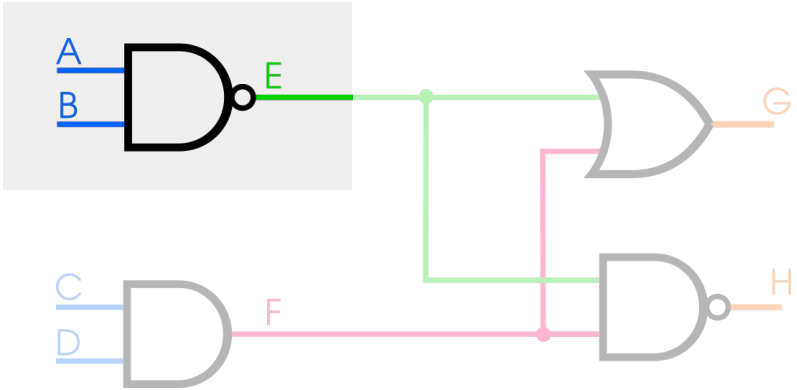
$PE_1 = 12/16$ $\quad PE_0 = 4/16$

$PF_1 = 4/16$ $\quad PF_0 = 12/16$

$PG_1 = 13/16$ $\quad PG_0 = 3/16$

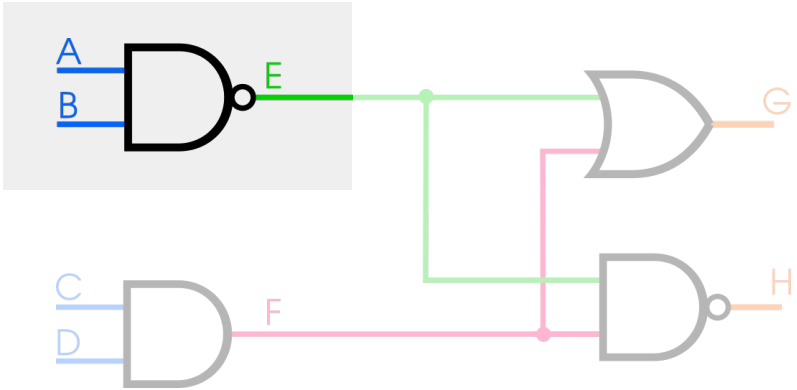
$PH_1 = 13/16$ $\quad PH_0 = 3/16$

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



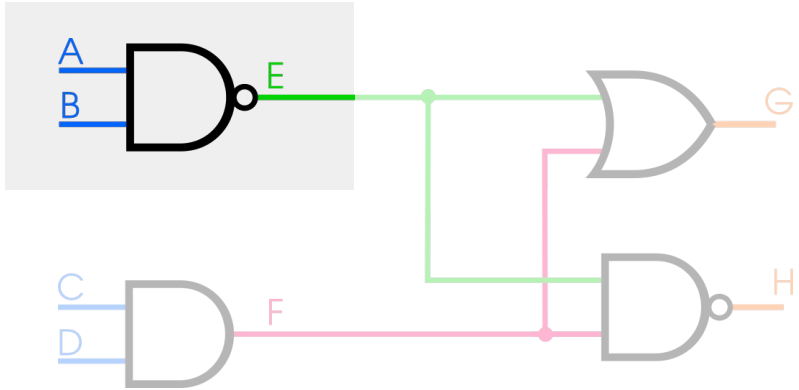
S_i	A	B	E
S_0	0	0	1
S_1	0	1	1
S_2	1	0	1
S_3	1	1	0

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



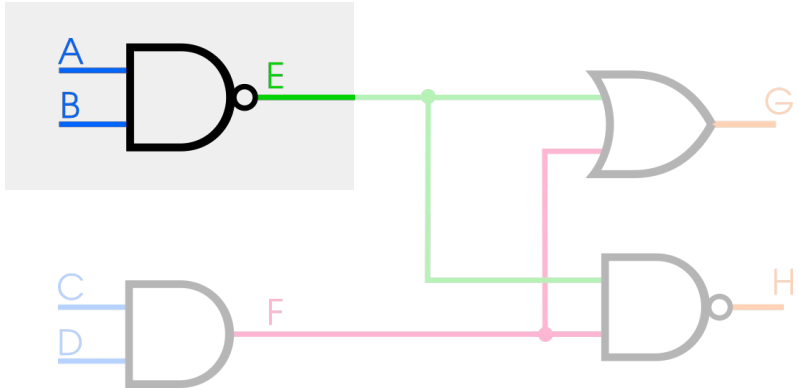
S_i	A	B	E
S_0	0	0	1
S_1	0	1	1
S_2	1	0	1
S_3	1	1	0

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



S_i	A	B	E
S_0	0	0	1
S_1	0	1	1
S_2	1	0	1
S_3	1	1	0

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



S_i	A	B	E	P
S_0	0	0	1	4/16
S_1	0	1	1	4/16
S_2	1	0	1	4/16
S_3	1	1	0	4/16

Probabilidade (P) e Contribuição(I)

$$I(s) = -P(s) \cdot \log_2(P(s))$$

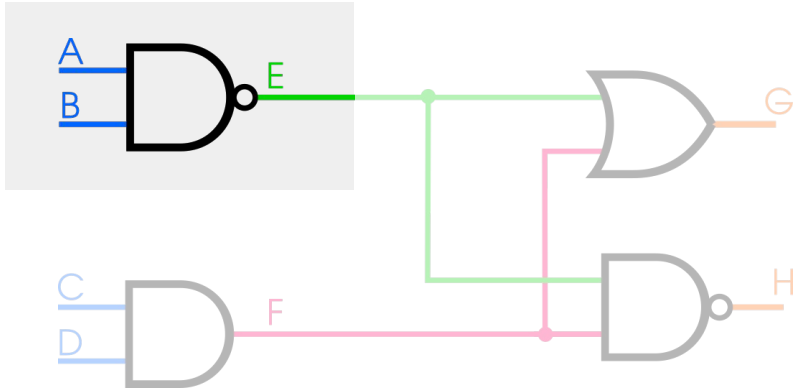
Entropia

Coincidente com a **Entropia de Shannon**

(Entropia da informação)

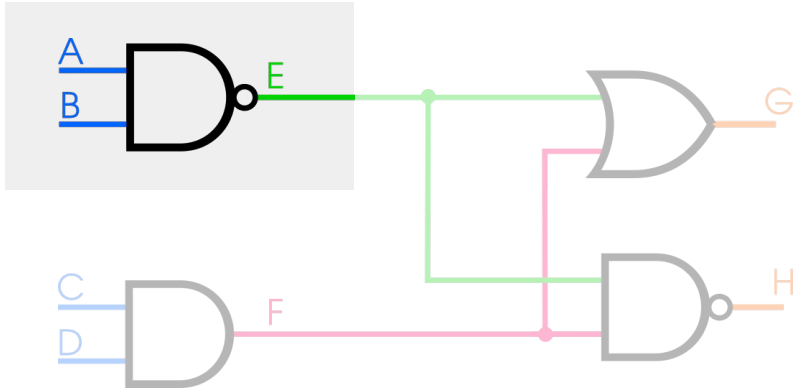
$$H(s) = \sum_{s \in S} I(s)$$

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



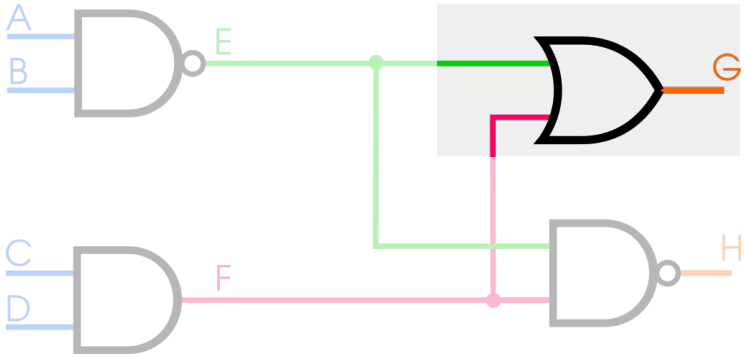
S_i	A	B	E	P	I
S_0	0	0	1	4/16	0,5
S_1	0	1	1	4/16	0,5
S_2	1	0	1	4/16	0,5
S_3	1	1	0	4/16	0,5

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



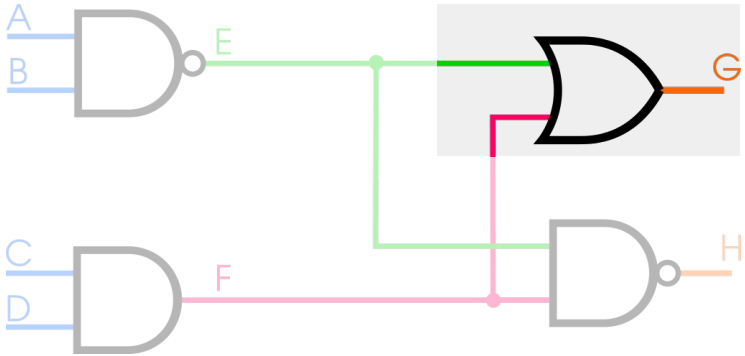
S_i	A	B	E	P	I
S_0	0	0	1	4/16	0,5
S_1	0	1	1	4/16	0,5
S_2	1	0	1	4/16	0,5
S_3	1	1	0	4/16	0,5
				Hx	2

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



S_i	E	F	G
S_0	0	0	0
S_1	0	1	1
S_2	1	0	1
S_3	1	1	1

X_i	A	B	C	D	E	F	G	H
X_0	0	0	0	0	1	0	1	1
X_1	0	0	0	1	1	0	1	1
X_2	0	0	1	0	1	0	1	1
X_3	0	0	1	1	1	1	1	0
X_4	0	1	0	0	1	0	1	1
X_5	0	1	0	1	1	0	1	1
X_6	0	1	1	0	1	0	1	1
X_7	0	1	1	1	1	1	1	0
X_8	1	0	0	0	1	0	1	1
X_9	1	0	0	1	1	0	1	1
X_{10}	1	0	1	0	1	0	1	1
X_{11}	1	0	1	1	1	1	1	0
X_{12}	1	1	0	0	0	0	0	1
X_{13}	1	1	0	1	0	0	0	1
X_{14}	1	1	1	0	0	0	0	1
X_{15}	1	1	1	1	0	1	1	1



S_i	E	F	G	P	I
S_0	0	0	0	3/16	0,45
S_1	0	1	1	1/16	0,25
S_2	1	0	1	9/16	0,47
S_3	1	1	1	3/16	0,45
				Hx	1,62

Otimização multiobjetivo

Minimizar as perdas (energia)
Minimizar a profundidade (níveis)
Minimizar a área (nº de transistores)

Minimizar as perdas

- Alterações em partes do circuito;
- Circuitos reversíveis;
- Substituição de portas lógicas;

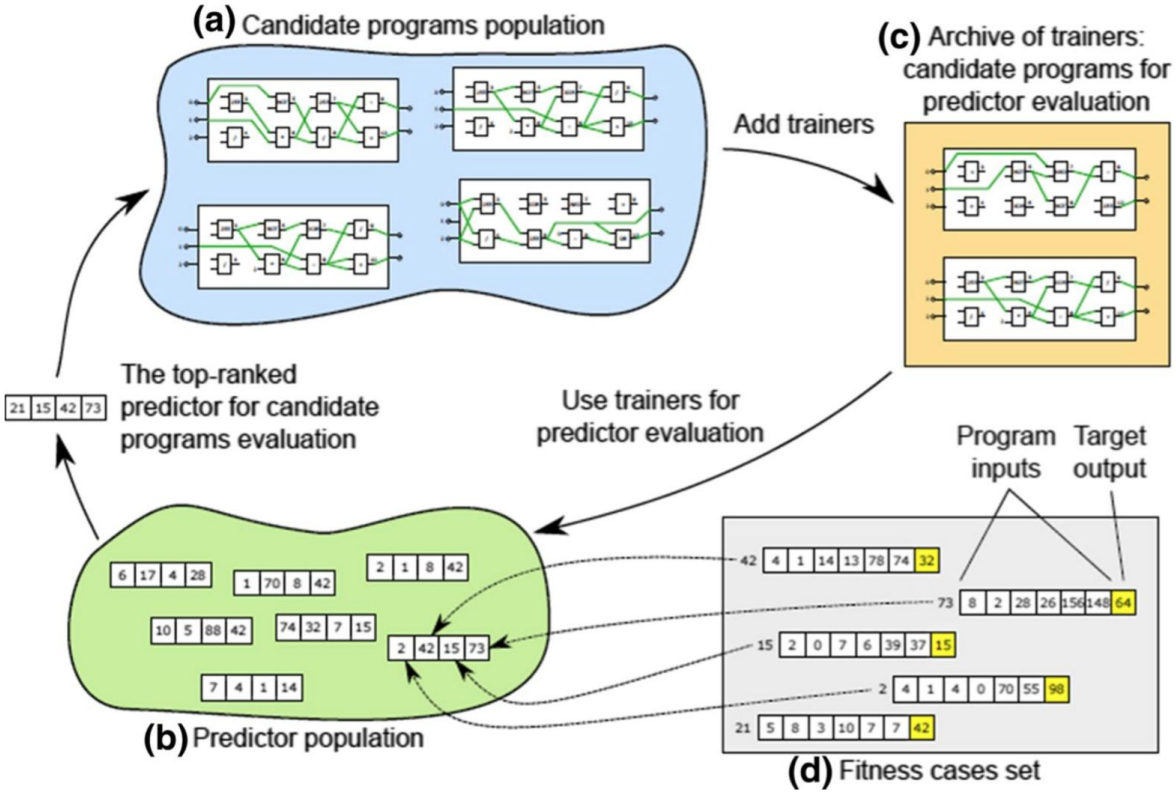
Minimizar
a profundidade e área

- Métodos algébricos
- Métodos Booleanos
- Síntese exata

Conforme Testa(2018)

EPFL Logic Synthesis Libraries

Conjunto modular e open-source de bibliotecas em C++
para desenvolvimento de aplicações de síntese lógica



Cartesian genetic programming

Considerações finais

Referências

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The EPFL Logic Synthesis Libraries (Showcase) - GitHub, disponível em *https://github.com/lsils/lstools-showcase*. Acesso em 13 de janeiro de 2021