Eng04075 – Eletrônica Digital I

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Aula 4

Sumário

- Circuitos Combinacionais
- Funções e Equações Lógicas
- Operadores e Portas Lógicas
- Suficiência de Portas Lógicas

luff.delet@gmail.com

Eng04075 – Eletrônica Digital I

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Sumário

Módulo-3

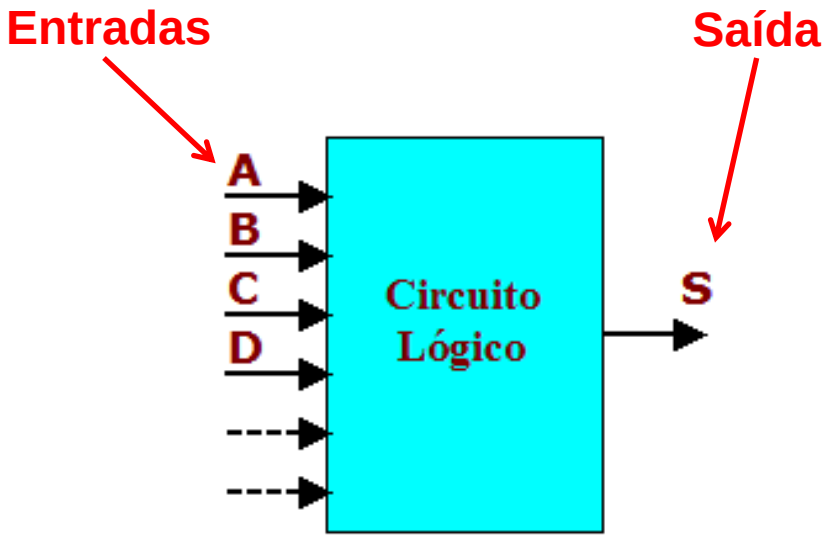
- Circuitos Combinacionais
  - Funções e Equações Lógicas
  - Operadores e Portas Lógicas
  - Suficiência de Portas Lógicas
  - Portas Lógicas CMOS
  - Projeto (SOP & POS)
  - Simplificação, Diagramas V-K, Condições Irrelevantes

luff.delet@gmail.com

Circuitos Combinacionais
Circuitos Lógicos Binários

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- As saídas só dependem das entradas
- A Análise e Projeto são baseados em conceitos de Álgebra Booleana (funções, teoremas, etc)

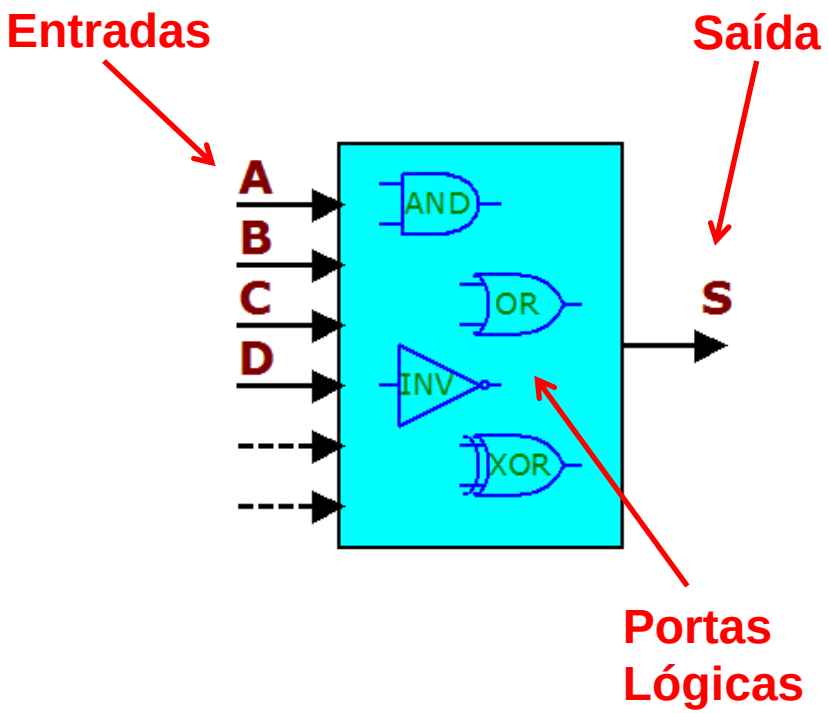
S = f((A+B).C.D, ...)

Equação Lógica da Saída

Circuitos Combinacionais
Circuitos Lógicos Binários

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- A Análise e Projeto são baseados em conceitos de Álgebra Booleana (funções, teoremas, etc)
- As Portas Lógicas representam uma equação lógica

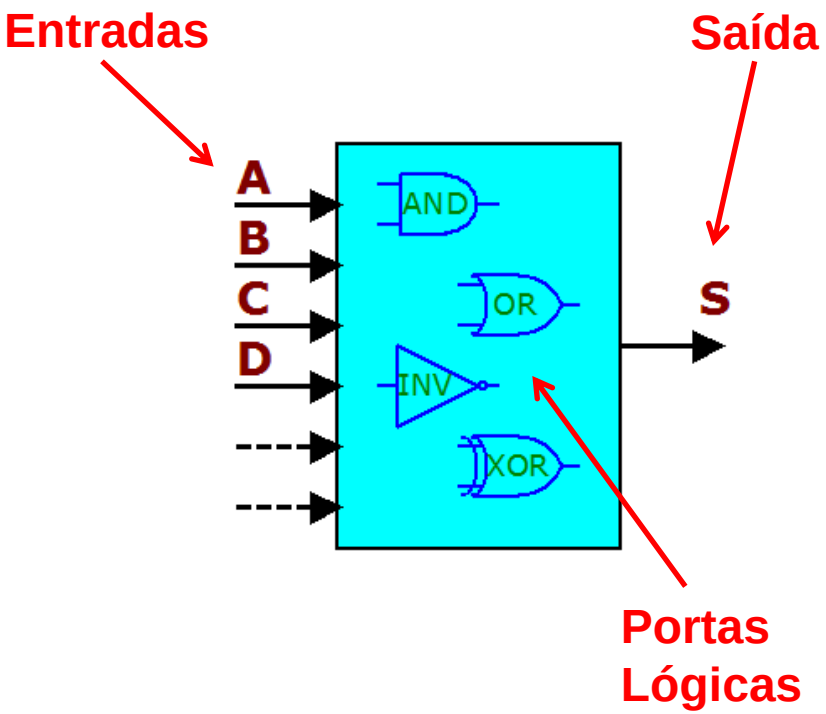
$$S = f((A+B).C.D, ...)$$

Variáveis e operadores lógicos

Circuitos Combinacionais
Circuitos Lógicos Binários

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- As Portas Lógicas representam uma equação lógica
- Na Lógica Binária as variáveis podem assumir dois (2) valores ou Níveis Lógicos

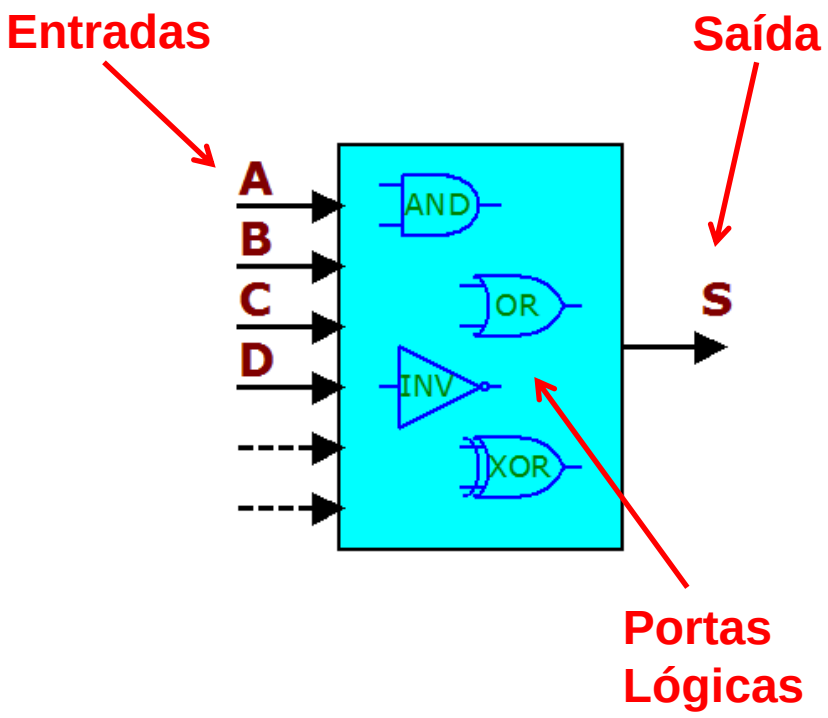
$$S = f((A+B).C.D, ...)$$

Variáveis e operadores lógicos

Circuitos Combinacionais
Circuitos Lógicos Binários

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- Na Lógica Binária as variáveis podem assumir dois (2) valores ou Níveis Lógicos
- Com 'n' entradas => 2^n possíveis configurações de entrada

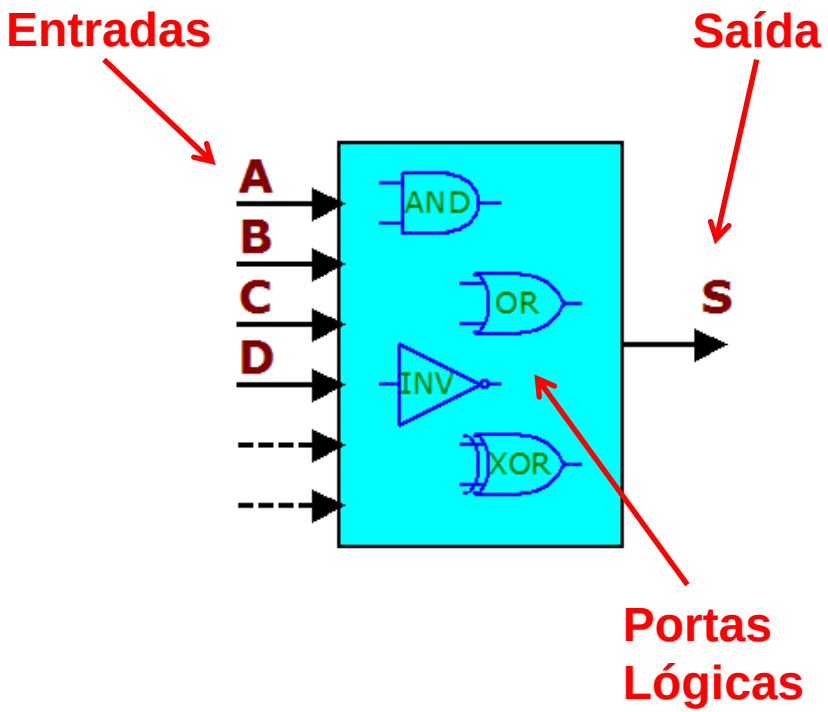
$$S = f((A+B).C.D, ...)$$

Variáveis e operadores lógicos

Circuitos Combinacionais
Circuitos Lógicos Binários

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- P.Ex. Com n=4 entradas => $2^4 = 16$ possíveis configurações de entrada
- A tabela com os valores das entradas e saídas é a Tabela Verdade da equação ou porta lógica

$$S = f((A+B).C.D, ...)$$

Variáveis e operadores lógicos

Circuitos Combinacionais

Circuitos Lógicos Binários - Exemplo

UFRGS
Eng. Elétrica
Eng04075

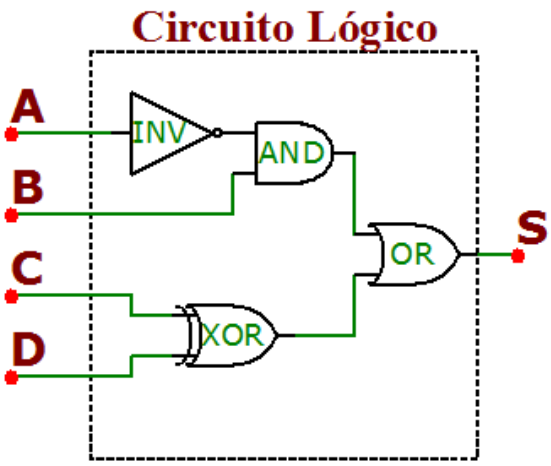
Prof. Luiz F Ferreira

Tabela Verdade

A	B	C	D	S
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	0	1
1	0	1	1	0
1	1	0	0	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	0

Equação Lógica da Saída

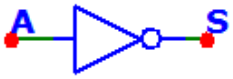
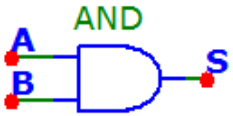
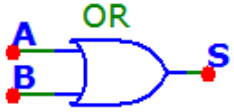
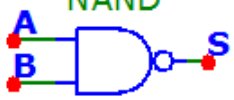
$$S = ((/A.B) + (C \oplus D))$$



Operadores e Portas Lógicas

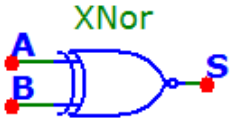
UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Porta Lógica	Equação Lógica	A	B	S
Inversor 	S = /A	0		1
		1		0
AND 	S = A.B	0	0	0
		0	1	0
		1	0	0
		1	1	1
OR 	S = A + B	0	0	0
		0	1	1
		1	0	1
		1	1	1
NAND 	S = /(A.B) = /A + /B	0	0	1
		0	1	1
		1	0	1
		1	1	0
NOR 	S = /(A + B) = /A . /B	0	0	1
		0	1	0
		1	0	0
		1	1	0

- **Operadores:**
  NOT (/) , AND (.), OR (+)

- **Portas Lógicas:**
  Inversor, AND, OR, NAND, NOR, XOR e XNOR

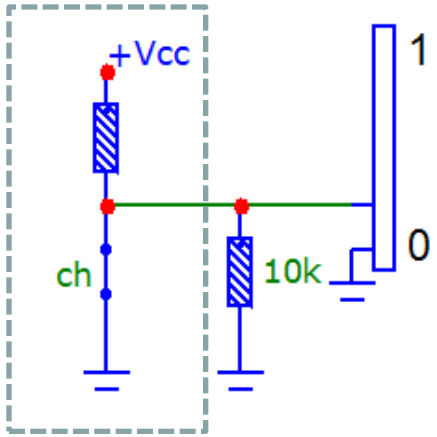
Porta Lógica	Equação Lógica	A	B	S
Xor 	S = A ⊕ B = /A.B + A./B	0	0	0
		0	1	1
		1	0	1
		1	1	0
XNor 	S = /(A ⊕ B) = /A./B + A.B	0	0	1
		0	1	0
		1	0	0
		1	1	1

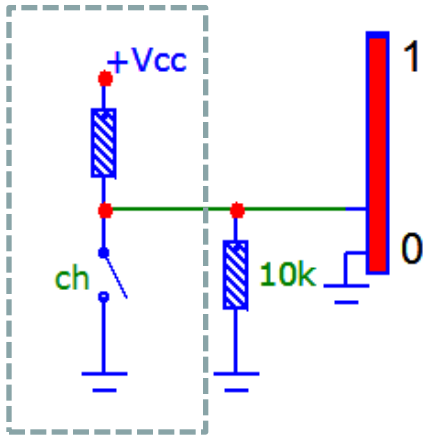
Portas Lógicas – Chaves

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Inversor





- Com “ch” ligada “on” - nível lógico ‘1’ - a tensão da fonte não é aplicada no resistor de 10K e a barra fica desligada “off” - nível lógico ‘0’
- Com “ch” desligada “off” - nível lógico ‘0’ - a tensão da fonte é aplicada no resistor de 10k e a barra fica ligada “on” - nível lógico ‘1’

- Porta “Inversor” ou “NOT”

Símbolo

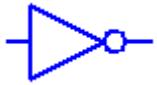


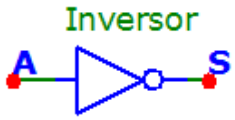
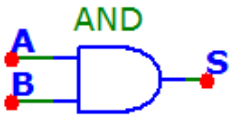
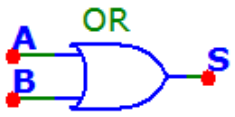
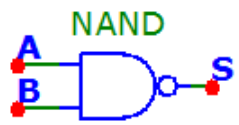
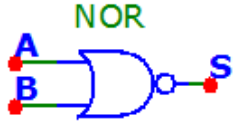
Tabela Verdade

ch	barra
on (‘1’)	off (‘0’)
off (‘0’)	on (‘1’)

Operadores e Portas Lógicas

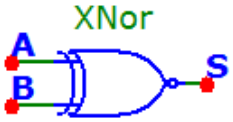
UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Porta Lógica	Equação Lógica	A	B	S
	S = /A	0		1
		1		0
	S = A.B	0	0	0
		0	1	0
		1	0	0
		1	1	1
	S = A + B	0	0	0
		0	1	1
		1	0	1
		1	1	1
	S = /(A.B) = /A + /B	0	0	1
		0	1	1
		1	0	1
		1	1	0
	S = /(A + B) = /A . /B	0	0	1
		0	1	0
		1	0	0
		1	1	0

- **Operadores:**
  NOT (/) , AND (.), OR (+)

- **Portas Lógicas:**
  Inversor, AND, OR, NAND, NOR, XOR e XNOR

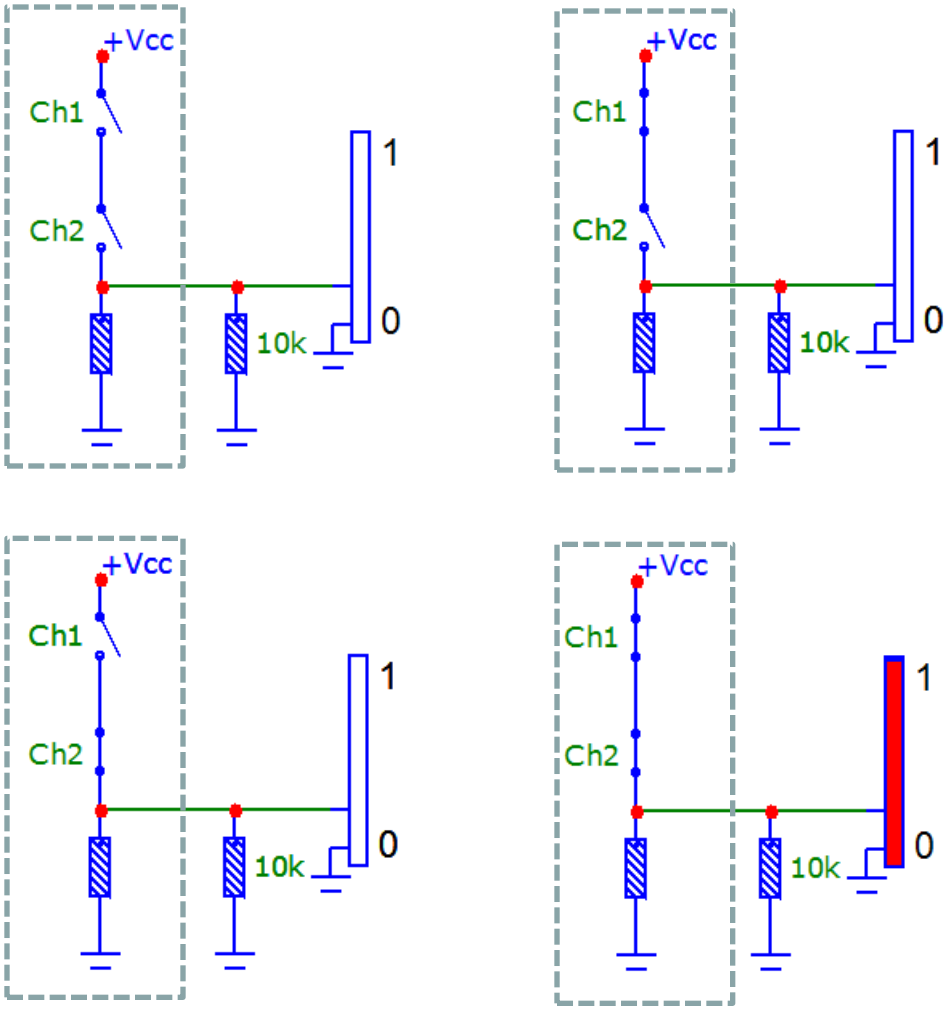
Porta Lógica	Equação Lógica	A	B	S
	S = A ⊕ B = /A.B + A./B	0	0	0
		0	1	1
		1	0	1
		1	1	0
	S = /(A ⊕ B) = /A./B + A.B	0	0	1
		0	1	0
		1	0	0
		1	1	1

AND

Portas Lógicas – Chaves

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- Somente quando "ch1" E "ch2" estão ligadas "on" ('1') a tensão da fonte é aplicada no resistor e a barra fica ligada "on" ('1')
- Porta "E" ou "AND"

Símbolo

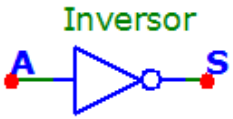
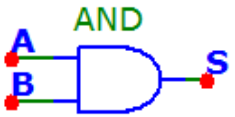
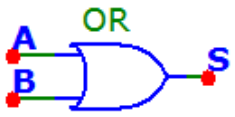
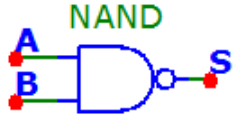
Tabela Verdade

ch1	ch2	barra
off ('0')	off ('0')	off ('0')
off ('0')	on ('1')	off ('0')
on ('1')	off ('0')	off ('0')
on ('1')	on ('1')	on ('1')

Operadores e Portas Lógicas

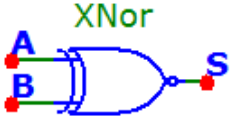
UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Porta Lógica	Equação Lógica	A	B	S
	S = /A	0		1
		1		0
	S = A.B	0	0	0
		0	1	0
		1	0	0
		1	1	1
	S = A + B	0	0	0
		0	1	1
		1	0	1
		1	1	1
	S = /(A.B) = /A + /B	0	0	1
		0	1	1
		1	0	1
		1	1	0
	S = /(A + B) = /A . /B	0	0	1
		0	1	0
		1	0	0
		1	1	0

- **Operadores:**
  NOT (/) , AND (.), OR (+)

- **Portas Lógicas:**
  Inversor, AND, OR, NAND, NOR, XOR e XNOR

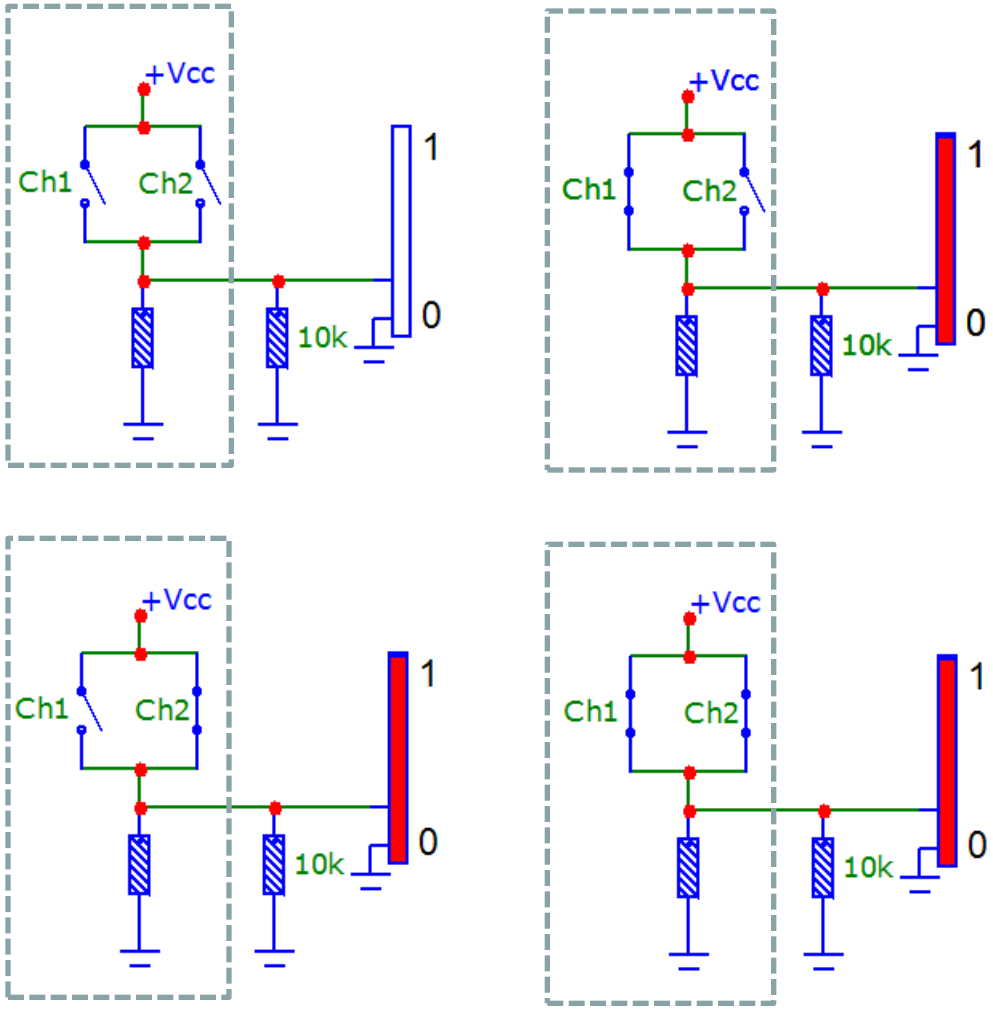
Porta Lógica	Equação Lógica	A	B	S
	S = A ⊕ B = /A.B + A./B	0	0	0
		0	1	1
		1	0	1
		1	1	0
	S = /(A ⊕ B) = /A./B + A.B	0	0	1
		0	1	0
		1	0	0
		1	1	1

OR

Portas Lógicas – Chaves

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- Sempre que “ch1” OU “ch2” estão ligadas “on” (‘1’)
- a tensão da fonte é aplicada no resistor e a barra fica ligada “on” (‘1’)
- Porta “OU” ou “OR”

Símbolo

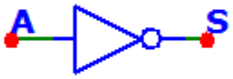
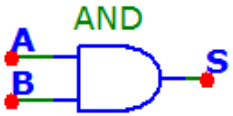
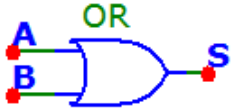
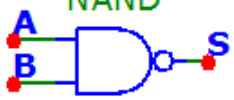
Tabela Verdade

ch1	ch2	barra
off (‘0’)	off (‘0’)	off (‘0’)
off (‘0’)	on (‘1’)	on (‘1’)
on (‘1’)	off (‘0’)	on (‘1’)
on (‘1’)	on (‘1’)	on (‘1’)

Operadores e Portas Lógicas

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Porta Lógica	Equação Lógica	A	B	S
Inversor 	S = /A	0		1
		1		0
AND 	S = A.B	0	0	0
		0	1	0
		1	0	0
		1	1	1
OR 	S = A + B	0	0	0
		0	1	1
		1	0	1
		1	1	1
NAND 	S = /(A.B) = /A + /B	0	0	1
		0	1	1
		1	0	1
		1	1	0
NOR 	S = /(A + B) = /A . /B	0	0	1
		0	1	0
		1	0	0
		1	1	0

- **Operadores:**
  NOT (/) , AND (.), OR (+)

- **Portas Lógicas:**
  Inversor, AND, OR, NAND, NOR, XOR e XNOR

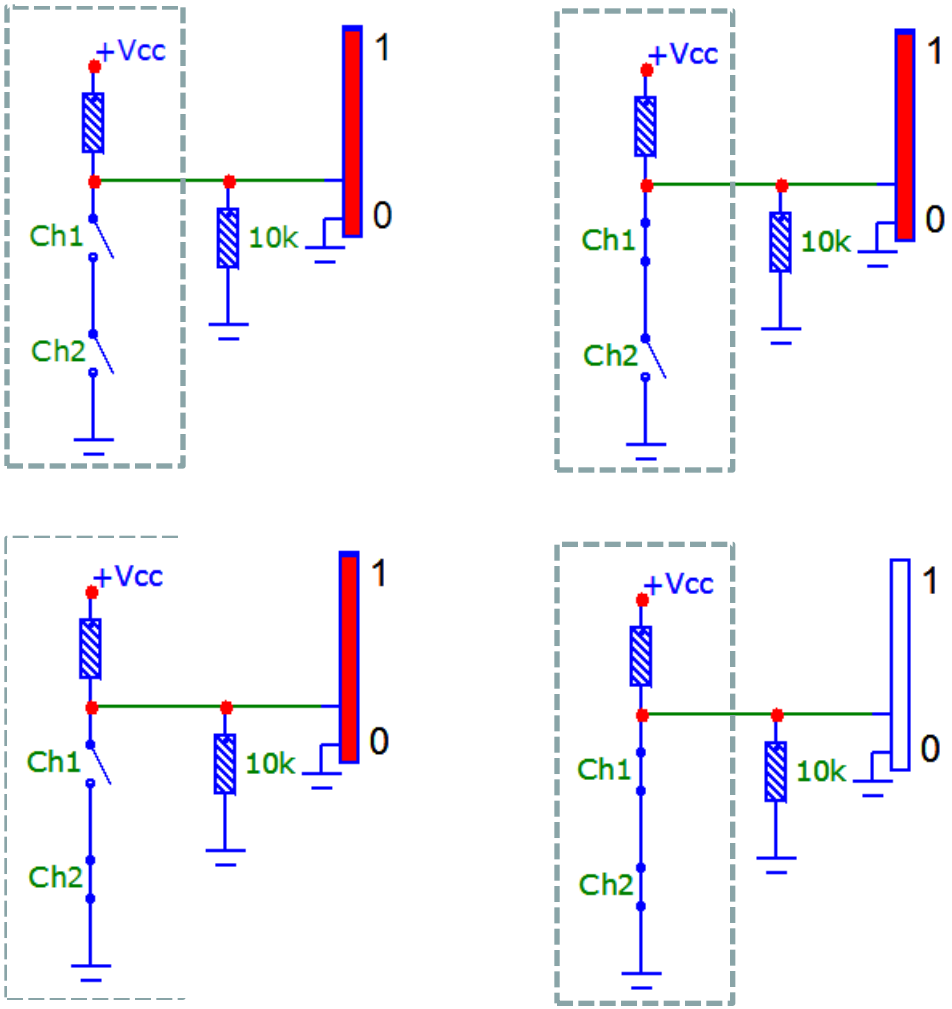
Porta Lógica	Equação Lógica	A	B	S
Xor 	S = A ⊕ B = /A.B + A./B	0	0	0
		0	1	1
		1	0	1
		1	1	0
XNor 	S = /(A ⊕ B) = /A./B + A.B	0	0	1
		0	1	0
		1	0	0
		1	1	1

NAND

Portas Lógicas – Chaves

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- Somente quando "ch1" E "ch2" estão ligadas "on" ('1') a tensão da fonte não é aplicada no resistor e a barra fica desligada "off" ('0')
- Porta "não E" ou "NAND"

Símbolo

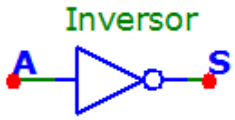
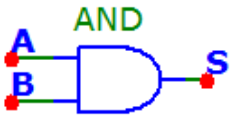
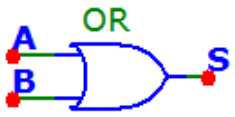
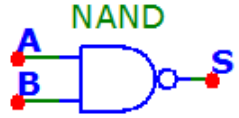
Tabela Verdade

ch1	ch2	barra
off ('0')	off ('0')	off ('1')
off ('0')	on ('1')	off ('1')
on ('1')	off ('0')	off ('1')
on ('1')	on ('1')	on ('0')

Operadores e Portas Lógicas

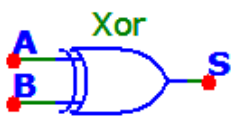
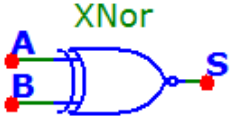
UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Porta Lógica	Equação Lógica	A	B	S
	S = /A	0		1
		1		0
	S = A.B	0	0	0
		0	1	0
		1	0	0
		1	1	1
	S = A + B	0	0	0
		0	1	1
		1	0	1
		1	1	1
	S = /(A.B) = /A + /B	0	0	1
		0	1	1
		1	0	1
		1	1	0
	S = /(A + B) = /A . /B	0	0	1
		0	1	0
		1	0	0
		1	1	0

- **Operadores:**
  NOT (/) , AND (.), OR (+)

- **Portas Lógicas:**
  Inversor, AND, OR, NAND, NOR, XOR e XNOR

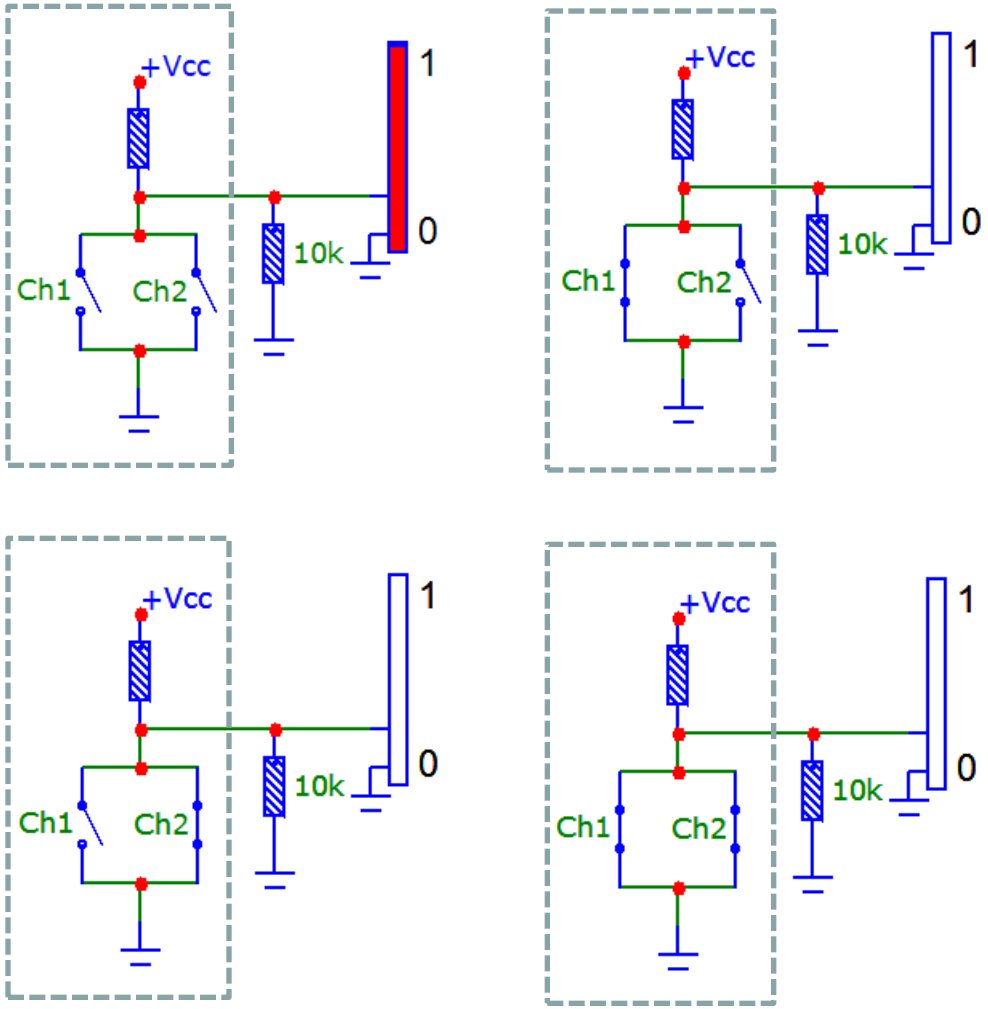
Porta Lógica	Equação Lógica	A	B	S
	S = A ⊕ B = /A.B + A./B	0	0	0
		0	1	1
		1	0	1
		1	1	0
	S = /(A ⊕ B) = /A./B + A.B	0	0	1
		0	1	0
		1	0	0
		1	1	1

NOR

Portas Lógicas – Chaves

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira



- Sempre que “ch1” OU “ch2” estão ligadas “on” (‘1’)
- a tensão da fonte não é aplicada no resistor e a barra fica desligada “off” (‘0’)
- Porta “não OU” ou “NOR”

Símbolo

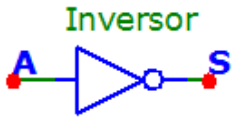
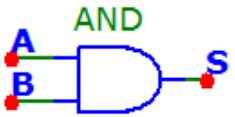
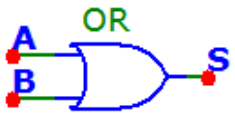
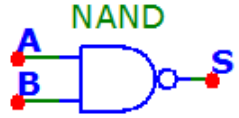
Tabela Verdade

ch1	ch2	barra
off (‘0’)	off (‘0’)	off (‘1’)
off (‘0’)	on (‘1’)	on (‘0’)
on (‘1’)	off (‘0’)	on (‘0’)
on (‘1’)	on (‘1’)	on (‘0’)

Operadores e Portas Lógicas

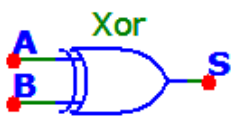
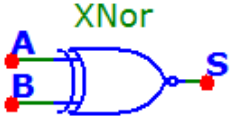
UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Porta Lógica	Equação Lógica	A	B	S
	S = /A	0		1
		1		0
	S = A.B	0	0	0
		0	1	0
		1	0	0
		1	1	1
	S = A + B	0	0	0
		0	1	1
		1	0	1
		1	1	1
	S = /(A.B) = /A + /B	0	0	1
		0	1	1
		1	0	1
		1	1	0
	S = /(A + B) = /A . /B	0	0	1
		0	1	0
		1	0	0
		1	1	0

- **Operadores:**
  NOT (/) , AND (.), OR (+)

- **Portas Lógicas:**
  Inversor, AND, OR, NAND, NOR, XOR e XNOR

Porta Lógica	Equação Lógica	A	B	S
	S = A ⊕ B = /A.B + A./B	0	0	0
		0	1	1
		1	0	1
		1	1	0
	S = /(A ⊕ B) = /A./B + A.B	0	0	1
		0	1	0
		1	0	0
		1	1	1

Principais Identidades e Teoremas

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

- **Identidades**

0.A = 0	0 + A = A
1.A = A	1 + A = 1
A.A = A	A + A = A
A./A = 0	A + /A = 1

- **Vizinhança Lógica**

A.B + A./B = A
(A + B).(A + /B) = A

- **Teoremas de Morgan**

/(A.B.C. ...) = (/A + /B + /C + ...)

/(A + B + C + ...) = (/A./B./C. ...)

- **Leis Comutativas**

(A + B) = (B + A)

(A.B) = (B.A)

- **Leis Associaticas**

A + B + C = (A + B) + C = A + (B + C)

A.B.C = (A.B).C= A.(B.C)

- **Leis Distributivas**

A.(B + C) = A.B + A.C

A + (B.C) = (A + B).(A + C)

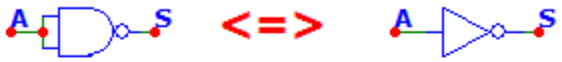
Principais Identidades e Teoremas

UFRGS
Eng. Elétrica
Eng04075

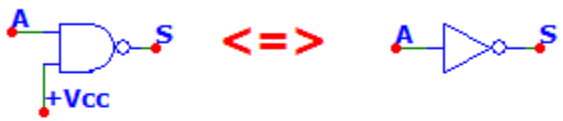
Prof. Luiz F Ferreira

Equivalências

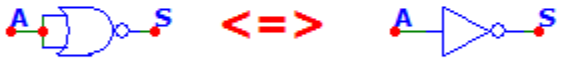
/(A.A) <=> /A



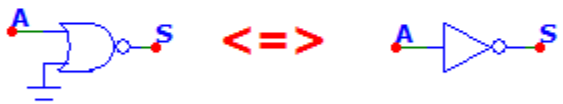
/(A.1) <=> /A



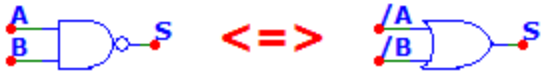
/(A + A) <=> /A



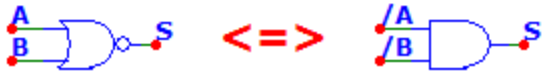
/(A + 0) <=> /A



/(A.B) <=> (/A + /B)



/(A + B) <=> (/A./B)



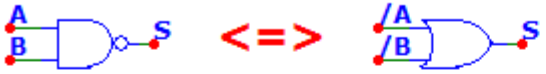
Principais Identidades e Teoremas

UFRGS
Eng. Elétrica
Eng04075

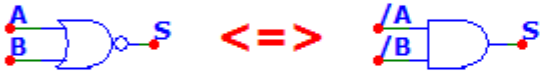
Prof. Luiz F Ferreira

Equivalências

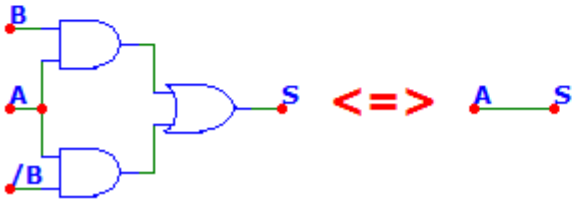
/(A.B) <=> (/A + /B)



/(A + B) <=> (/A./B)



A.B + A./B <=> A



A.B + C.D <=> /(/(A.B) . /(C.D))

(A + B).(C + D) <=> /(/(A + B) + /(C + D))

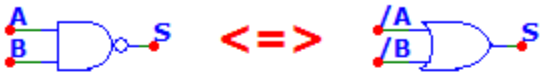
Principais Identidades e Teoremas

UFRGS
Eng. Elétrica
Eng04075

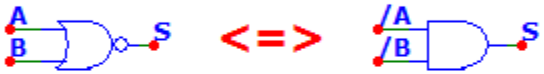
Prof. Luiz F Ferreira

Equivalências

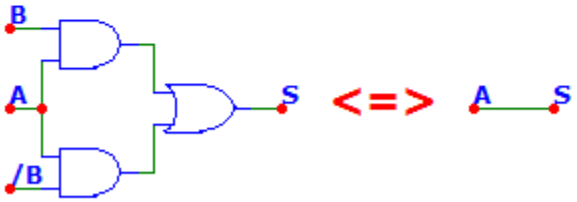
/(A.B) <=> (/A + /B)



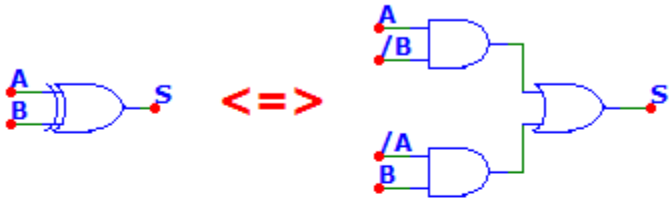
/(A + B) <=> (/A./B)

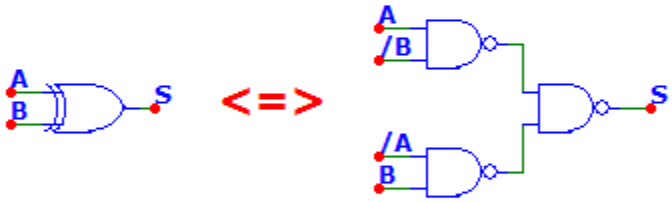


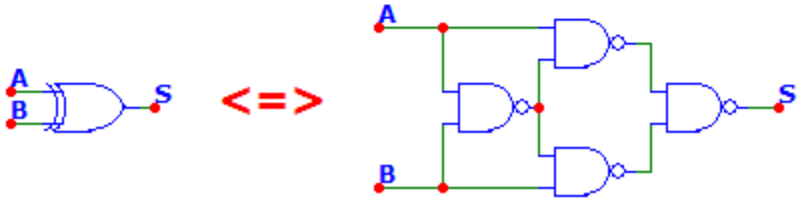
A.B + A./B <=> A



A xor B <=> /A.B + A./B







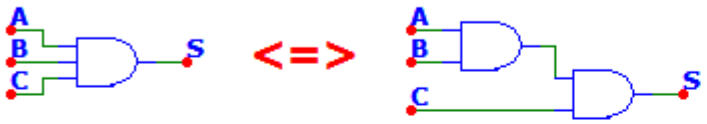
Principais Identidades e Teoremas

UFRGS
Eng. Elétrica
Eng04075

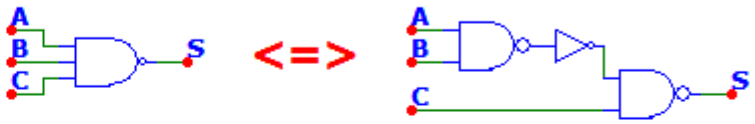
Prof. Luiz F Ferreira

Equivalências

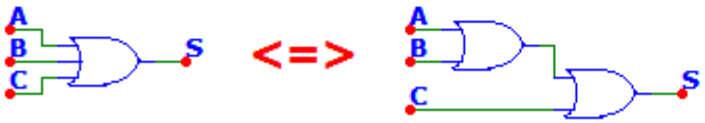
A.B.C <=> (A.B).C



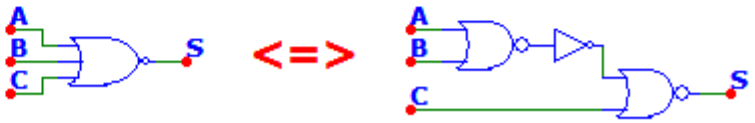
/(A.B.C) <=> /(/(/(A.B)) . C)



(A + B + C) <=> (A + B) + C



/(A + B + C) <=> /(/(/(A+B)) + C)



Principais Identidades e Teoremas

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

- **Identidades**

0.A = 0	0 + A = A
1.A = A	1 + A = 1
A.A = A	A + A = A
A./A = 0	A + /A = 1

- **Vizinhança Lógica**

A.B + A./B = A
(A + B).(A + /B) = A

- **Teoremas de Morgan**

/(A.B.C. ...) = (/A + /B + /C + ...)

/(A + B + C + ...) = (/A./B./C. ...)

- **Leis Comutativas**

(A + B) = (B + A)

(A.B) = (B.A)

- **Leis Associaticas**

A + B + C = (A + B) + C = A + (B + C)

A.B.C = (A.B).C= A.(B.C)

- **Leis Distributivas**

A.(B + C) = A.B + A.C

A + (B.C) = (A + B).(A + C)

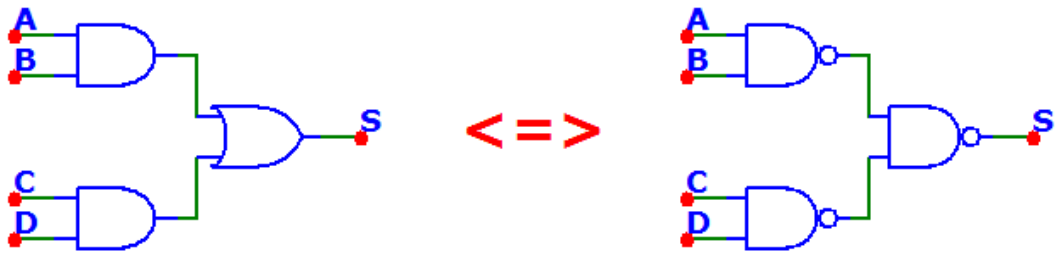
Suficiência de Portas

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

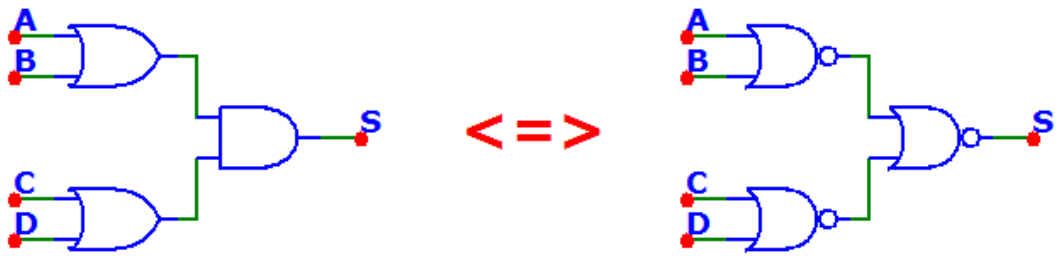
Equivalências

A.B + C.D <=> /(/(A.B) . /(C.D))



Suficiência NAND

(A + B).(C + D) <=> /(/(A + B) + /(C + D))



Suficiência NOR

Portas Lógicas
- Montagens -

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Pinagem dos CIs 7400 e 4011

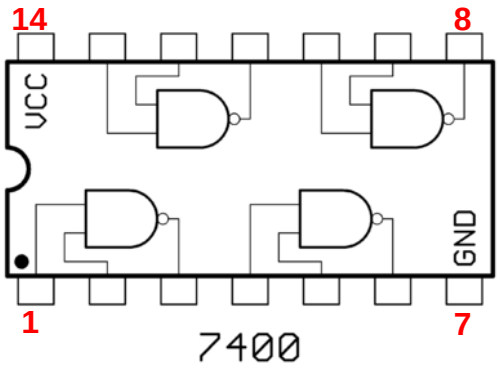
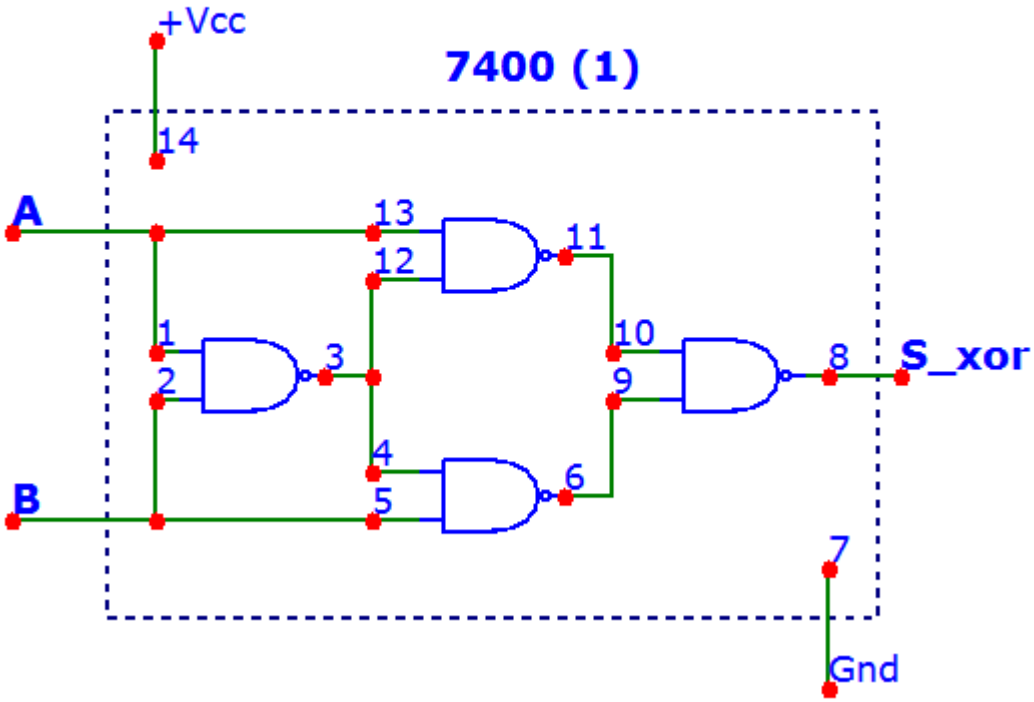


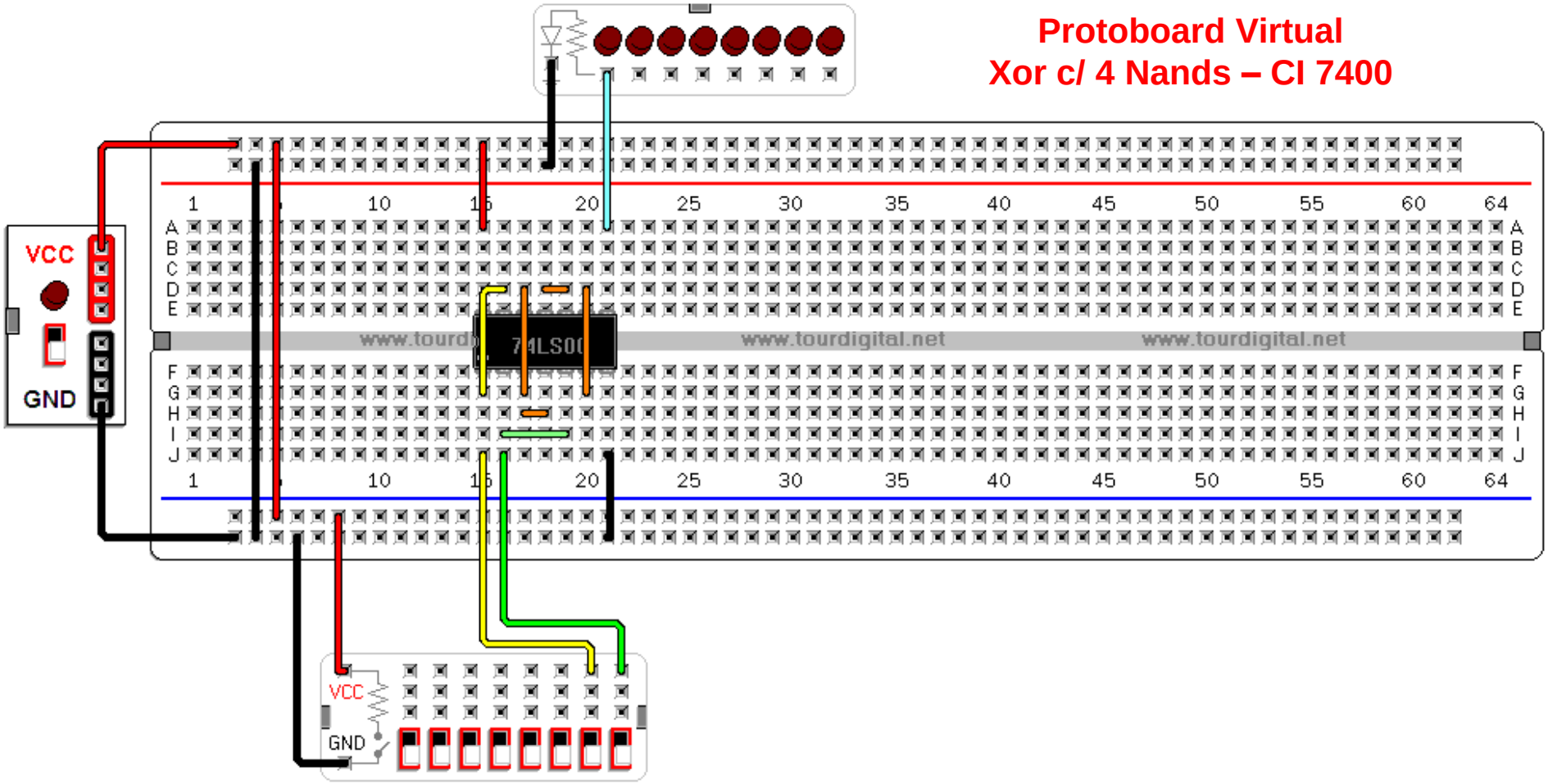
Diagrama Esquemático e Pinagem
Xor c/ Nands - CI 7400



Portas Lógicas
- Montagens -

UFRGS
Eng. Elétrica
Eng04075

Protoboard Virtual
Xor c/ 4 Nands – CI 7400



Portas Lógicas
- Montagens -

UFRGS
Eng. Elétrica
Eng04075

Prof. Luiz F Ferreira

Protoboard Real
Xor c/ 4 Nands – CI 7400