



MC 602

IC/Unicamp

2011s2

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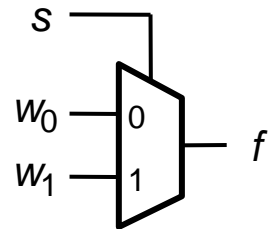
VHDL

Circuitos Combinacionais

Tópicos

- Multiplexadores
- Decodificadores
- Decodificadores de prioridade
- Conversores de código
- Conversão bin-> 7 segmentos

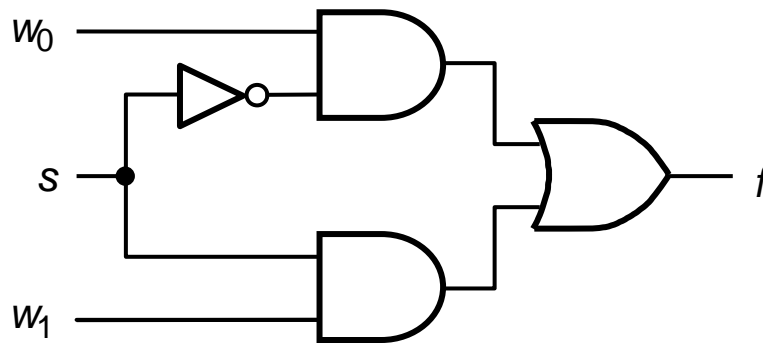
Mux 2:1



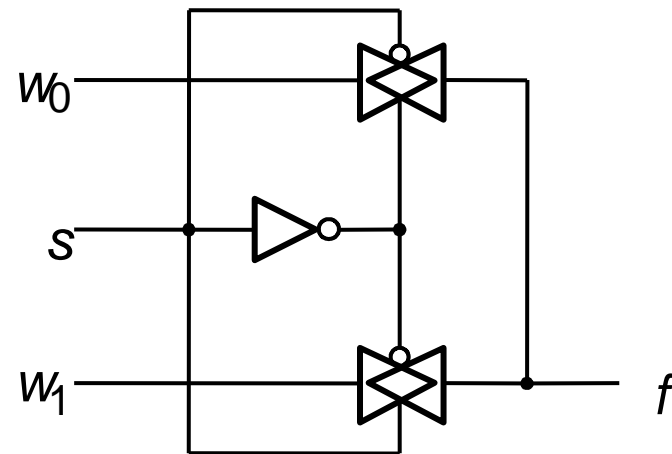
(a) Graphical symbol

s	f
0	w_0
1	w_1

(b) Truth table



(c) Sum-of-products circuit



(d) Circuit with transmission gates

MUX 2:1 com atribuição selecionada de sinal– VHDL

```
LIBRARY ieee ;  
USE ieee.std_logic_1164.all ;  
  
ENTITY mux2to1 IS  
    PORT ( w0, w1, s: IN STD_LOGIC ;  
          f : OUT STD_LOGIC ) ;  
END mux2to1 ;  
  
ARCHITECTURE Behavior OF mux2to1 IS  
BEGIN  
    WITH s SELECT  
        f <=  w0 WHEN '0',  
             w1 WHEN OTHERS ;  
END Behavior ;
```

MUX 2:1 com atribuição condicional – VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY mux2to1 IS
    PORT ( w0, w1, s : IN STD_LOGIC ;
          f : OUT  STD_LOGIC ) ;
END mux2to1 ;

ARCHITECTURE Behavior OF mux2to1 IS
BEGIN
    f <= w0 WHEN s = '0' ELSE w1 ;
END Behavior ;
```

VHDL: Selected Signal Assignment (Atribuição selecionada de sinal)

- A atribuição a um sinal pode ter vários valores em função de um sinal de “seleção”
 - IMPORTANTE: **todas as combinações(*)** de valores do sinal de seleção têm que ser explicitamente listadas (como um MUX)
 - Variante: uso do OTHERS
 - Exemplo: sinal de seleção = ctl de 2 bits

```
WITH ctl SELECT
  f <= w0 WHEN "00",
    w1 WHEN "01",
    w1 WHEN "10",
    w1 WHEN "11";
```

```
WITH ctl SELECT
  f <=w0 WHEN "00",
    w1 WHEN OTHERS
  ;
```

(*) Atenção com o tipo do sinal

VHDL: Atribuição condicional

- Ao contrário do que parece, não é equivalente a “Selected Signal Assignment”
 - As condições listadas após o WHEN não precisam ser mutuamente exclusivas (elas têm prioridade da esquerda para a direita)

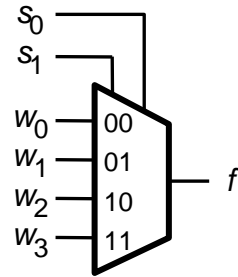
- Exemplo com uma condição

```
f <= w0 WHEN ct1 = "00" ELSE w1;
```

- Exemplo com 3 condições

```
f <=      w0 WHEN ct1 = "00" ELSE  
          w1 WHEN ct1 = "01" ELSE  
          w3;
```

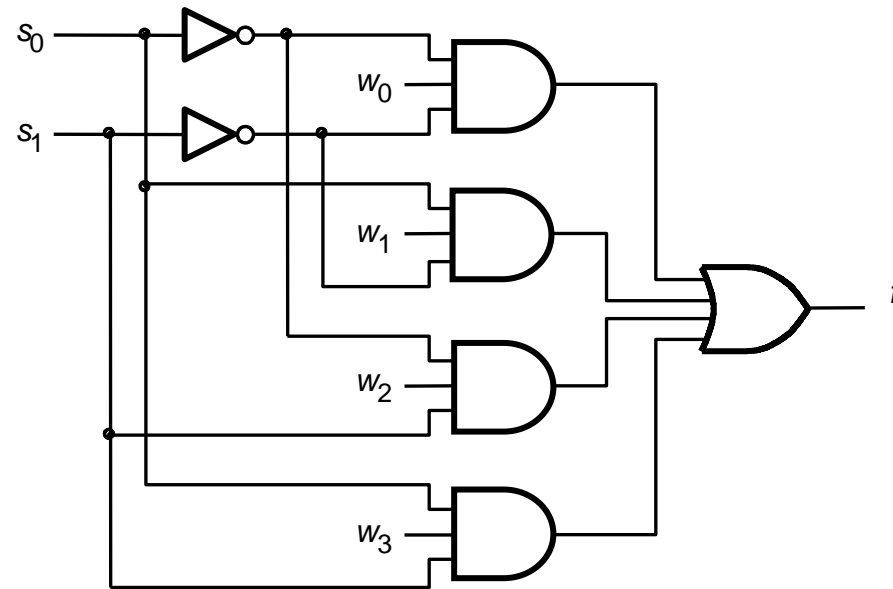
Mux 4:1



s_1	s_0	f
0	0	w_0
0	1	w_1
1	0	w_2
1	1	w_3

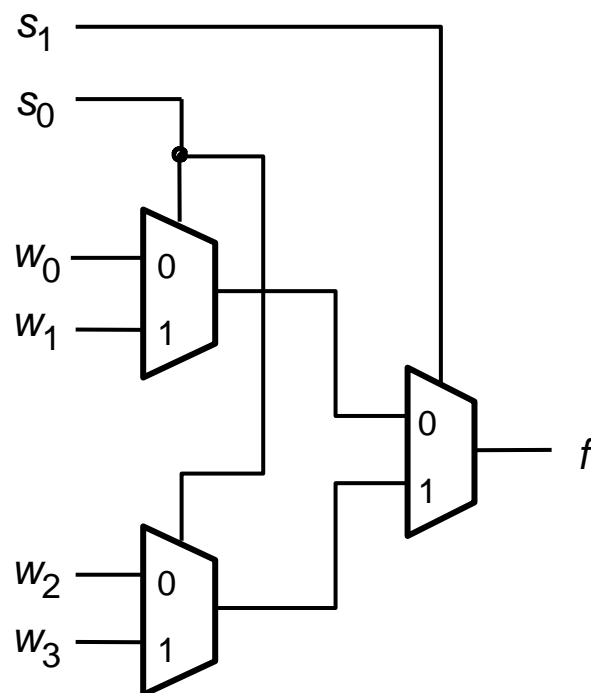
(a) Graphic symbol

(b) Truth table



(c) Circuit

Mux 4:1 construído com Mux 2:1





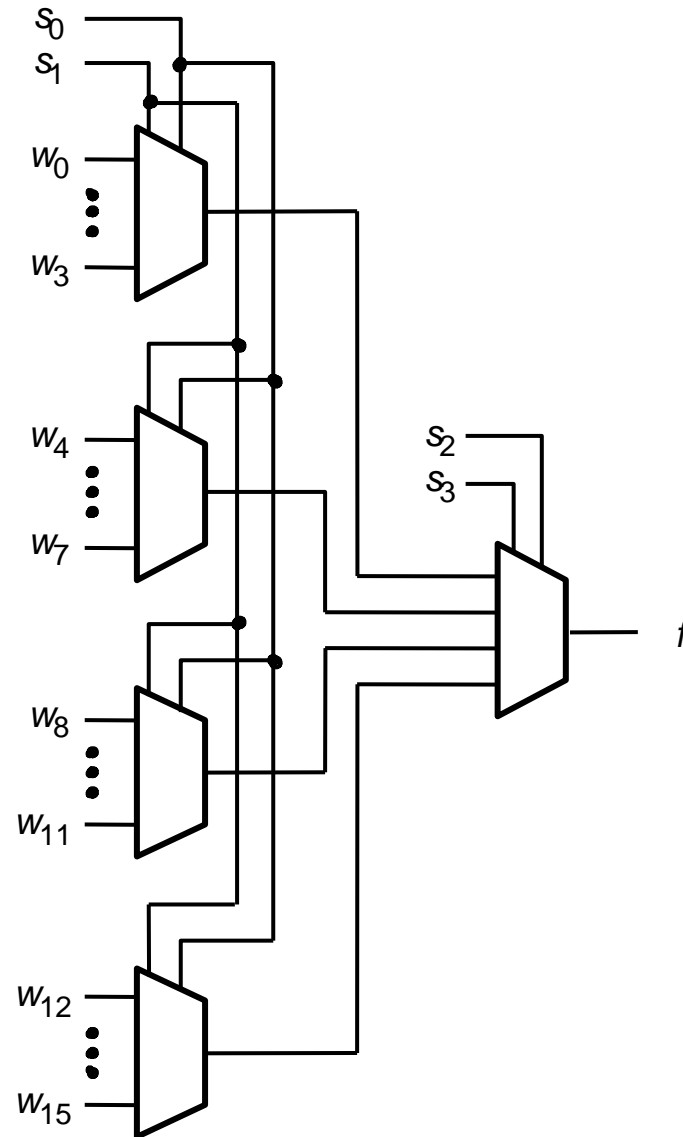
MUX 4:1 – VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY mux4to1 IS
    PORT (w0, w1, w2, w3: IN    STD_LOGIC ;
          s: IN  STD_LOGIC_VECTOR(1 DOWNTO 0) ;
          f: OUT STD_LOGIC ) ;
END mux4to1 ;

ARCHITECTURE Behavior OF mux4to1 IS
BEGIN
    WITH s SELECT
        f <= w0 WHEN "00",
            w1 WHEN "01",
            w2 WHEN "10",
            w3 WHEN OTHERS ;
END Behavior ;
```

Mux 16:1





MUX 4:1 – Declaração de Component

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
PACKAGE mux4to1_package IS
    COMPONENT mux4to1
        PORT ( w0, w1, w2, w3: IN      STD_LOGIC ;
              s: IN STD_LOGIC_VECTOR(1 DOWNTO 0) ;
              f: OUT      STD_LOGIC ) ;
    END COMPONENT ;
END mux4to1_package ;
```

Neste exemplo:

- Declaração de um componente
- Dentro de um “package”
- A ser referenciado posteriormente

MUX 16:1 hierárquico – VHDL (1)

Usa o pacote definido

```
LIBRARY ieee ;  
USE ieee.std_logic_1164.all ;  
LIBRARY work ;  
USE work.mux4to1_package.all ;  
  
ENTITY mux16to1 IS  
    PORT (w : IN STD_LOGIC_VECTOR(0 TO 15) ;  
          s : IN STD_LOGIC_VECTOR(3 DOWNTO 0) ;  
          f : OUT STD_LOGIC ) ;  
END mux16to1 ;
```

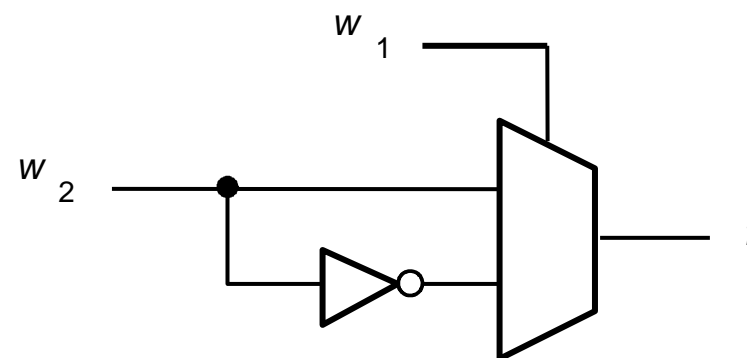
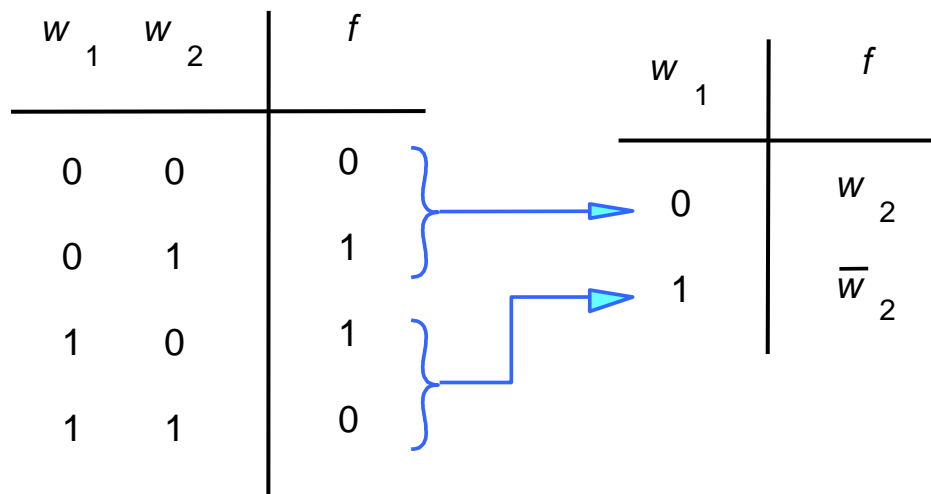
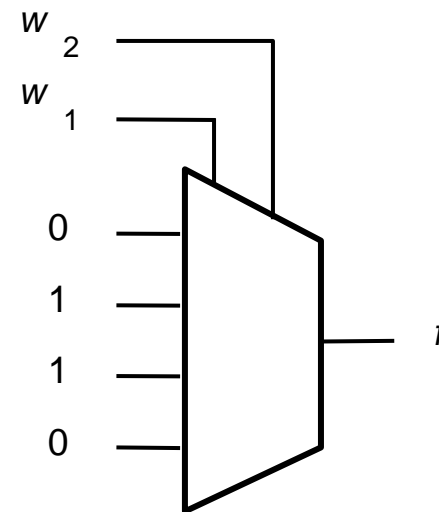


MUX 16:1 hierárquico – VHDL (2)

```
ARCHITECTURE Structure OF mux16to1 IS
    SIGNAL m : STD_LOGIC_VECTOR(0 TO 3) ;
BEGIN
    Mux1: mux4to1 PORT MAP
        ( w(0), w(1), w(2), w(3), s(1 DOWNT0 0), m(0) ) ;
    Mux2: mux4to1 PORT MAP
        ( w(4), w(5), w(6), w(7), s(1 DOWNT0 0), m(1) ) ;
    Mux3: mux4to1 PORT MAP
        ( w(8), w(9), w(10), w(11), s(1 DOWNT0 0), m(2) )
;
    Mux4: mux4to1 PORT MAP
        ( w(12), w(13), w(14), w(15), s(1 DOWNT0 0), m(3)
);
    Mux5: mux4to1 PORT MAP
        ( m(0), m(1), m(2), m(3), s(3 DOWNT0 2), f ) ;
END Structure ;
```

Mux: implementação de funções lógicas

w_1	w_2	f
0	0	0
0	1	1
1	0	1
1	1	0



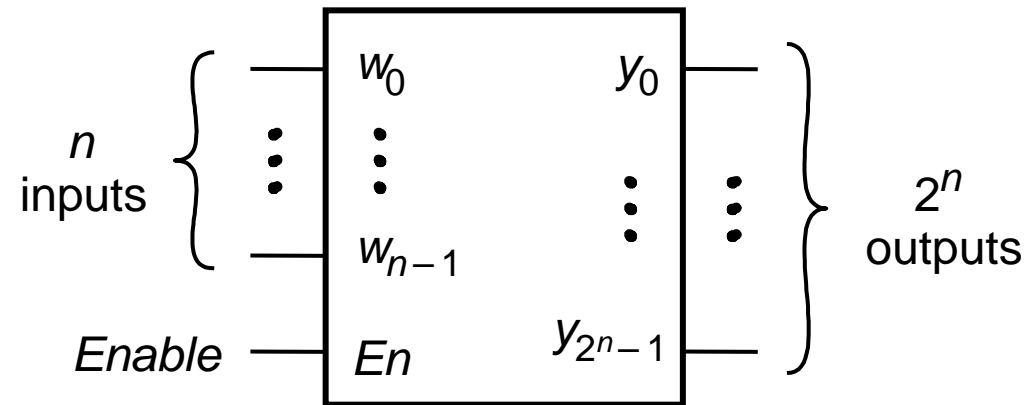
Implementação com VHDL (2ª alt)

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY circuito IS
    PORT (w1, w2      : IN  STD_LOGIC ;
          f          : OUT   STD_LOGIC ) ;
END circuito ;

ARCHITECTURE Behavior OF circuito IS
BEGIN
    WITH w1 SELECT
        f <=  w2 WHEN '0',
            NOT w2 WHEN OTHERS ;
END Behavior ;
```


Decodificadores

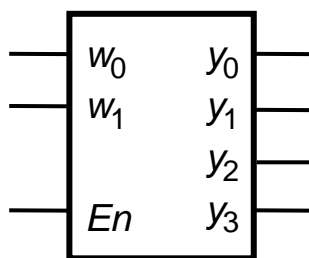


Decodificador n -to- 2^n

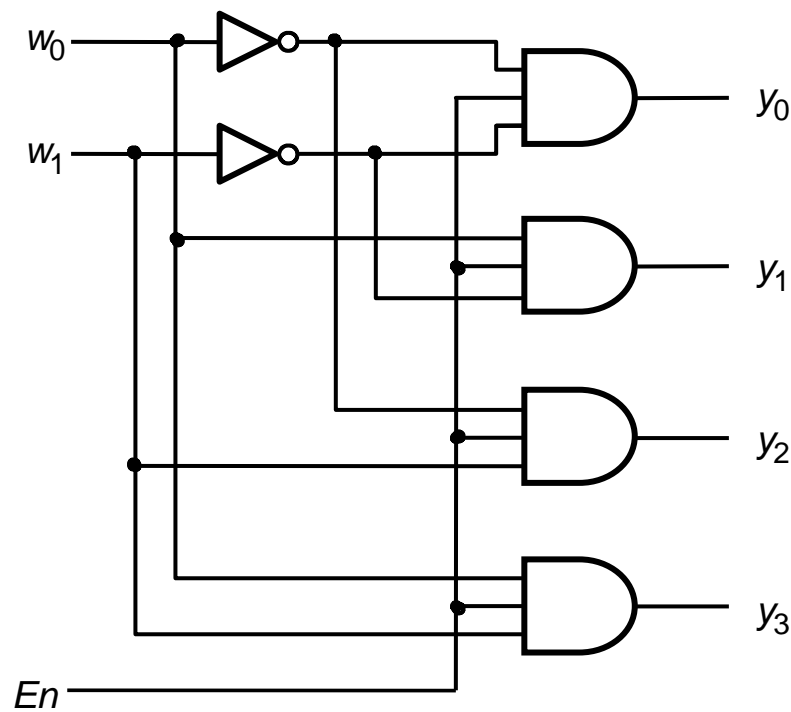
Decod. 2:4

En	w_1	w_0	y_0	y_1	y_2	y_3
1	0	0	1	0	0	0
1	0	1	0	1	0	0
1	1	0	0	0	1	0
1	1	1	0	0	0	1
0	x	x	0	0	0	0

(a) Truth table



(b) Graphic symbol



(c) Logic circuit



Decoder 2:4 – VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY dec2to4 IS
    PORT (w : IN STD_LOGIC_VECTOR(1 DOWNTO 0) ;
          En : IN STD_LOGIC ;
          y : OUT STD_LOGIC_VECTOR(0 TO 3) ) ;
END dec2to4 ;

ARCHITECTURE Behavior OF dec2to4 IS
    SIGNAL Enw : STD_LOGIC_VECTOR(2 DOWNTO 0) ;
BEGIN
    Enw <= En & w ;
    WITH Enw SELECT
        y <= "1000" WHEN "100",
            "0100" WHEN "101",
            "0010" WHEN "110",
            "0001" WHEN "111",
            "0000" WHEN OTHERS ;
END Behavior ;
```



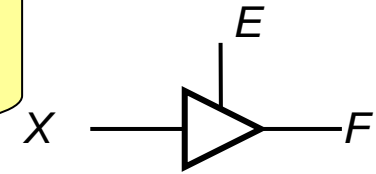
Buffers tri-state em VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY zbuffer IS
    GENERIC ( N : INTEGER := 8 ) ;
    PORT ( X : IN STD_LOGIC_VECTOR(N-1 DOWNTO 0) ;
          E : IN STD_LOGIC ;
          F : OUT STD_LOGIC_VECTOR(N-1 DOWNTO 0) ) ;
END zbuffer ;

ARCHITECTURE Behavior OF zbuffer IS
BEGIN
    F <= ( OTHERS => 'Z' ) WHEN E = '0' ELSE X ;
END Behavior ;
```

Permite configurar
parâmetros (n bits)



Construção (OTHERS => '1')

- usada principalmente em vetores para atribuir um mesmo valor para todos os bits (aqui todos 8 bits de $F \leftarrow 'Z'$)

Component Buffer

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

PACKAGE ZBuffer_package IS
  COMPONENT ZBuffer
    GENERIC (N : INTEGER) ;
    PORT (X, IN STD_LOGIC_VECTOR(N-1 DOWNT0 0) ;
          E: IN STD_LOGIC ;
          f: OUT STD_LOGIC_VECTOR(N-1 DOWNT0 0)) ;
  END COMPONENT ;
END ZBuffer_package ;
```

Encapsulando o buffer three-state em componente
Precisa informar o tipo do parâmetro N

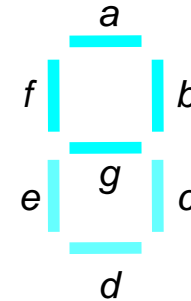
Gerando Adaptador 32-bits

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
USE work.ZBuffer_package.all ;

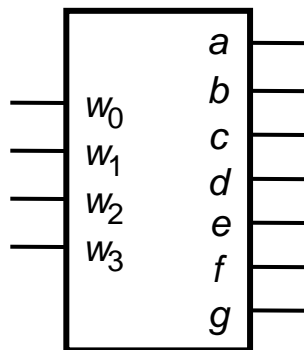
ENTITY bus32adapter IS
    GENERIC ( N : INTEGER := 32 );
    PORT (X: IN STD_LOGIC_VECTOR(N-1 DOWNT0 0) ;
          Z: IN STD_LOGIC ;
          B: OUT STD_LOGIC_VECTOR(N-1 DOWNT0 0) ) ;
END bus32adapter ;

ARCHITECTURE behavior OF bus32adapter IS
BEGIN
    buf: ZBuffer
        GENERIC MAP( N =>32 )
        port map (X, Z, B) ;
END behavior ;
```

Conversor Bin \rightarrow BCD (7 segmentos)



(b) 7-segment display



(a) Code converter

w_3	w_2	w_1	w_0	a	b	c	d	e	f	g
0	0	0	0	1	1	1	1	1	1	0
0	0	0	1	0	1	1	0	0	0	0
0	0	1	0	1	1	0	1	1	0	1
0	0	1	1	1	1	1	1	0	0	1
0	1	0	0	0	1	1	0	0	1	1
0	1	0	1	1	0	1	1	0	1	1
0	1	1	0	1	0	1	1	1	1	1
0	1	1	1	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1	1	1	1
1	0	0	1	1	1	1	1	0	1	1

(c) Truth table

Implementação convencional

Segment a

	00	01	11	10
00	0	1	0	0
01	1	0	1	0
11	0	0	0	1
10	0	0	0	0

Segment f

	00	01	11	10
00	0	0	0	0
01	1	0	1	0
11	1	1	0	0
10	1	0	0	0

Segment g

	00	01	11	10
00	1	0	1	0
01	1	0	0	0
11	0	1	0	0
10	0	0	0	0

Segment e

	00	01	11	10
00	0	1	0	0
01	1	1	0	1
11	1	1	0	0
10	0	0	0	0

Segment d

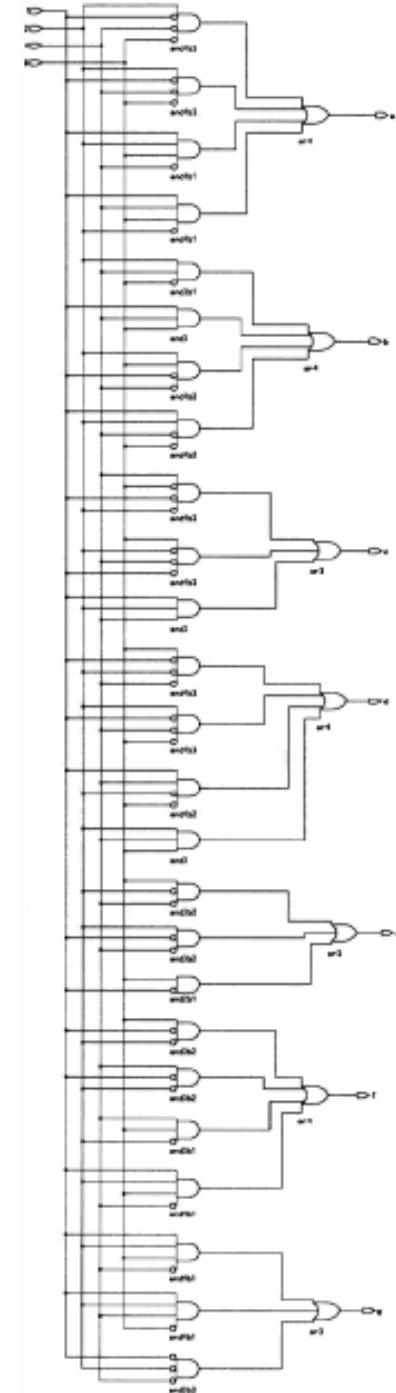
	00	01	11	10
00	0	1	0	0
01	1	0	0	0
11	0	1	1	0
10	0	0	0	1

Segment b

	00	01	11	10
00	0	0	1	0
01	0	1	0	0
11	0	0	1	1
10	0	1	1	0

Segment c

	00	01	11	10
00	0	0	1	0
01	0	0	0	0
11	0	0	1	0
10	1	0	1	0

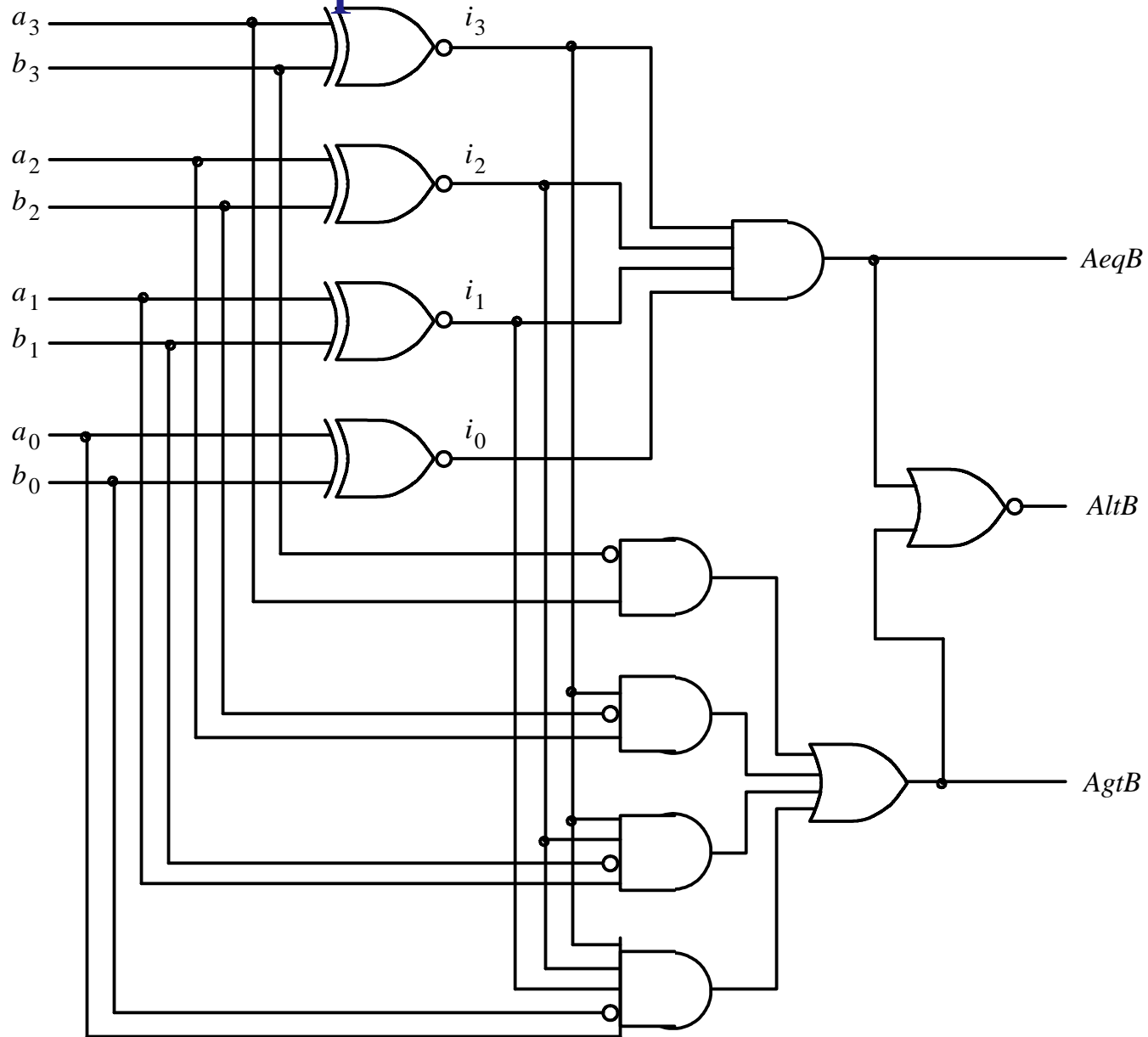


Implementação VHDL

- Implementar de forma mais elegante
- Usando a construção do tipo

```
WITH num SELECT
  leds <=
    "1111110" WHEN "0000",
    "0110000" WHEN "0001" ,
    .....
```

Comparador de 4 bits



Comparador de 4 bits – VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
USE ieee.std_logic_unsigned.all ;

ENTITY compare IS
    PORT (A, B: IN      STD_LOGIC_VECTOR(3 DOWNTO 0) ;
          AeqB, AgtB, AltB : OUT      STD_LOGIC ) ;
END compare ;

ARCHITECTURE Behavior OF compare IS
BEGIN
    AeqB <= '1' WHEN A = B ELSE '0' ;
    AgtB <= '1' WHEN A > B ELSE '0' ;
    AltB <= '1' WHEN A < B ELSE '0' ;
END Behavior ;
```



Comparador de 4 bits (signed) – VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
USE ieee.std_logic_arith.all ;

ENTITY compare IS
    PORT (A, B: IN     SIGNED(3 DOWNT0 0) ;
          AeqB, AgtB, AltB : OUT     STD_LOGIC ) ;
END compare ;

ARCHITECTURE Behavior OF compare IS
BEGIN
    AeqB <= '1' WHEN A = B ELSE '0' ;
    AgtB <= '1' WHEN A > B ELSE '0' ;
    AltB <= '1' WHEN A < B ELSE '0' ;
END Behavior ;
```

Números com sinal

- PORT (A, B: IN **SIGNED**(3 DOWNT0 0)
- Necessita da biblioteca
 - **USE ieee.std_logic_arith.all**
- Qual é o efeito nos valores de **AeqB**, **AgtB**, **AltB**?

Codificador de prioridade – VHDL

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY priority IS
    PORT (w : IN  STD_LOGIC_VECTOR(3 DOWNTO 0) ;
          y : OUT   STD_LOGIC_VECTOR(1 DOWNTO 0) ;
          z : OUT   STD_LOGIC ) ;
END priority ;

ARCHITECTURE Behavior OF priority IS
BEGIN
    y <= "11" WHEN w(3) = '1' ELSE
        "10" WHEN w(2) = '1' ELSE
        "01" WHEN w(1) = '1' ELSE
        "00" ;
    z <= '0' WHEN w = "0000" ELSE '1' ;
END Behavior ;
```



Codificador de prioridade – ineficiente (1)

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY priority IS
    PORT ( w: IN      STD_LOGIC_VECTOR(3 DOWNTO 0) ;
          y: OUT     STD_LOGIC_VECTOR(1 DOWNTO 0) ;
          z: OUT     STD_LOGIC ) ;
END priority ;
```



Codificador de prioridade – ineficiente (2)

```
ARCHITECTURE Behavior OF priority IS
BEGIN
    WITH w SELECT
        y <= "00" WHEN "0001",
            "01" WHEN "0010",
            "01" WHEN "0011",
            "10" WHEN "0100",
            "10" WHEN "0101",
            "10" WHEN "0110",
            "10" WHEN "0111",
            "11" WHEN OTHERS ;
    WITH w SELECT
        z <= '0' WHEN "0000",
            '1' WHEN OTHERS ;
END Behavior ;
```




MUX 16:1 com GENERATE (1)

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
USE work.mux4to1_package.all ;

ENTITY mux16to1 IS
    PORT ( w      : IN  STD_LOGIC_VECTOR(0 TO 15) ;
          s      : IN  STD_LOGIC_VECTOR(3 DOWNT0 0) ;
          f      : OUT  STD_LOGIC ) ;
END mux16to1 ;
```



MUX 16:1 com GENERATE (2)

ARCHITECTURE Structure OF mux16to1 IS

```
SIGNAL m : STD_LOGIC_VECTOR(0 TO 3) ;
```

```
BEGIN
```

```
  G1: FOR i IN 0 TO 3 GENERATE
```

```
    Muxes: mux4to1 PORT MAP (
```

```
      w(4*i), w(4*i+1), w(4*i+2),
```

```
      w(4*i+3), s(1 DOWNTO 0), m(i) ) ;
```

```
  END GENERATE ;
```

```
  Mux5: mux4to1 PORT MAP
```

```
    ( m(0), m(1), m(2), m(3), s(3 DOWNTO 2), f ) ;
```

```
END Structure ;
```



Decodificador 4:16 – projeto hierárquico (1)

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY dec4to16 IS
    PORT ( w : IN      STD_LOGIC_VECTOR(3 DOWNT0 0) ;
          En : IN      STD_LOGIC ;
          y : OUT     STD_LOGIC_VECTOR(0 TO 15) ) ;
END dec4to16 ;

ARCHITECTURE Structure OF dec4to16 IS
    COMPONENT dec2to4
        PORT ( w : IN      STD_LOGIC_VECTOR(1 DOWNT0 0)
              En : IN      STD_LOGIC ;
              y : OUT     STD_LOGIC_VECTOR(0 TO 3) ) ;
    END COMPONENT ;
```



Decodificador 4:16 – projeto hierárquico (2)

```
SIGNAL m : STD_LOGIC_VECTOR(0 TO 3) ;
BEGIN
  G1: FOR i IN 0 TO 3 GENERATE
    Dec_ri: dec2to4 PORT MAP
      ( w(1 DOWNTO 0), m(i), y(4*i TO 4*i+3) );
  G2: IF i=3 GENERATE
    Dec_left: dec2to4 PORT MAP
      ( w(i DOWNTO i-1), En, m ) ;
  END GENERATE ;
END GENERATE ;
END Structure ;
```

VHDL: comandos sequenciais

- Visto até agora: comandos concorrentes
 - Ordem entre os comandos não importa
 - Analogia com componentes eletrônicos
- Novo conceito: process

```
C <= D and E;  
PROCESS ( A, B )  
  VARIABLE  x: STD_LOGIC  
  BEGIN  
    .....  -- corpo do processo  
  END PROCESS ;  
E <= A or B;
```

Algumas características de processo

- Trecho entre Begin e End é executado sequencialmente (a ordem importa)
- O processo é executado concorrentemente como as demais declarações (3 comandos concorrentes no exemplo)
- O processo é invocado quando muda algum sinal/variável na lista de sensibilidade (A,B)
- VARIABLE: possível somente dentro de processos
 - Atribuição `x := '1'`
 - Escopo somente dentro do processo
 - Para usar valor fora do processo, atribuir para um sinal
- Sinais são escalonados ao longo dos comandos do processo e só atribuídos no final

```
C <= D and E;
```

```
PROCESS ( A, B )
```

```
VARIABLE x: STD_LOGIC
```

```
BEGIN
```

```
.....-- corpo do processo
```

```
END PROCESS ;
```

```
E <= A or B;
```



Processos: uso em circuitos digitais

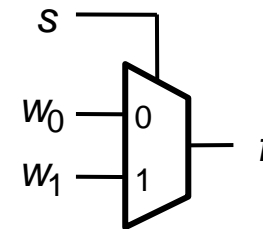
- Principal aplicação
 - Descrição de circuitos sequenciais (a ser visto nas próximas aulas)
 - Implementação de funções complexas
- Mas também é possível implementar circuitos combinacionais

MUX 2:1 com if-then-else

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY mux2to1 IS
    PORT (    w0, w1, s    : IN    STD_LOGIC ;
           f            : OUT    STD_LOGIC ) ;
END mux2to1 ;

ARCHITECTURE Behavior OF mux2to1 IS
BEGIN
    PROCESS ( w0, w1, s )
    BEGIN
        IF s = '0' THEN
            f <= w0 ;
        ELSE
            f <= w1 ;
        END IF ;
    END PROCESS ;
END Behavior ;
```



MUX 2:1 alternativo

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY mux2to1 IS
    PORT ( w0, w1, s : IN STD_LOGIC ;
          f : OUT STD_LOGIC ) ;
END mux2to1 ;

ARCHITECTURE Behavior OF mux2to1 IS
BEGIN
    PROCESS ( w0, w1, s )
    BEGIN
        f <= w0 ;
        IF s = '1' THEN
            f <= w1 ;
        END IF ;
    END PROCESS ;
END Behavior ;
```

MUX 2:1 com CASE

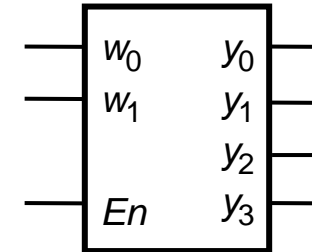
```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY mux2to1 IS
    PORT (w0, w1, s : IN      STD_LOGIC ;
          f       : OUT     STD_LOGIC ) ;
END mux2to1 ;

ARCHITECTURE Behavior OF mux2to1 IS
BEGIN
    PROCESS ( w0, w1, s )
    BEGIN
        CASE s IS
            WHEN '0' =>
                f <= w0 ;
            WHEN OTHERS =>
                f <= w1 ;
        END CASE ;
    END PROCESS ;
END Behavior ;
```



Decodificador 2:4 – com processo (1)



```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
ENTITY dec2to4 IS
    PORT (w  : IN  STD_LOGIC_VECTOR(1 DOWNTO 0) ;
          En : IN  STD_LOGIC ;
          y  : OUT STD_LOGIC_VECTOR(0 TO 3) ) ;
END dec2to4 ;
```

Decodificador 2:4 – com processo (2)

ARCHITECTURE Behavior OF dec2to4 IS

BEGIN

PROCESS (w, En)

BEGIN

IF En = '1' THEN

CASE w IS

WHEN "00" => y <= "1000" ;

WHEN "01" => y <= "0100" ;

WHEN "10" => y <= "0010" ;

WHEN OTHERS => y <= "0001" ;

END CASE ;

ELSE

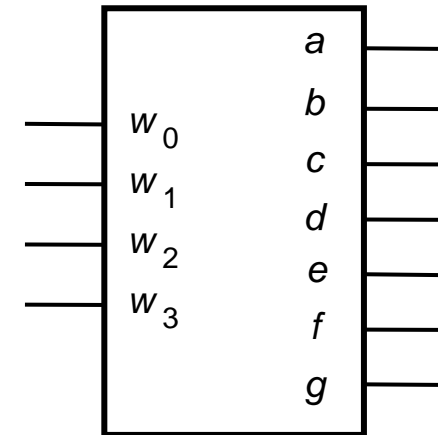
y <= "0000" ;

END IF ;

END PROCESS ;

END Behavior ;

BCD \rightarrow 7 segmentos (1)



```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
ENTITY seg7 IS
    PORT (bcd : IN  STD_LOGIC_VECTOR(3 DOWNTO 0) ;
          leds: OUT STD_LOGIC_VECTOR(1 TO 7) ) ;
END seg7 ;
ARCHITECTURE Behavior OF seg7 IS
```



BCD → 7 segmentos (2)

ARCHITECTURE Behavior OF seg7 IS

BEGIN

PROCESS (bcd)

BEGIN

CASE bcd IS --

abcdefg

```
    WHEN "0000" => leds <= "1111110" ;
    WHEN "0001" => leds <= "0110000" ;
    WHEN "0010" => leds <= "1101101" ;
    WHEN "0011" => leds <= "1111001" ;
    WHEN "0100" => leds <= "0110011" ;
    WHEN "0101" => leds <= "1011011" ;
    WHEN "0110" => leds <= "1011111" ;
    WHEN "0111" => leds <= "1110000" ;
    WHEN "1000" => leds <= "1111111" ;
    WHEN "1001" => leds <= "1110011" ;
    WHEN OTHERS => leds <= "-----" ;
```

END CASE ;

END PROCESS ;

END Behavior ;

Don't care

Codificador prioridade (1)

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;
ENTITY priority IS
    PORT ( w      : IN  STD_LOGIC_VECTOR(3 DOWNTO 0) ;
          y      : OUT  STD_LOGIC_VECTOR(1 DOWNTO 0) ;
          z      : OUT  STD_LOGIC ) ;
END priority ;
```

Codificador prioridade (1)

```
ARCHITECTURE Behavior OF priority IS
BEGIN
    PROCESS ( w )
    BEGIN
        IF w(3) = '1' THEN
            y <= "11" ;
        ELSIF w(2) = '1' THEN
            y <= "10" ;
        ELSIF w(1) = '1' THEN
            y <= "01" ;
        ELSE
            y <= "00" ;
        END IF ;
    END PROCESS ;
    z <= '0' WHEN w = "0000" ELSE '1' ;
END Behavior ;
```




Outro codificador prioridade (1)

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY priority IS
    PORT (
        w      : IN  STD_LOGIC_VECTOR(3 DOWNTO 0) ;
        y      : OUT  STD_LOGIC_VECTOR(1 DOWNTO 0) ;
        z      : OUT  STD_LOGIC ) ;
END priority ;
```

Outro codificador prioridade (1)

```
ARCHITECTURE Behavior OF priority IS
BEGIN
  PROCESS ( w )
  BEGIN
    y <= "00" ;
    IF w(1) = '1' THEN y <= "01" ; END IF ;
    IF w(2) = '1' THEN y <= "10" ; END IF ;
    IF w(3) = '1' THEN y <= "11" ; END IF ;

    z <= '1' ;
    IF w = "0000" THEN z <= '0' ; END IF ;
  END PROCESS ;
END Behavior ;
```



Erros comuns no uso de processo

- Memória implícita
- Atribuição múltipla de um sinal dentro de um processo
- Feedback de sinal: oscilação



Problema: Comparador de 1 bit

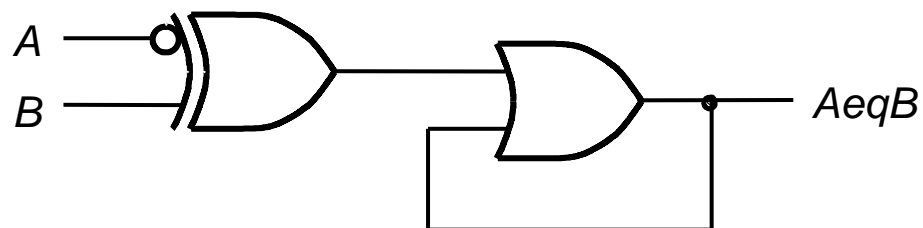
```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY implied IS
    PORT (
        A, B : IN      STD_LOGIC ;
        AeqB : OUT STD_LOGIC ) ;
END implied ;

ARCHITECTURE Behavior OF implied IS
BEGIN
    PROCESS ( A, B )
    BEGIN
        IF A = B THEN
            AeqB <= '1' ;
        END IF ;
    END PROCESS ;
END Behavior ;
```

Problema: memória implícita

```
...  
PROCESS ( A, B )  
BEGIN  
    IF A = B THEN  
        AeqB <= '1' ;  
    END IF ;  
END PROCESS ;  
...
```



Comparador de 1 bit corrigido

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY compare1 IS
    PORT (
        A, B : IN      STD_LOGIC ;
        AeqB : OUT STD_LOGIC ) ;
END compare1 ;

ARCHITECTURE Behavior OF compare1 IS
BEGIN
    PROCESS ( A, B )
    BEGIN
        AeqB <= '0' ;
        IF A = B THEN
            AeqB <= '1' ;
        END IF ;
    END PROCESS ;
END Behavior ;
```

Contador de 1s

```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY numbits IS
    PORT ( X : IN STD_LOGIC_VECTOR(1 TO 3) ;
          Count : BUFFER INTEGER RANGE 0 TO 3 ) ;
END numbits ;
```

Intenção: iniciar sinal Count com 0 e
incrementar a cada '1' encontrado no vetor X

Contador de 1s: 2 problemas

Realimentação → oscilação

```
ARCHITECTURE Behavior OF numbit
BEGIN
  PROCESS ( X ) - conta nº de 1s em X
  BEGIN
    Count <= 0 ; -- o 0 em aspas é decimal
    FOR i IN 1 TO 3 LOOP
      IF X(i) = '1' THEN
        Count <= Count + 1 ;
      END IF ;
    END LOOP ;
  END PROCESS ;
END Behavior ;
```

Dupla atribuição de Count → só a última vai ser atribuída

Contador de 1s: corrigido

```
ARCHITECTURE Behavior OF Numbits IS
BEGIN
    PROCESS ( X ) -- conta n° de 1s em X
        VARIABLE TMP : INTEGER ;
    BEGIN
        Tmp := 0 ;
        FOR i IN 1 TO 3 LOOP
            IF X(i) = '1' THEN
                Tmp := Tmp + 1 ;
            END IF ;
        END LOOP ;
        Count <= Tmp ;
    END PROCESS ;
END Behavior ;
```



Construções de VHDL vistas nesta aula

- Selected Signal Assignment:

```
WITH ct1 SELECT f <= w0 WHEN '0', w1 WHEN OTHERS
```

- Conceito de OTHERS na atribuição
- Atribuição condicional de sinal

```
f <= w0 WHEN ct1 = '0' ELSE w3;
```

- Componentes e packages
- GENERATE
- OTHERS => '1'
- Tipo signed
- Biblioteca std_logic_arith
- Vetores de bits: STD_LOGIC_VECTOR(3 DOWNT0 0)
- Generic



Construções de VHDL vistas nesta aula

- Conceito de processo e comandos sequenciais
- Construções internas ao processo
 - Variáveis
 - **IF .. THEN ELSIF .. THEN ELSE ..**
 - **CASE .. IS WHEN .. => ..**