CPRE 281: HW 02

1) a. & (ampersand)
b. |
c. ^
d. ~

2) • structural Verilog - by specifying the module's internal structure.
  • specifies how components are interconnected.
• behavioral Verilog - by describing its behavior in a program-like manner.
  • specifies how a particular design should respond to a given set of inputs.

The largest difference is how structural uses set components while behavioral uses assign to describe the behavior of the module.

3)
• structural:

```
module problem3(x1, x2, x3, f);
  input x1, x2, x3;
  output f;
  wire k, g, h;
  not(k, x3);
  or(h, x2, k);
  or(g, x1, x2);
  and(f, g, h);
endmodule;
```

- behavioral:

```
module problem3(x1,x2,x3,f);
  input x1,x2,x3;
  output f;
  assign f=(~x3 | x2) & (x1 | x2);
endmodule
```

4)

- structural:

```
module problem4(A,B,C,f);
  input A,B,C,f;
  output f;
  not(l,A);
  not(m,C);
  and(g,l,B,C);
  and(h,l,B,m);
  and(K,A,C);
  or(f,g,h,K);
endmodule
```

- behavioral:

```
module problem3(A,B,C,f);
  input A,B,C;
  output f;
  assign f=(~A&B&C) | (~A&B&~C)
| (A&C);
endmodule
```

5) a) $\bar{A}+A \Rightarrow 1$

b) $\bar{A}B + A\bar{B} \Rightarrow \bar{A}B + A\bar{B}$

c) $\bar{A}\bar{B}\bar{C} + \bar{A}BC + A\bar{B}C + AB\bar{C}$

$\Rightarrow \bar{A}\bar{B}\bar{C} + \bar{A}BC + A\bar{B}C + AB\bar{C}$

d) $\bar{A}\bar{B}C + \bar{A}BC + A\bar{B}\bar{C} + A\bar{B}C + AB\bar{C}$

$\Rightarrow$

1 3 4 5 6

$\bar{A}\bar{B}C + \bar{A}BC + A\bar{B}\bar{C} + A\bar{B}C + AB\bar{C}$

$\Rightarrow \bar{A}C(\bar{B}+B) + A\bar{C}(\bar{B}+B) + A\bar{B}C$

$\Rightarrow \bar{A}C + A\bar{C} + A\bar{B}C$

$\Rightarrow A\bar{C} + C(\bar{A} + A\cdot\bar{B})$ $\quad x + \bar{x}\cdot y = x + y$ $\quad \bar{A}+\bar{B}$

d) $\Rightarrow (A\bar{C}) + (C\bar{A}) + (C\bar{B})$

0 1 2 4 5

e) $\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + \bar{A}B\bar{C}\bar{D} + A\bar{B}\bar{C}\bar{D} + \bar{A}B\bar{C}D$

$+ \bar{A}BC\bar{D} + A\bar{B}\bar{C}\bar{D} + AB\bar{C}\bar{D} + A\bar{B}CD + AB\bar{C}\bar{D} + AB\bar{C}D$

6 8 9 10 12 13

$\Rightarrow \bar{A}\bar{B}\bar{C}(\bar{D}+D) + \bar{B}C\bar{D}(\bar{A}+A) + A\bar{B}\bar{C}(\bar{D}+D)$

$+ \bar{A}BC\bar{D} + A\bar{B}\bar{C}(\bar{D}+D) + AB\bar{C}(\bar{D}+D)$

$\Rightarrow \bar{A}\bar{B}\bar{C} + \bar{B}C\bar{D} + \bar{A}B\bar{C} + A\bar{B}C\bar{D} + A\bar{B}\bar{C} + AB\bar{C}$

$\Rightarrow \bar{A}C(\bar{B}+B) + C\bar{D}(\bar{B}+\bar{A}\cdot B) + A\bar{C}(\bar{B}+B)$

$\Rightarrow \bar{A}C + A\bar{C} + C\bar{D}(\bar{B}+B\cdot\bar{A})$

$\Rightarrow C\bar{D}(\bar{B}+B\cdot\bar{A})$ $\quad B\cdot\bar{B}+A = BA$

$x + \bar{x}\cdot y = x+y$

$\Rightarrow \bar{C}A + \bar{C}\bar{A} + C\bar{D}(\bar{B}+\bar{A})$

$x\cdot y \quad + \quad x\cdot\bar{y}$

$\Rightarrow \bar{C} + C\bar{D}(\bar{B}+\bar{A})$

$\Rightarrow (\bar{C} + C\bar{D})(\bar{B}+\bar{A})$

$x + xy = x+y$

$\Rightarrow \bar{C} + \bar{D}(\bar{B}+\bar{A}) \Rightarrow \bar{C} + \bar{D}\bar{B} + \bar{D}\bar{A}$

6)

A	B	C	D	f
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

$\Rightarrow \bar{A}BCD + A\bar{B}CD + AB\bar{C}D + ABC\bar{D} + ABCD$

$\Rightarrow BCD(\bar{A}+A) + A\bar{B}CD + AB\bar{C}D + ABC\bar{D}$

$\Rightarrow BCD + A\bar{B}CD + AB\bar{C}D + ABC\bar{D}$

$\Rightarrow CD(B+\bar{B}\cdot A) + AB\bar{C}D + ABC\bar{D}$

$\Rightarrow CD(B+A) + AB\bar{C}D + ABC\bar{D}$

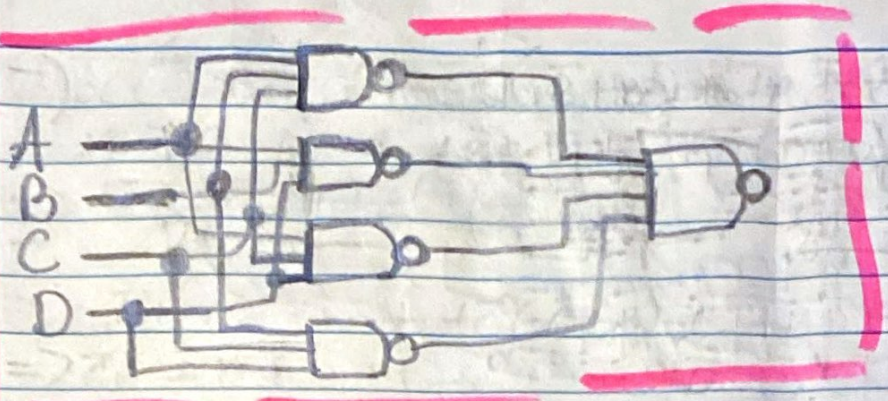
$\Rightarrow BCD + ACD + AB\bar{C}D + ABC\bar{D}$

$\Rightarrow BD(C+\bar{C}\cdot A) + AC(D+\bar{D}\cdot B)$

$\Rightarrow BD(C+A) + AC(D+B)$

$\Rightarrow BCD + ABD + ACD + ABC$

$\Rightarrow ABC + ABD + ACD + BCD$



7)

A	B	C	D	F
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	0
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	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	0

$F(A,B,C,D) = \Sigma m(3,5,6,7,9,10,11,12,13,14)$

$\Rightarrow \bar{A}\bar{B}CD + A\bar{B}CD + \bar{A}B\bar{C}D + \bar{A}BC\bar{D} + AB\bar{C}D + A\bar{B}C\bar{D} + ABCD + \bar{A}BC\bar{D}$

$+ AB\bar{C}\bar{D} + A\bar{B}C\bar{D}$

$\bullet 13,11 + 7,5 + 13,9 + 11,10 + 6,14$

$\Rightarrow AB\bar{C}(\bar{D}+D) + \bar{A}BD(\bar{C}+C) + A\bar{C}D(B+\bar{B}) + AB\bar{C}(\bar{D}+D)$

$+ B\bar{C}D(\bar{A}+A)$

$\Rightarrow AB\bar{C} + \bar{A}BD + A\bar{C}D + AB\bar{C} + B\bar{C}D$

x x + x +

$\Rightarrow A\bar{B}\bar{C} + A\bar{B}C + \bar{A}BD + A\bar{C}D + BC\bar{D}$