

INTRODUCTION TO DIGITAL SYSTEMS

SYSC2310 (Fall 2020)

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Lab 3: Answer Sheet

Exercise 1: Design an Arbitrary Function.

$$P = \overline{A_2} A_1 A_0 + \overline{A_3} \overline{A_2} A_1 + \overline{A_3} A_2 A_0 + A_2 \overline{A_1} A_0$$

$$D = \overline{A_3} A_2 A_0 + A_3 \overline{A_2} \overline{A_1} + A_3 \overline{A_1} \overline{A_0} + \overline{A_3} \overline{A_2} A_1 A_0 + A_3 A_2 A_1 A_0$$

The total number of AND and OR gates is:
3-pin AND: 4-pin AND: 4-pin OR: 5-pin OR:
7 2 1 1

Exercise 2: BCD to 7-Segment Decoder (IC 7447)

$$S_a = \overline{D_2} \overline{D_0} + D_3 + D_1 + D_2 D_0$$

$$S_b = \overline{D_2} + \overline{D_1} \overline{D_0} + D_1 D_0$$

$$S_c = \overline{D_1} + D_0 + D_2$$

$$S_d = \overline{D_2} D_0 + \overline{D_2} D_1 + D_1 \overline{D_0} + D_3 + D_2 \overline{D_1} D_0$$

$$S_e = \overline{D_0} (\overline{D_2} + D_1)$$

$$S_f = \overline{D_1} \overline{D_0} + D_2 \overline{D_0} + D_2 \overline{D_1} + D_3$$

$$S_g = D_2 \overline{D_1} + D_3 + \overline{D_2} D_1 + D_1 \overline{D_0}$$

The total number of AND and OR gates is:

2-pin AND: 3-pin AND: 4-pin OR: 3-pin OR: 5-pin OR: 2-pin OR:
14 1 3 2 1 1

Part 1A

SPSC2221D Lab 3 - Exercise 1 : PART 1A

= 4 inputs, 2 outputs

- let A3, A2, A1, AD be w, x, y, z respectively

A3	A2	A1	AD	P	D
w	x	y	z	0	0
0	0	0	1	0	0
0	0	1	0	1	0
0	0	1	1	1	1
0	1	0	0	0	1
0	1	0	1	1	0
0	1	1	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	0	1	0	1
1	0	1	0	0	0
1	0	1	1	1	0
1	1	0	0	0	0
1	1	1	0	0	1
1	1	1	1	1	1

r { true number is PRIME
false, if not PRIME

D { true if divisible by 3 or 4
false, "

Find P

wx	yz	00	01	11	10
00	-	1	1	-	-
01	-	-	1	1	-
11	-	-	-	1	-
10	-	-	-	-	1

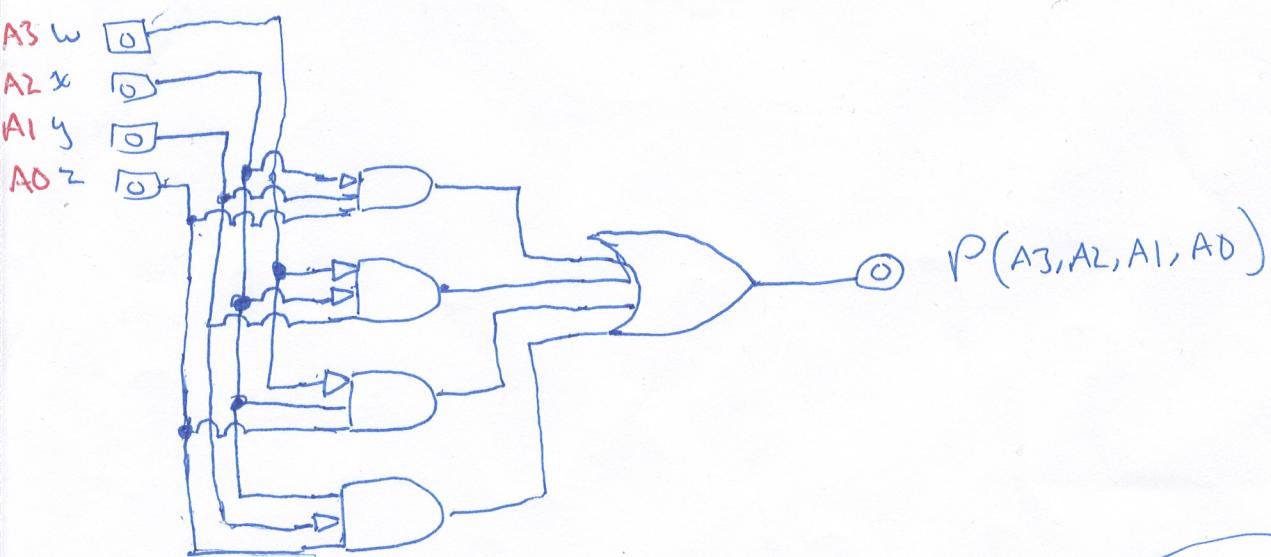
$$P(w, x, y, z) = x'y'z + w'x'y + w'x'z + xy'z$$

Find D

wx	yz	00	01	11	10
00	-	1	1	1	1
01	-	1	1	1	1
11	-	1	1	1	1
10	-	1	1	1	1

$$D(w, x, y, z) = w'x'z + wx'y' + wy'z' + w'x'y'z + wxy'z$$

Find P again

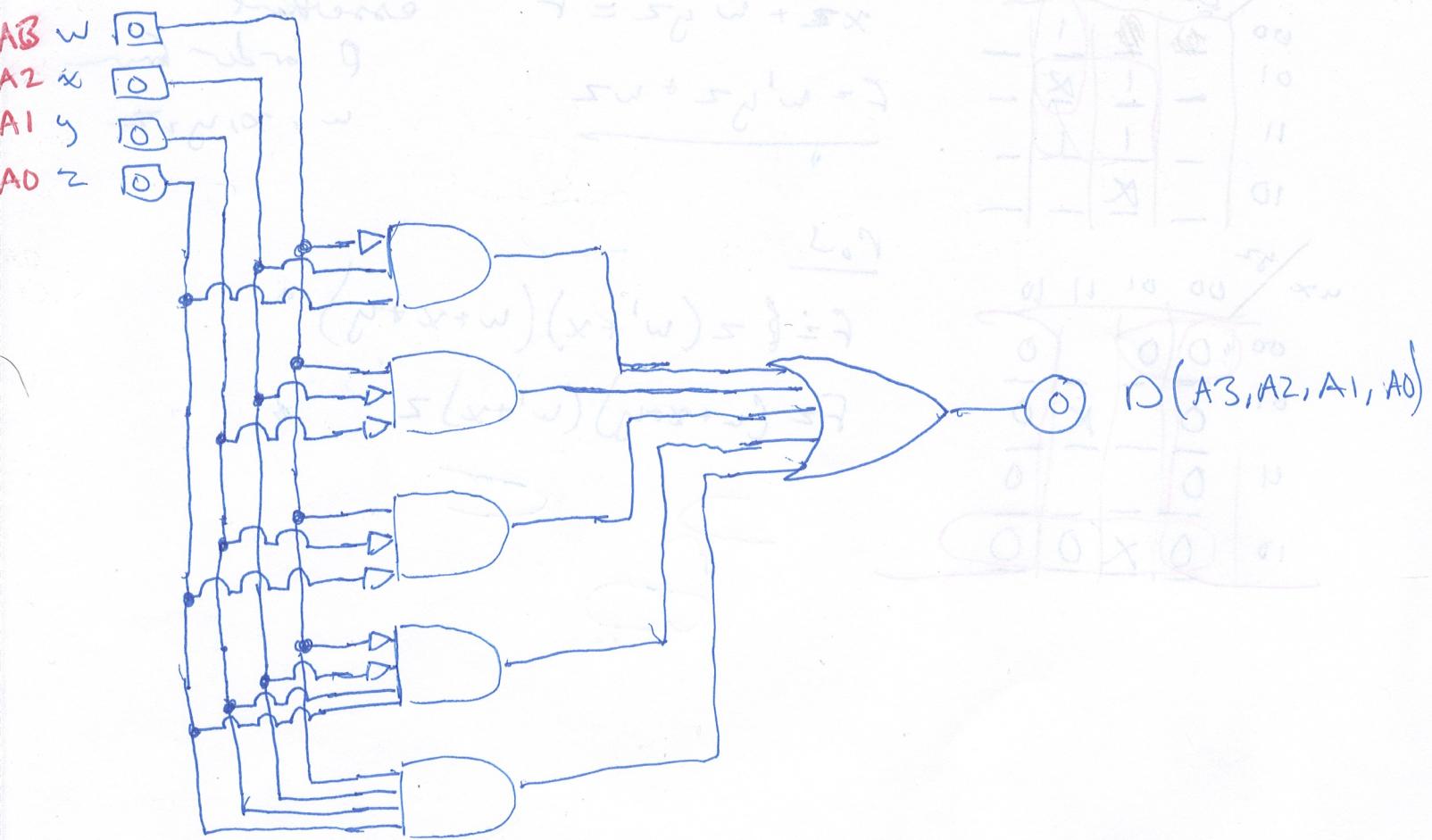


$$P(A3, A2, A1, AD)$$

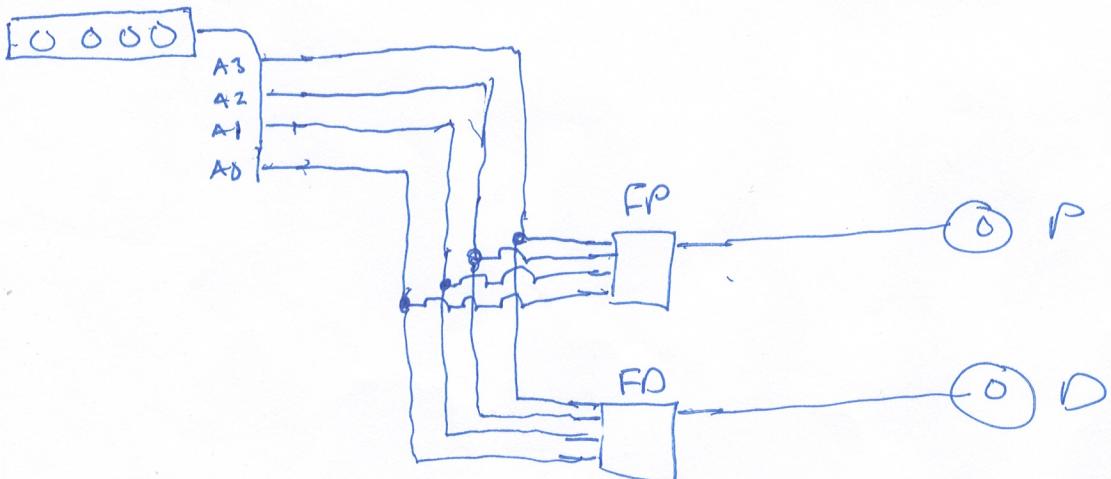
PART 1A

page 1

Function D diagram



Main Program



PART IA page 2

Counting the # of gates

3-input AND: 7

4-input AND: 2

4-input OR: 1

5-input OR: 1

Input		Output	
0	0	0	0
0	0	0	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

white school out
Liberty 40V

$$S' \oplus A + J \oplus A + S' \oplus A + S' \oplus A + (S \oplus A)_{\text{not}}$$

↑ shows 2 like not, instead of subtract
not gate & count goes up into the last not

$$J \oplus S \oplus A =$$

single term

1st term

2nd term

3rd term



last one

PART 1A Page 3

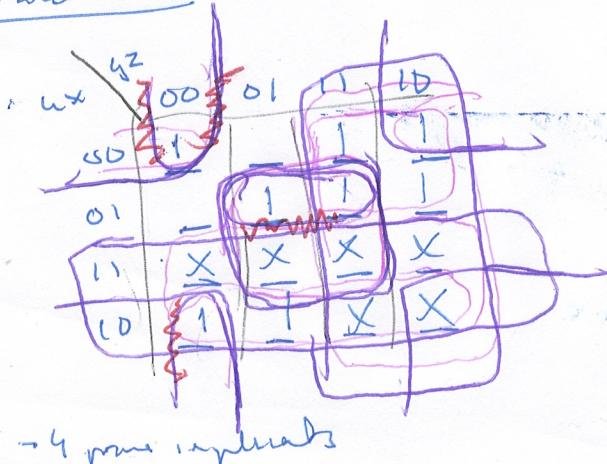
PART 2A

SYSC237D - LAB3 - Exercise 2: PART 2A

- let w, x, y, z be D3, D2, D1, D0

D3	D2	D1	D0	w	x	y	z	S _a	S _b	S _c	S _d	S _e	S _f	S _g
0	0	0	0	1	1	1	1	1	1	1	1	1	1	0
0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
0	0	1	0	1	1	0	1	1	0	1	1	0	1	0
0	0	1	1	1	1	1	1	0	0	0	1	0	0	1
0	1	0	0	0	1	1	0	0	0	1	1	1	1	1
0	1	0	1	1	0	1	1	0	1	1	1	1	1	1
0	1	1	0	1	0	1	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
1	0	0	1	1	1	1	1	0	1	1	1	1	1	1
1	0	1	1	X	X	X	X	X	X	X	X	X	X	X
1	1	0	0	X	X	X	X	X	X	X	X	X	X	X
1	1	0	1	X	X	X	X	X	X	X	X	X	X	X
1	1	1	0	X	X	X	X	X	X	X	X	X	X	X
1	1	1	1	X	X	X	X	X	X	X	X	X	X	X

Find the S_a

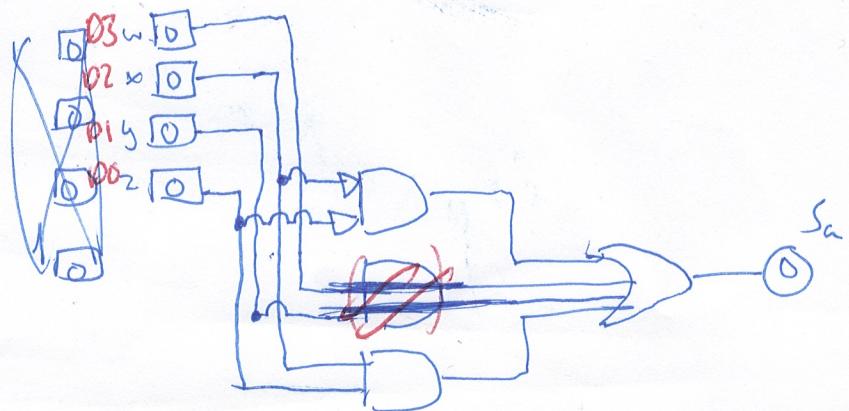


→ 4 prime implicants

Now S_a:

$$S_a(w, x, y, z) = x'z' + w + y + xz$$

$$S_a(D_3, D_2, D_1, D_0) = D_2'D_0D_1 + D_3 + D_1 + D_2D_0$$



Function S_b

wx	yz	00	01	11	10
00	1	1	1	1	1
01	1	0	1	0	1
11	X	X	X	X	X
10	1	1	X	X	X

-> prime implicants

using SOP:

$$S_b(w, x, y, z) = w' + y'z' + yz$$

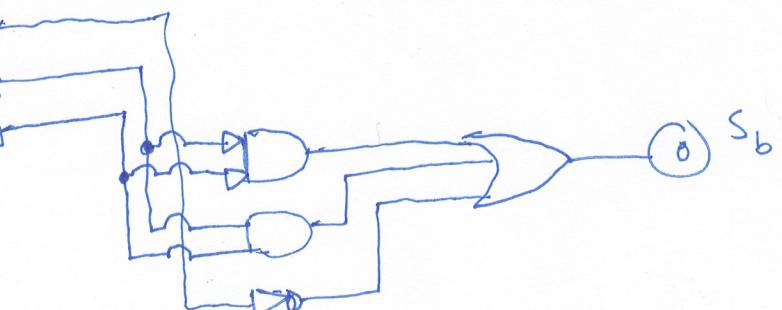
$$S_b(D_3, D_2, D_1, D_0) = D_2' + D_1'D_0' + D_1D_0$$

D₃ w

D₂ x

D₁ y

D₀ z



Function S_c

wx	yz	00	01	11	10
00	1	1	1	1	1
01	1	1	1	1	1
11	X	X	X	X	X
10	1	1	X	X	X

-> prime implicants

using SOP:

$$\Rightarrow S_c(w, x, y, z) = y' + z + x$$

$$S_c(D_3, D_2, D_1, D_0) = D_1' + D_0 + D_2$$

D₃ w

D₂ x

D₁ y

D₀ z



Function S_d

wx	yz	00	01	11	10
00	1	1	1	1	1
01	1	1	1	1	1
11	X	X	X	X	X
10	1	1	X	X	X

-> prime implicants

$$S_d(w, x, y, z) = x'z + x'y + yz' + w + xy'z$$

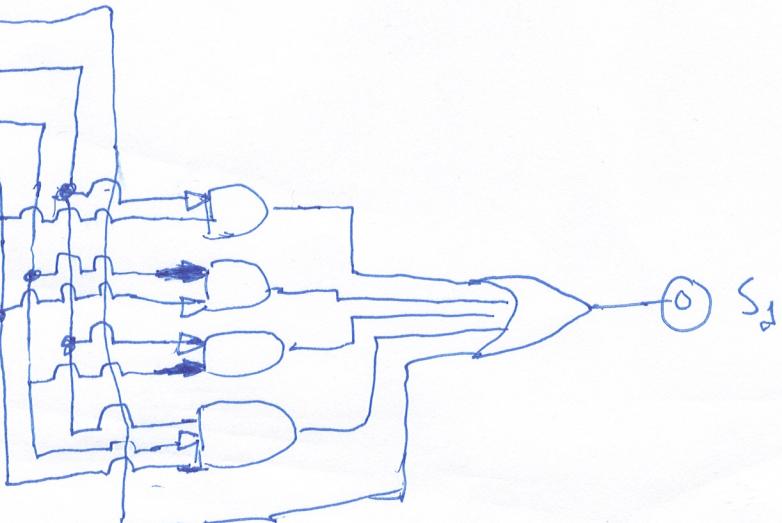
$$S_d(D_3, D_2, D_1, D_0) = D_2'D_0 + D_2'D_1 + D_1D_0' + D_3 + D_2D_1'D_0$$

D₃ w

D₂ x

D₁ y

D₀ z



Function S_e

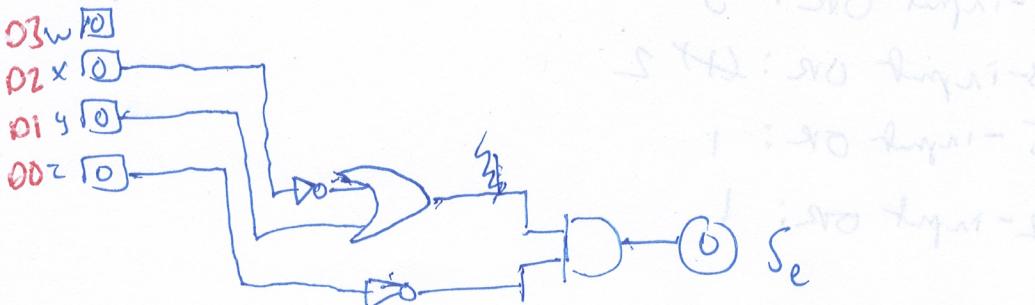
wx	yz	00	01	11	10
00	1	0	0	1	1
01	0	0	0	1	1
11	X	X	X	X	X
10	1	0	X	X	X

- 2 inputs

Using $P_0, S:$

$$S_e(w, x, y, z) = z'(x' + y)$$

$$S_e(D_3, D_2, D_1, D_0) = D_0'(D_2' + D_1)$$



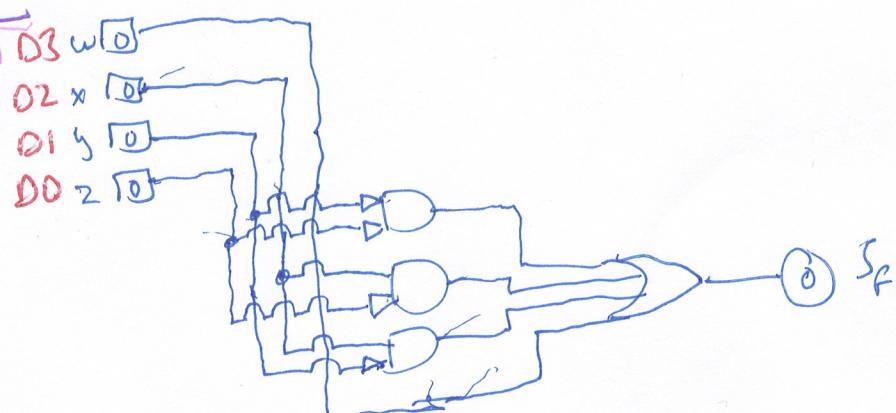
Function S_f

wx	yz	00	01	11	10
00	1	1	1	1	1
01	1	1	1	1	1
11	X	X	X	X	X
10	1	1	X	X	X

- 4 inputs

$$S_f(w, x, y, z) = y'z' + xz' + xy' + w$$

$$S_f(D_3, D_2, D_1, D_0) = D_1'D_0' + D_2D_0' + D_2D_1' + D_3$$



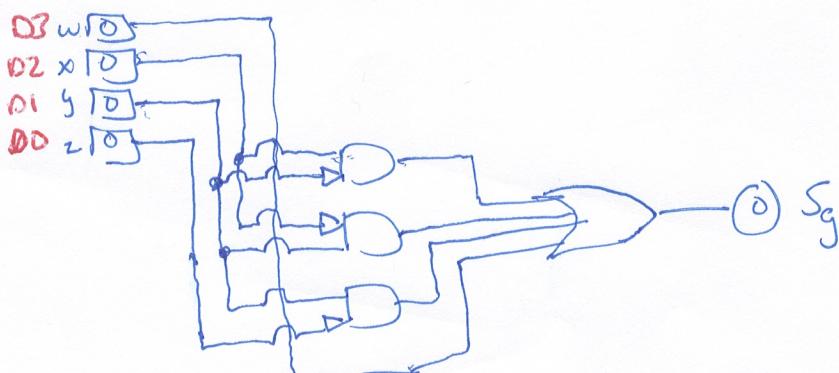
Function S_g

wx	yz	00	01	11	10
00	1	1	1	1	1
01	1	1	1	1	1
11	X	X	X	X	X
10	1	1	X	X	X

- 4 inputs

$$S_g(w, x, y, z) = xy' + w + x'y + yz'$$

$$S_g(D_3, D_2, D_1, D_0) = D_2D_0' + D_3 + D_2'D_1 + D_1D_0'$$



Counting # of gates:

2-input AND: 14

3-input AND: 1

4-input OR: 3

3-input OR: 6+2

5-input OR: 1

2-input OR: 1



2.9 min

3b worked

$$(w+x)'s = (wxyw)_{10}$$

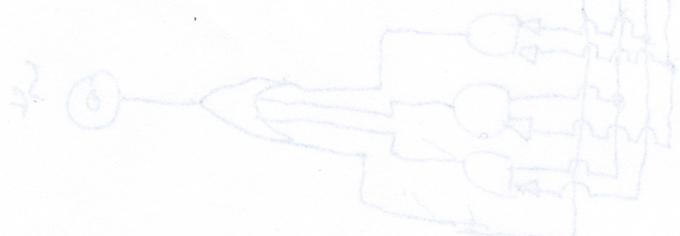
$$(1+w)(1+s) = (ws+w, ws, w)_{10}$$

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

Strategy

$$w + (wx + sx + s'x) = (wxyw)_{10}$$

$$ws + (wsx + wsx + ws + ws') = (ws, wsx, ws, ws')_{10}$$

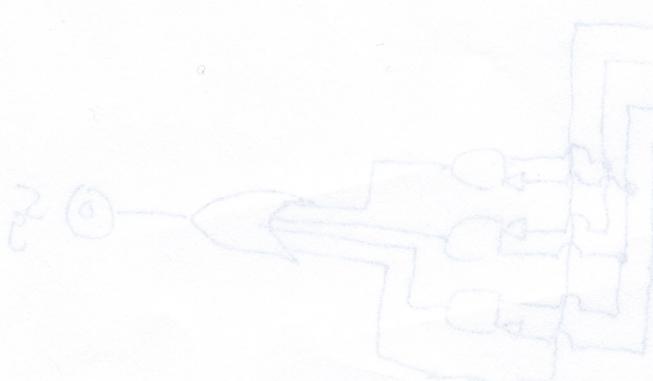


0	0	0	1	00
1	0	0	0	10
x	x	x	1	01
0	x	1	0	11

Strategy

$$w + (wx + s'x + w + x) = (wxyw)_{10}$$

$$ws + (wsx + wsx + ws + ws') = (ws, wsx, ws, ws')_{10}$$



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

Strategy