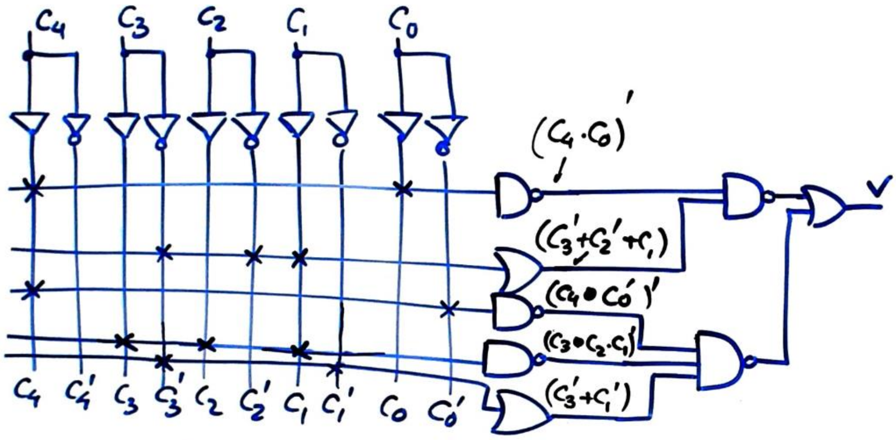
Problem 1



Circuit $\xrightarrow{\text{analysis}}$ Circuit equation $\xrightarrow{\text{simplify using algebra}}$ SoP

$$V = f(C_4, C_3, C_2, C_1, C_0) =$$

(1)

$$\boxed{V = \left((C_4\cdot C_0)'\cdot(C_3'+C_2'+C_1)\right)' + \left((C_4\cdot C_0')'\cdot(C_3\cdot C_2\cdot C_1)'\cdot(C_3'+C_1')\right)'}$$

$$V = (C_4\cdot C_0)'' + (C_3'+C_2'+C_1)' + (C_4\cdot C_0')'' + (C_3C_2C_1)'' + (C_3'+C_1')'$$

$$= C_4\cdot C_0 + C_3\cdot C_2\cdot C_1' + C_4\cdot C_0' + C_3C_2C_1 + C_3\cdot C_1$$

$$= C_4\underbrace{(C_0+C_0')}_{1} + C_3C_2\underbrace{(C_1'+C_1)}_{1} + C_3C_1$$

(2)

$$\boxed{V\Big|_{SoP} = C_4 + C_3C_2 + C_3C_1}$$

(3)

$C_3C_1 \rightarrow x\cdot C_3\cdot x\cdot C_1\cdot x$ (C_4, C_2, C_0)

0 1 0 1 0	$\rightarrow m_{10}$
0 1 0 1 1	$\rightarrow m_{11}$
0 1 1 1 0	$\rightarrow m_{14}$
0 1 1 1 1	$\rightarrow m_{15}$
1 1 0 1 0	$\rightarrow m_{26}$
1 1 0 1 1	$\rightarrow m_{27}$
1 1 1 1 0	$\rightarrow m_{30}$
1 1 1 1 1	$\rightarrow m_{31}$

C_3C_2

$\downarrow$

$x\cdot C_3\cdot C_2\cdot x\cdot x$

$\downarrow$

$m_{12}, m_{13}, m_{14}, m_{15}$
$m_{28}, m_{29}, m_{30}, m_{31}$

$C_4 \longrightarrow C_4(C_3+C_3') = C_4C_3 + C_4C_3' = \ldots\ldots$

$C_4\cdot x\cdot x\cdot x\cdot x \Rightarrow m_{16}, m_{17} \ldots\ldots m_{31}$

$$\boxed{V = \sum m(10, 11, 12, 13, 14, 15, 16, \ldots\ldots 31)}$$

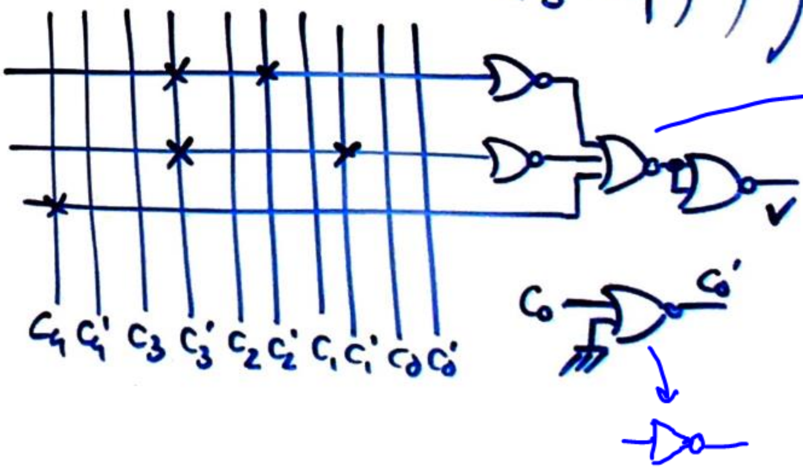
4

$V = C_4 + C_3C_2 + C_3C_1$

$= \left(C_4 + (C_3 \cdot C_2)'' + (C_3C_1)''\right)''$

$= \left(\left(C_4 + (C_3' + C_2')' + (C_3' + C_1')'\right)'\right)'$

1. Using NOR
2. NOR 3-input → with NOR 2-inputs

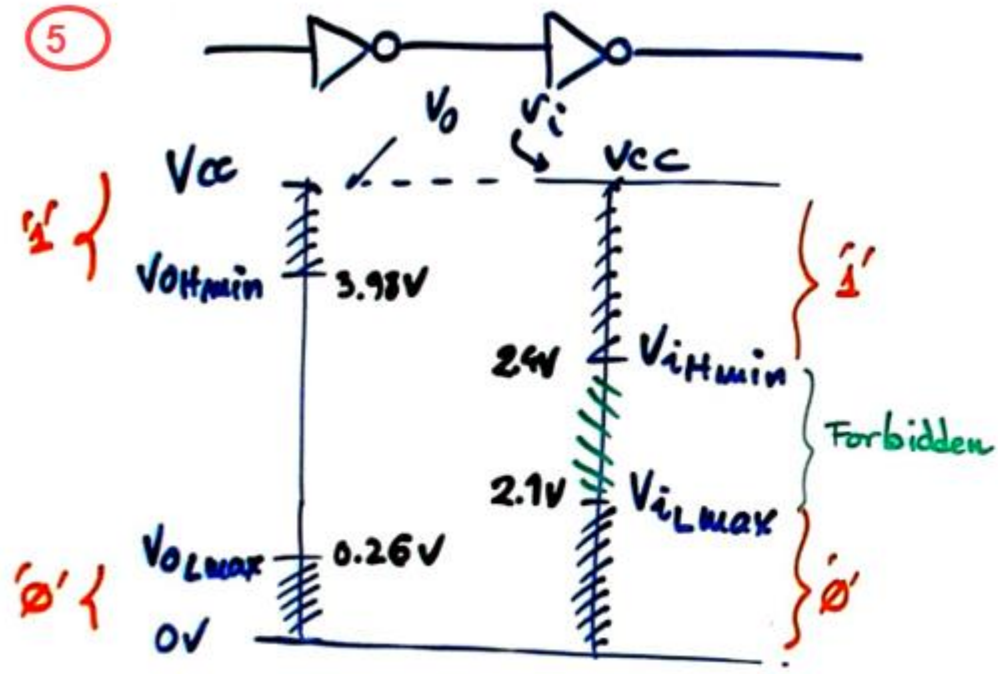


$f = (a+b+c)'$

↓

$f = \left((a+b)'' + c\right)'$

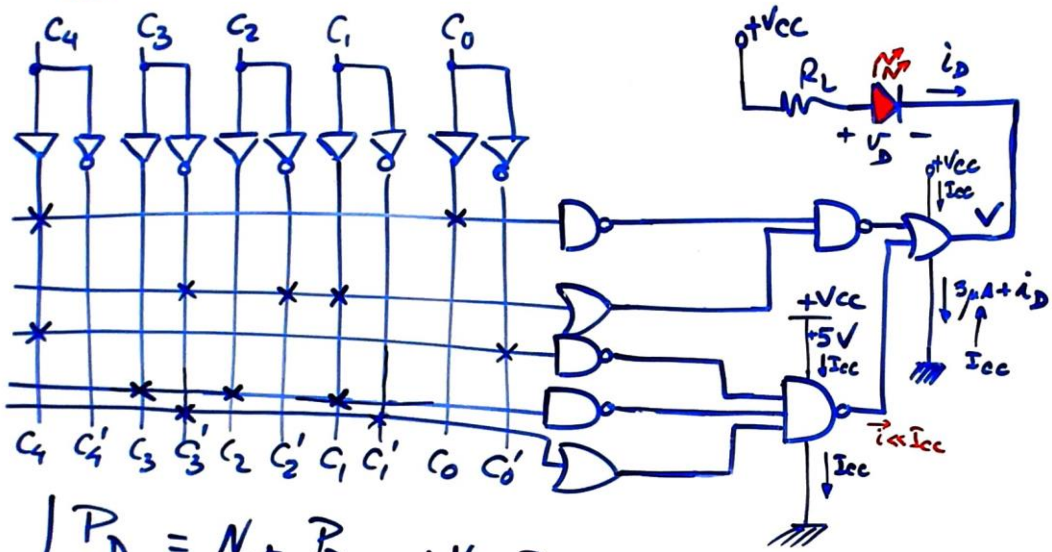
5



$NMH = V_{OHmin} - V_{iHmin} = 1.58\,V$

$NML = V_{iLmax} - V_{OLmax} = 1.84\,V$

⑥

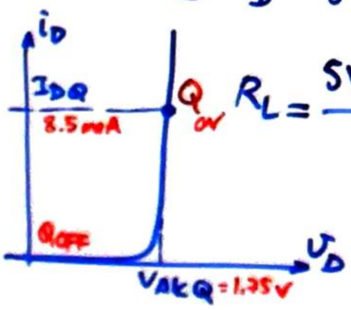


$$\begin{cases} P_{D_{ON}} = N_{gates} P_{D_{gate}} + V_{CC}\, I_{DQ} & \text{when ON} \\ P_{D_{OFF}} = N_{gates} \cdot P_{D_{gate}} & \text{when OFF} \end{cases}$$

$$P_{D\,ON} = 18 \cdot 15\mu W + 5V \cdot 8.5mA = 42.77\, mW$$

$$P_{D\,OFF} = 270\mu W$$

$$V_{CC} = R_L \cdot i_D + v_D + v_o \rightarrow R_L = \frac{V_{CC} - V_{AKQ} - V_{OL\,max}}{I_{DQ}}$$



$$R_L = \frac{5V - 1.75V - 0.26V}{8.5mA} = 352\,\Omega$$

⑦ To complete the truth table simulation:

$2.7ns = t_p$

4 levels of gates

$$t_{p_{circuit}} = 4 \cdot t_{p_{gate}} = 10.8\, ns$$

Thus, if Min_Pulse $= t_{p_{circuit}}$

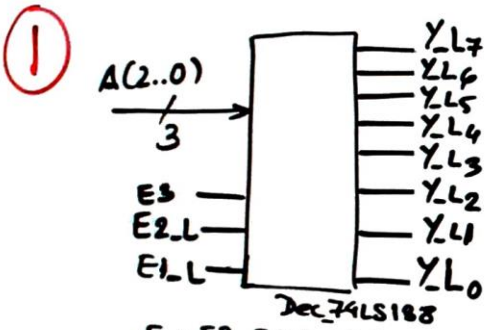
minimum simulation time

$$t_{run} \geq 2^5 \cdot t_{p_{circuit}} = \underline{346\, ns}$$

$$T = \sum m(1, 3, 4, 6, 9, 11, 12, 14)$$

Problem 2

1

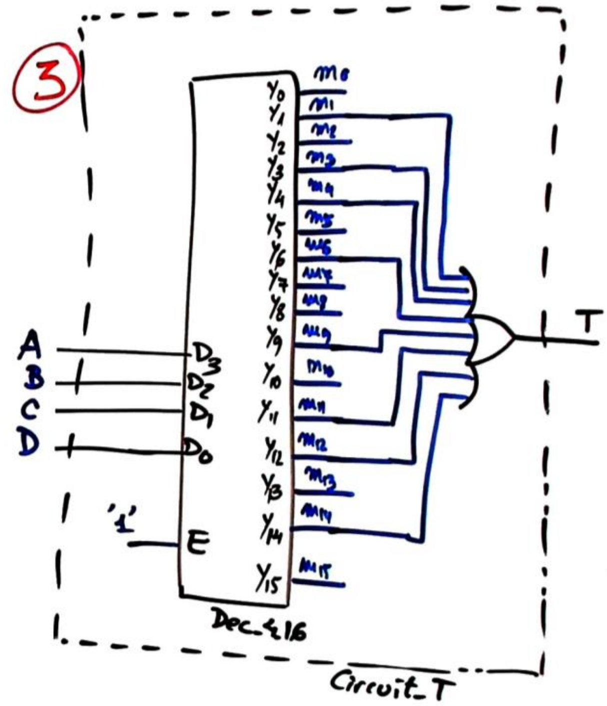


E = E3 · E2_L · E1_L

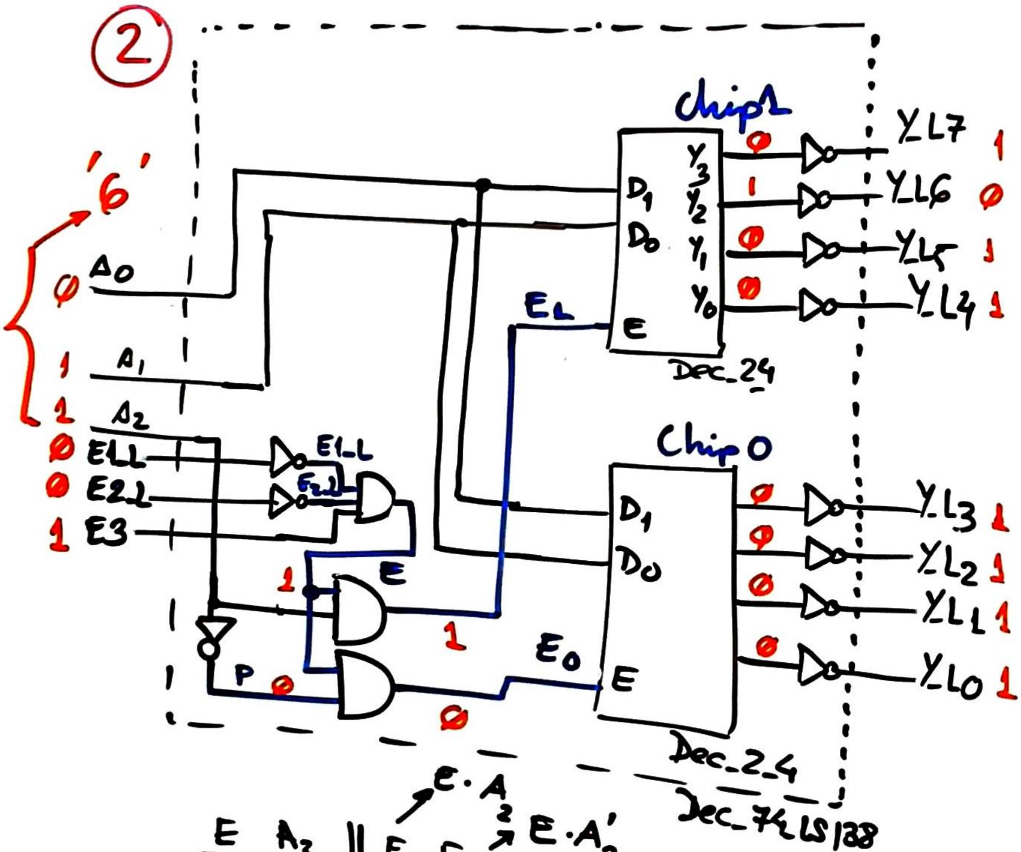
E = 1 when E3 = 1 and E2_L = 0 and E1_L = 0

E	A_2	A_1	A_0	Y_L7	Y_L6	....	Y_L1	Y_L0
0	X	X	X	1	1	...	1	1
1	0	0	0	1	1	...	1	0
1	0	0	1	1	1	...	0	1
⋮								
1	1	1	1	0	1	....	1	1

3



2

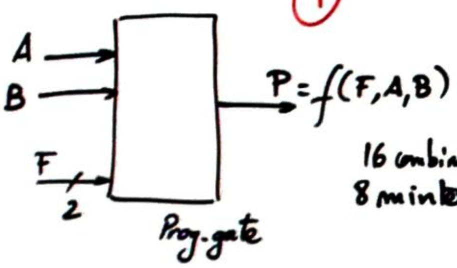


E	A_2	E_1	E_0	
0	X	0	0	→ Disabled
1	0	0	1	→ Chip0
1	1	1	0	→ Chip1

$E_1 = E \cdot A_2$, $E_0 = E \cdot A_2'$

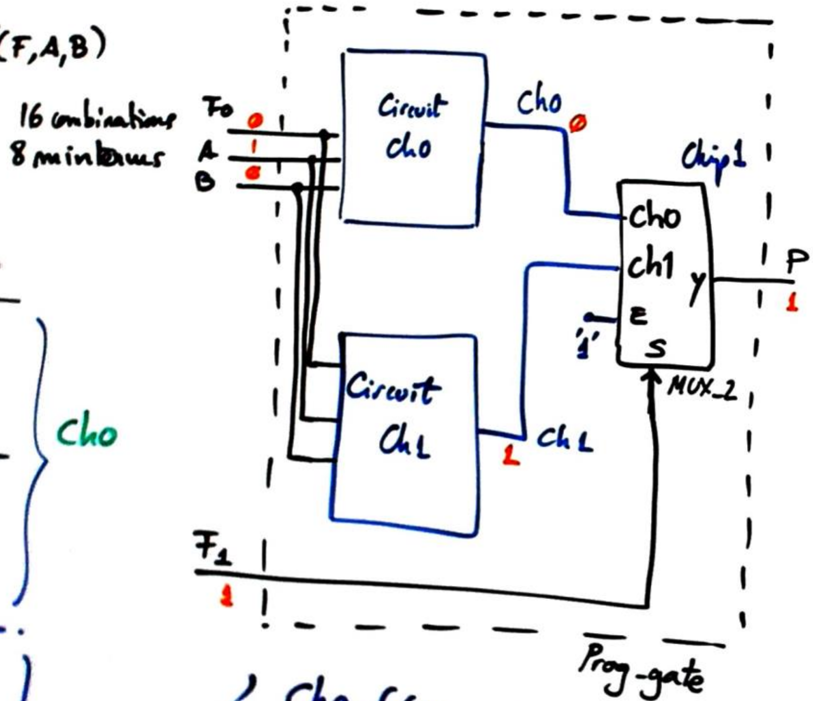
Problem 3

1



	F_1	F_0	A	B	P	
NOR	0	0	0	0	1	Ch0
	0	0	0	1	0	
	0	0	1	0	0	
	0	0	1	1	0	
NAND	0	1	0	0	1	
	0	1	0	1	1	
	0	1	1	0	1	
	0	1	1	1	0	
XOR	1	0	0	0	0	Ch1
	1	0	0	1	1	
	1	0	1	0	1	
	1	0	1	1	0	
NXOR	1	1	0	0	1	
	1	1	0	1	0	
	1	1	1	0	0	
	1	1	1	1	1	

2



$Ch0 = f(F_0, A, B) = \sum m(0,4,5,6)$

$Ch1 = f(F_0, A, B) = \sum m(1,2,4,7)$

gates (Buffer - NOT - AND - OR)

MUX_2.vhd

Prog-gate.vhd

3

Assuming Circuit Ch0 and Circuit Ch1 and MUX_2 of 3 levels of gates

$t_p = 6 \cdot t_{p_{gate}} = 16.2 \text{ ns}$

$f_{max} = 61.7 \text{ MHz}$

If $P = f(F, A, B)$ is solved using 3 levels of gates

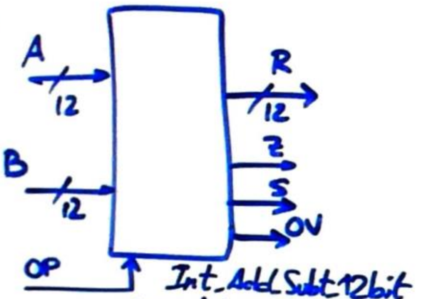
$t_p = 3 \cdot t_{p_{gate}} = 8.1 \text{ ns}$

$f_{max} = 123.5 \text{ MHz}$

(faster than using plan C2)

Problem 4

1



{ OP='0' Add
{ OP='1' Subtract

$2^{25} \equiv 32$ M combinations

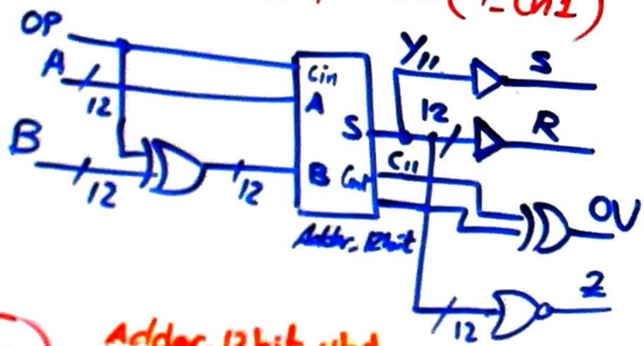
range 12 bit, integer, 2C

$-2^{11} \leq A, B, R \leq +2^{11}-1$

$-2048 \leq A, B, R \leq +2047$

3

→ Architecture plan C2 (P_Ch1)



4

Adder_12bit.vhd
Int_Add_Subt_12bit.vhd
Adder_1bit.vhd

2

OP='0' R=A+B

S='0'
Z='0'
OV='0'

(-2001) + (+2021) = 20

$\boxed{1}$000 0010 1111

$\boxed{0}$111 1110 0101

$\boxed{0}$000 0001 0100

OP='1' R=A-B

(-2001) - (+2021) → OV=1

0

+ $\boxed{1}$000 0010 1111
$\boxed{1}$000 0001 1011

1 $\boxed{0}$000 0100 1010 → positive number? wrong "X"

$OV = C_{out} \oplus C_{11} = 1$

S='0' "X"
Z='0' "X"

OP='1' R=A-B

$\boxed{0}$110 0011 1110

0

+ $\boxed{1}$010 0011 1110
$\boxed{1}$001 1100 0010

$\boxed{0}$1000 0000 0000

1

OV=1

(-1474)
-(+1598)
overflow out of range

OP='0' R=A+B

1

+ $\boxed{1}$010 0011 1110
$\boxed{0}$110 0011 1110

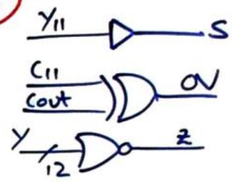
-1474
+(+1598)

1 $\boxed{0}$000 0111 1100 → R

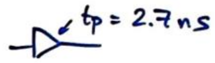
+64+32+16+12 = +124 ✓

S=0
OV=0 Z=0

5



6



If Adder_12bit →
12 * Adder_1bit (ripple carry)
3 levels of gates

$t_p = (1 + 12\times3 + 1)\, t_{p,gate}$

$t_p = 38 \cdot t_{p,gate} = 102.6$ ns

9.75 Moperations/s

7

ModelSim gate-level simulation

Min_Pulse = 102.6 ns

Simulation run time to solve all the truth table

runtime = 2^{25} * Min_Pulse

= 3.44 s