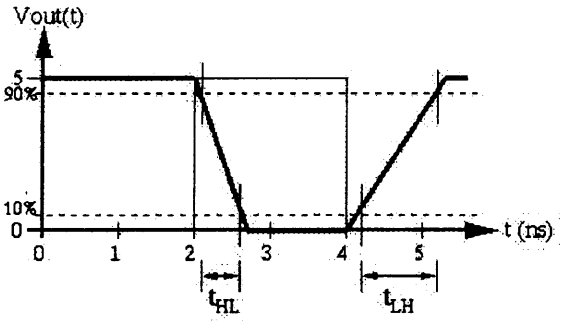
Chapter 4 Digital Hardware

[4.1] P = (5V)(125*m*A) = 625 *m*W.

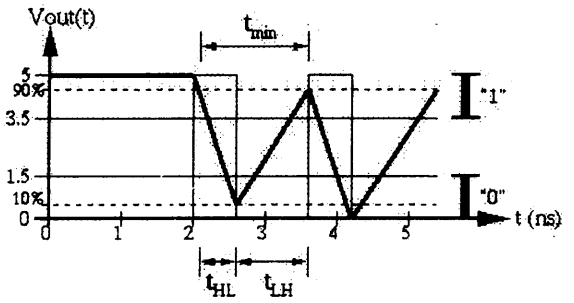
[4.2] I = (10W) / (3V) = 3.33A

[4.3] (a) P = (5V)(210*m*A) = 1.05W
(b) P = (3.1V)(1.4A) = 4.34W
(c) I = (15W) / (2.6V) = 5.77A

[4.4]
(a)

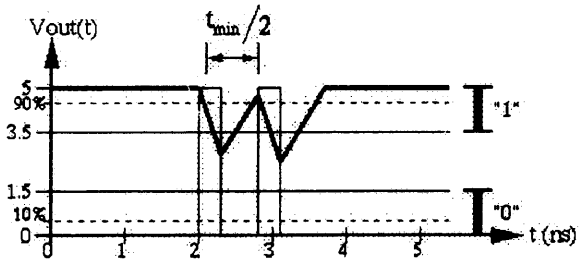


(b) $f_{max} = 1/t_{min} = 1/(t_{HL}+t_{LH}) = 1/(1.5ns)$
= 666.67 *M*Hz



For the discussion purpose in (c), let's assume the following voltage range to represent logic "1" and "0":
3.5v – 5.0v ⇔ "1"
0.0v – 1.5v ⇔ "0"
As shown by the sketch above, $V_{out}(t)$ does return the correct logic values with certain delay.

(c) The sketch below shows $V_{out}(t)$ when the input is driven at twice f_{max}.



The reason that this inverter will not operate properly at this high frequency because there is not enough time for V_{out} to settle down in the right logic value as clearly shown by the sketch.

[4.5] $t_{p,total} = 3\times(t_{p0,NOT} + t_{pL,NOT})$
$= 3\times(0.5 + 0.5) = 3$ *n*s.

[4.6] $t_{p,total} = 3\times(t_{p0,NOT} + 2t_{pL,NOT})$
$+ (t_{p0,NOT} + t_{pL,NOT})$
$= 3\times(0.5 + 0.8) + (0.5 + 0.4) = 4.8$ *n*s.

[4.7] $t_{p,total} = (t_{p0,NOR} + t_{pL,NOT})$
$+ (t_{p0,NOT} + t_{pL,NOT})$
$= (0.75 + 0.5) + (0.5 + 0.5) = 2.25$ *n*s.

[4.8] $t_{p,total} = 5\times(t_{p0,NOT} + t_{pL,NOT}) + (t_{p0,NOT} + t_L)$
$= 5\times(1.0 + 0.25) + (1.0 + t_L) = 7.25$ *n*s.
If the load at the output is an inverter,
$t_L = 0.25$ ns. and thus $t_{p,total} = 7.5$ *n*s.

[4.9] V = IR = (25*m*A)(500Ω) = 12.5V.

[4.10] I = V/R = 0.86V / 1500Ω = 0.57 *m*A.

[4.11] $t_{p,total} = (t_{p0,NAND} + t_{pL,NOT} + t_{pL,NOR})$
$+ (t_{p0,NOR} + t_{pL,NOT} + t_{pL,NOR})$
$+ (t_{p0,NOT} + t_{pL,NOT})$
$= (0.85 + 0.4 + 0.9)$
$+ (0.75 + 0.4 + 0.9)$
$+ (0.5 + 0.4) = 5.1$ *n*s.

[4.12] $P = V^2 / R = (0.35V)^2 / (1200\Omega) = 0.1$ *m*W

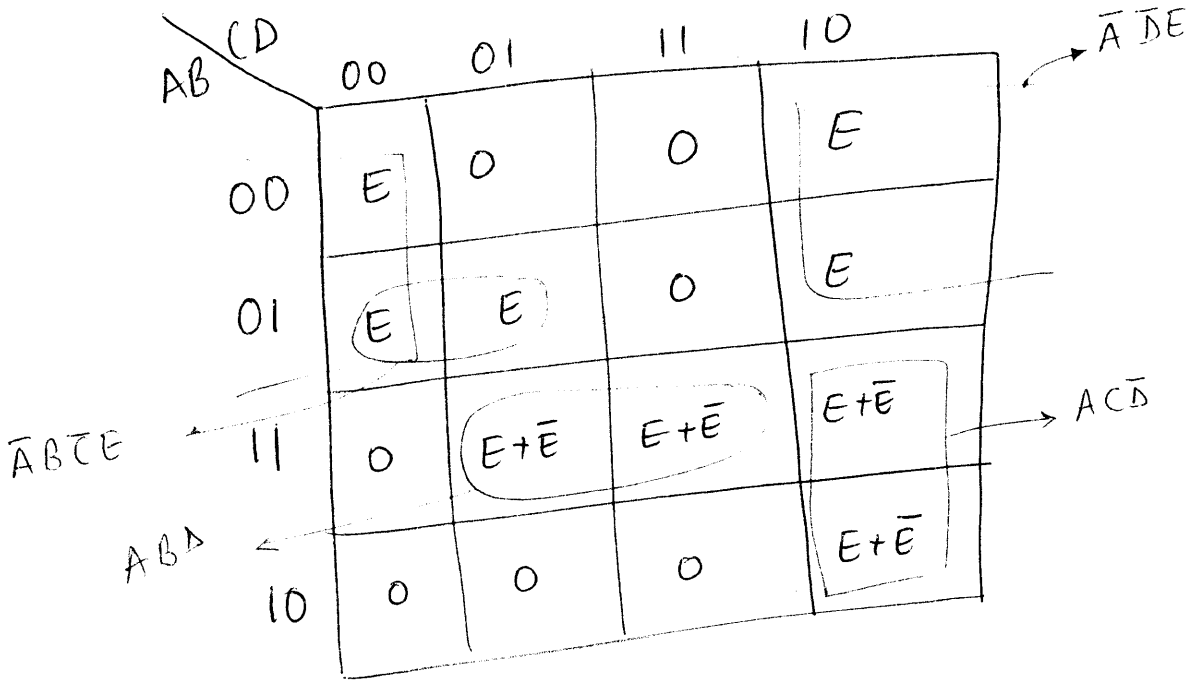
[4.13] (a) $R_{xz} = R_1 + R_2 = 200 + 450 = 650\Omega$
(b) $R_{yw} = R_2 + R_3 = 450 + 80 = 530\Omega$
(c) $R_{xw} = R_1+R_2+R_3 = 200+450+80 = 730\Omega$

[4.14] (a) $I(t=2ns) = V_R(t=2ns) / R$
$= 3.03V / 1200\Omega = 2.53$ *m*A
(b) $I(t=4ns) = V_R(t=4ns) / R$
$= 1.84V / 1200\Omega = 1.53$ *m*A
(c) $I(t=6ns) = V_R(t=6ns) / R$
$= 1.12V / 1200\Omega = 0.93$ *m*A

The plot on the next page shows the exponential decline of current with time.

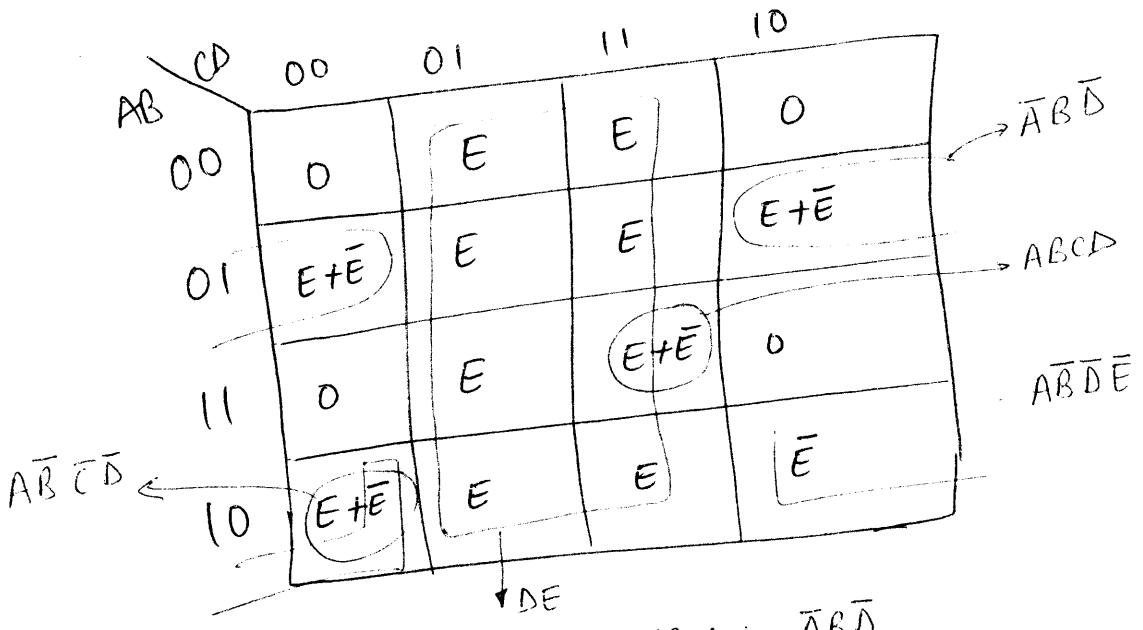
	ABCDE	F1	F1(E)	F2	F2(E)	F3	F3(E)	F4	F4(E)	F5	F5(E)
0	00000	0	E	0	0	0	$\bar{E}$	1	$E+\bar{E}$	X	$\bar{E}X+E$
1	00001	1		0		1		X		X	
2	00010	0	0	0	E	1	$\bar{E}$	1	$\bar{E}X+E$	1	$\bar{E}X+E$
3	00011	0		1		0		X		X	
4	00100	0	E	0	0	1	$\bar{E}$	1	$\bar{E}X+E$	1	$\bar{E}X+E$
5	00101	1		0		0		0	0	0	0
6	00110	0	0	0	E	1	$\bar{E}$	0		0	
7	00111	0		1		0		0	0	0	0
8	01000	0	E	1	$E+\bar{E}$	1	$\bar{E}$	0		0	
9	01001	1		1		0	0	0	$\bar{E}$	0	0
10	01010	0	E	0	E	1		0		0	
11	01011	1		1		0	$\bar{E}$	0	$\bar{E}+EX$	1	$\bar{E}+EX$
12	01100	1	E	1	$E+\bar{E}$	1		X		X	
13	01101	1		1		0	$E+\bar{E}$	0	EX	0	EX
14	01110	0	0	0	E	1		X		X	
15	01111	0		1		1	$\bar{E}$	1	$\bar{E}+EX$	0	EX
16	10000	0	0	1	$E+\bar{E}$	0		X		X	
17	10001	0		1		0	$\bar{E}$	1	$\bar{E}$	1	$\bar{E}$
18	10010	0	0	0	E	1		0		0	
19	10011	0		1		0	$\bar{E}$	0	E	0	0
20	10100	1	$E+\bar{E}$	1	$\bar{E}$	1		1		0	
21	10101	1		0		0	$\bar{E}$	X	X	X	X
22	10110	0	0	0	E	1		X		X	
23	10111	0		1		0	0	0	0	0	EX
24	11000	0	0	0	0	0		0		X	
25	11001	0		0		0	0	1	$\bar{E}$	1	$\bar{E}+E$
26	11010	1	$E+\bar{E}$	0	E	0		0		1	
27	11011	1		1		0	0	0	0	0	0
28	11100	1	$E+\bar{E}$	0	0	0		0		0	
29	11101	1		1		1	$E+\bar{E}$	1	$\bar{E}+EX$	1	$\bar{E}+EX$
30	11110	1	$E+\bar{E}$	1	$E+\bar{E}$	1		X		X	
31	11111	1		1		1					

F1



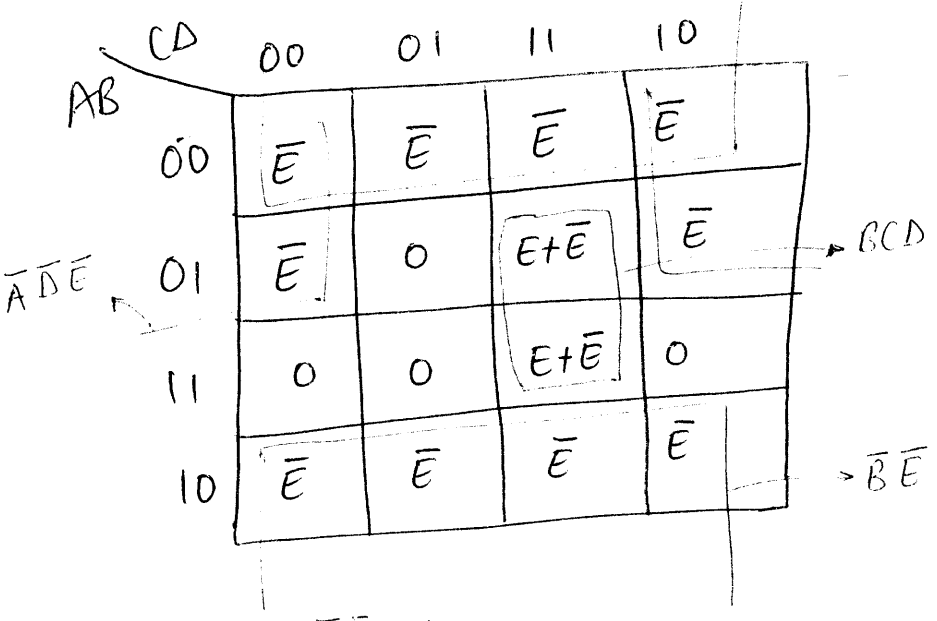
$F1 = AB\bar{D} + \bar{A}B\bar{C}\bar{E} + AC\bar{D} + \bar{A}\bar{D}E$

F2



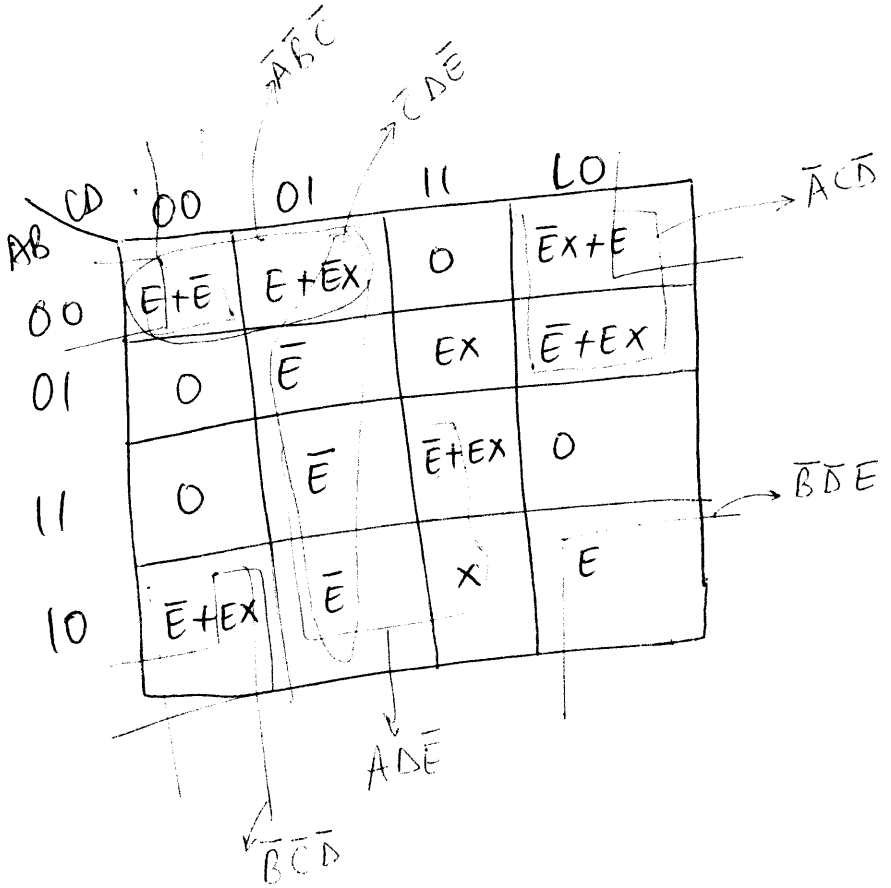
$F2 = A\bar{B}\bar{C}\bar{D} + DE + A\bar{B}\bar{D}\bar{E} + ABC\bar{D} + \bar{A}B\bar{D}$

F3



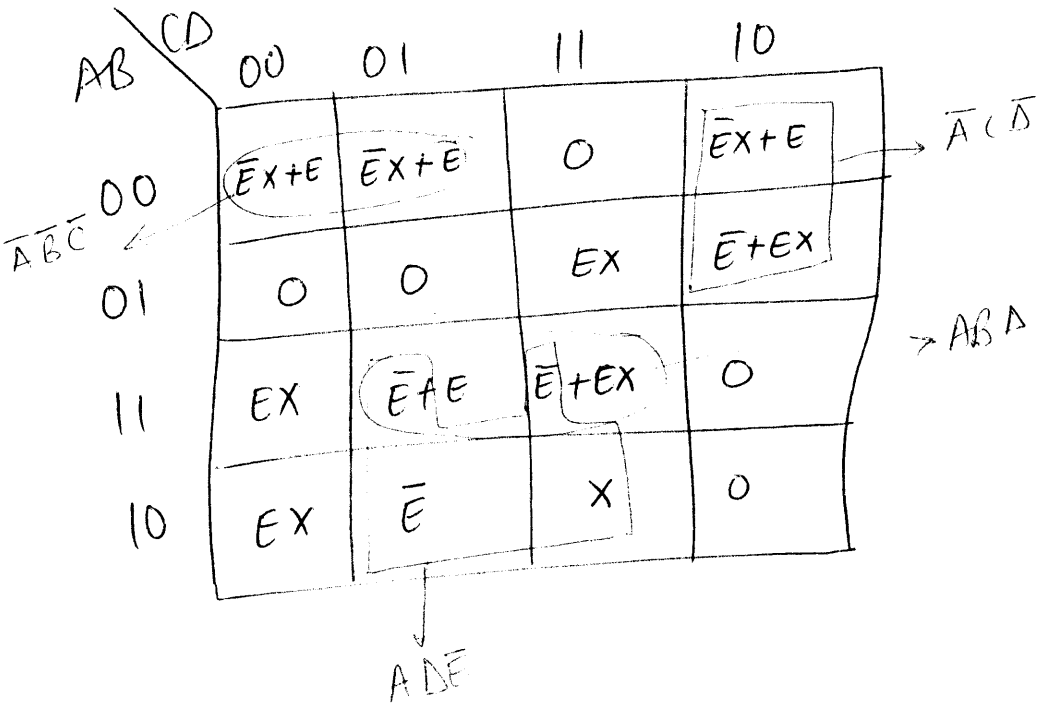
$F3 = \bar{A}\bar{D}\bar{E} + \bar{B}\bar{E} + BCD$

F4



$F4 = \bar{B}\bar{C}\bar{D} + A\bar{D}\bar{E} + \bar{B}\bar{D}E + \bar{A}C\bar{D} + \bar{C}D\bar{E} + \bar{A}\bar{B}\bar{C}$

FS



$$FS = \bar{A}\bar{B}\bar{C} + AD\bar{E} + AB\bar{D} + \bar{A}C\bar{D}$$