

Fig. 1 Pseudo-Potential Energy of Connection States

Order gate input	AND	O R	NOT	NAND	NOR
0	①1-connect ②Inverter connect ③direct connect ④0-connect	①1-connect ②Inverter connect ③direct connect ④0-connect	①0-connect ②direct- connect ③Inverter connect ④1-connect	①0-connect ②direct- connect ③Inverter connect ④1-connect	①0-connect ②direct- connect ③Inverter connect ④1-connect
1	①1-connect ②direct- connect ③Inverter connect ④0-connect	①1-connect ②direct- connect ③Inverter connect ④0-connect	①0-connect ②Inverter connect ③direct connect ④1-connect	①0-connect ②Inverter connect ③direct connect ④1-connect	①0-connect ②Inverter connect ③direct connect ④1-connect

Fig. 2 Modification method of pseudo-potential energy of connection states

Teacher's signal	output Signal	A N D	O R	N O T	N A N D	N O R	Remark
0	0	0	0	0	0	0	
0	1	- 1	- 1	- 1	- 1	- 1	note 1
1	0	1	1	1	1	1	note 2
1	1	0	0	0	0	0	

1= pseudo-potential energy to upper

-1= pseudo-potential energy to lower

0= pseudo-potential energy hold

note 1 :Connection States①and②only

note 2 :Connection States③and④only

Fig. 3 combinational network

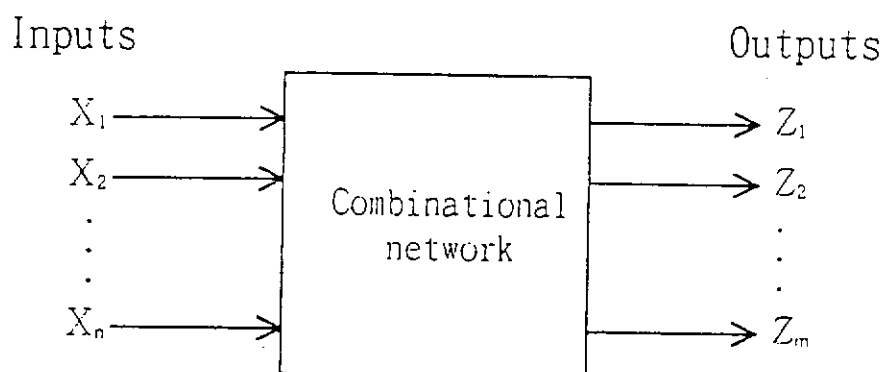


Fig.4 Sequential Circuit

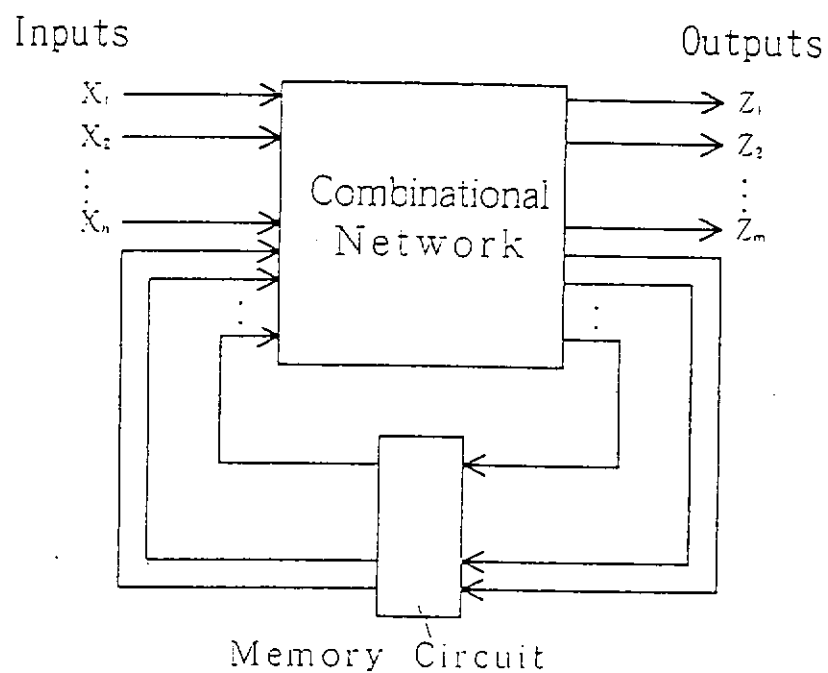


Fig.5 AND - OR network

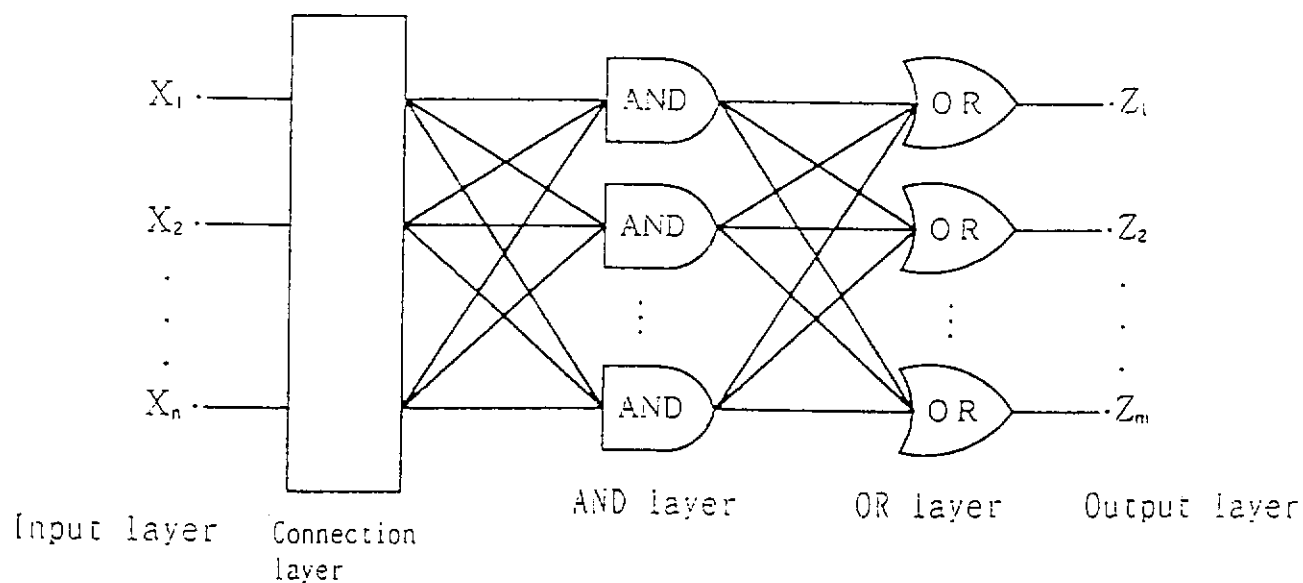


Fig.6 AND - OR network

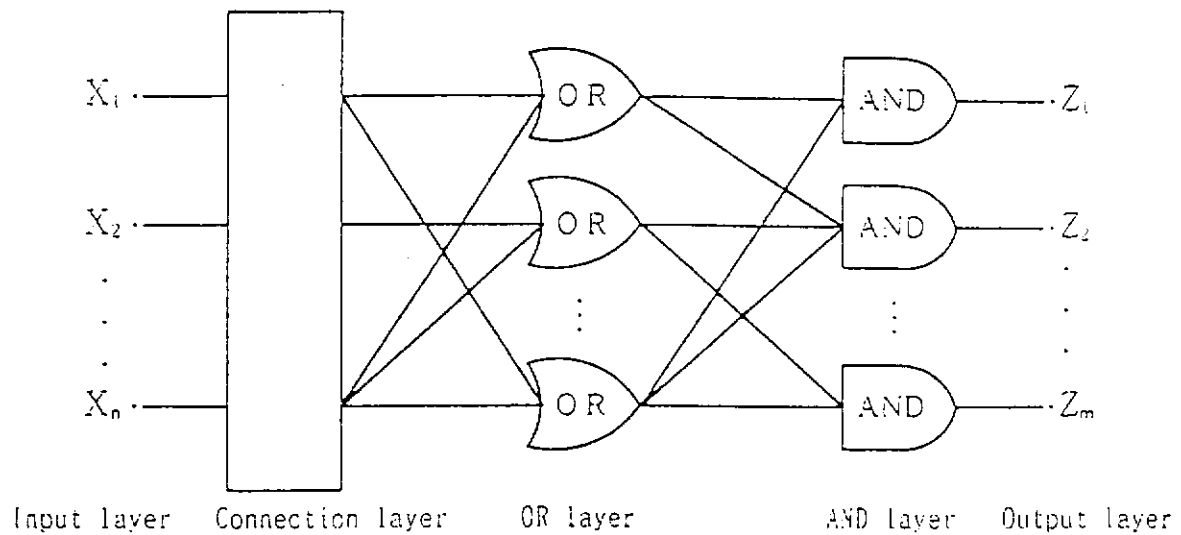


Fig.7 network by layered NANDS

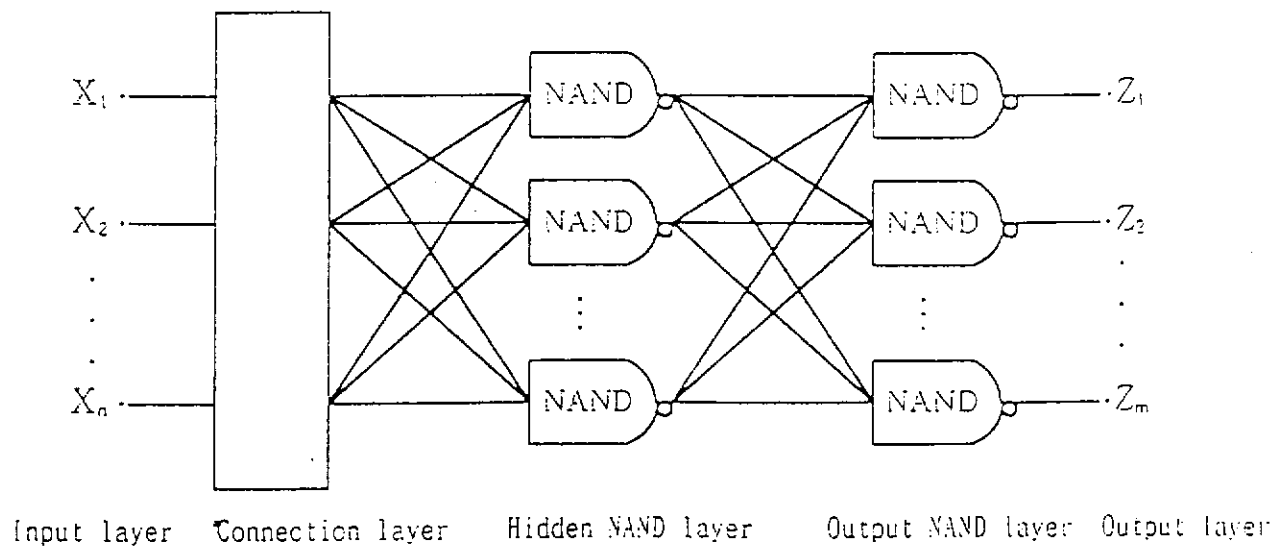
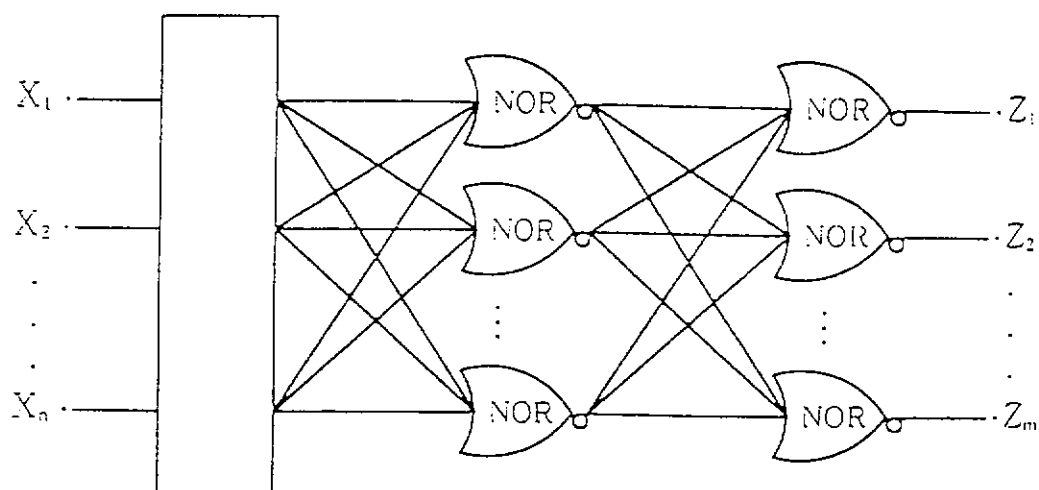
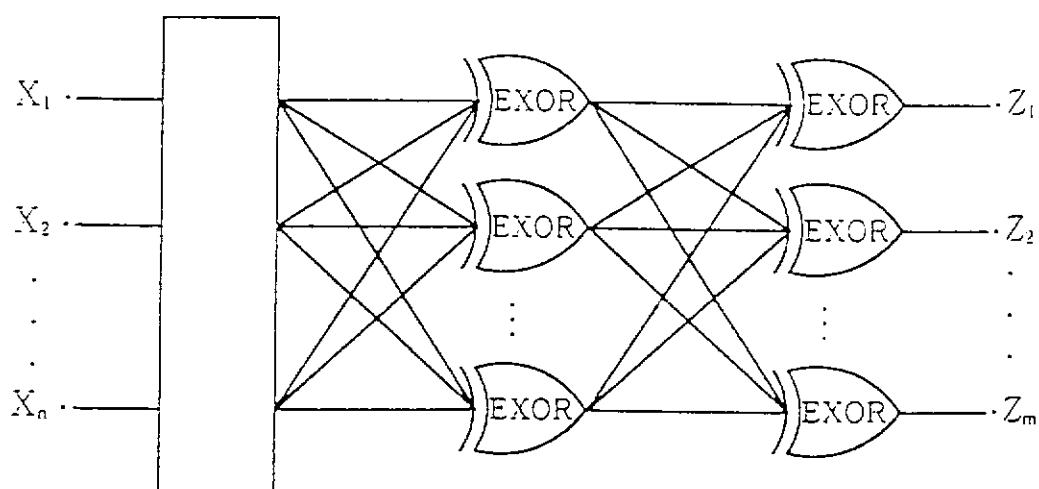


Fig.8 Network by layered NORs



Input layer Connection layer Hidden NOR layer Output NOR layer Output layer

Fig.9 Network by layered EXORs



Input layer Connection layer Hidden EXOR layer Output EXOR layer Output layer

Fig.10 Truth table

X_1	X_2	X_3	X_4	Z
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	
1	1	1	1	

Fig.11 Karnaugh map

$X_1 X_2 \backslash X_3 X_4$	0 0	0 1	1 1	1 0
0 0		1	1	
0 1		1	1	
1 1	1	1		1
1 0		1		

$X_2 \bar{X}_3$ (grouping the 1s in the first two rows)
 $\bar{X}_2 X_3 X_4$ (grouping the 1s in the third and fourth rows)
 $\bar{X}_1 X_2$ (grouping the 1s in the third and fourth rows)
 $\bar{X}_2 X_3 X_4$ (grouping the 1s in the third and fourth rows)

Fig. 12 AND-OR network

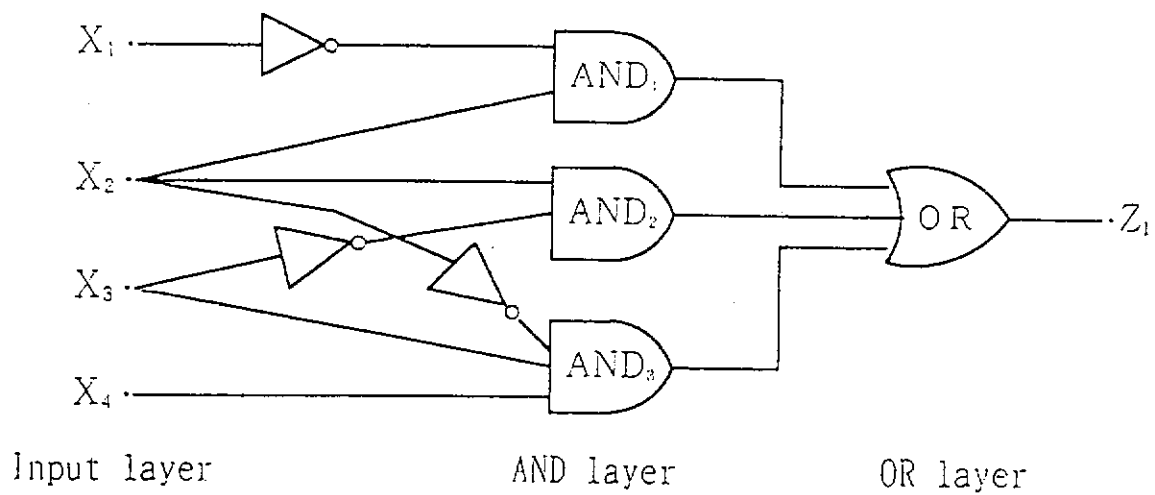


Fig. 13 Threshold function and model of the pseudo-neuron

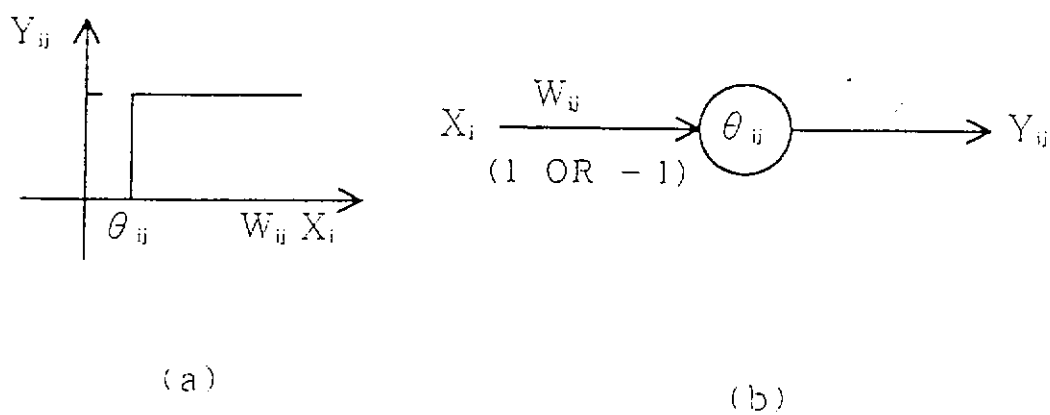


Fig. 14 Connection state expression with pseudo-neuron

weights	Threshold θ_{ij}	Input X_i	Output Y_{ij}	Connection states
1	- 1.5	0	1	1-connect
		1	1	
	- 0.5	0	1	1-connect
		1	1	
	0.5	0	0	direct connect
		1	1	
	1.5	0	0	0-connect
		1	0	
- 1	- 1.5	0	1	1-connect
		1	1	
	- 0.5	0	1	Inverter connect
		1	0	
	0.5	0	0	0-connect
		1	0	
	1.5	0	0	0-connect
		1	0	

Fig. 15 One-output AND-OR network with pseudo-neurons

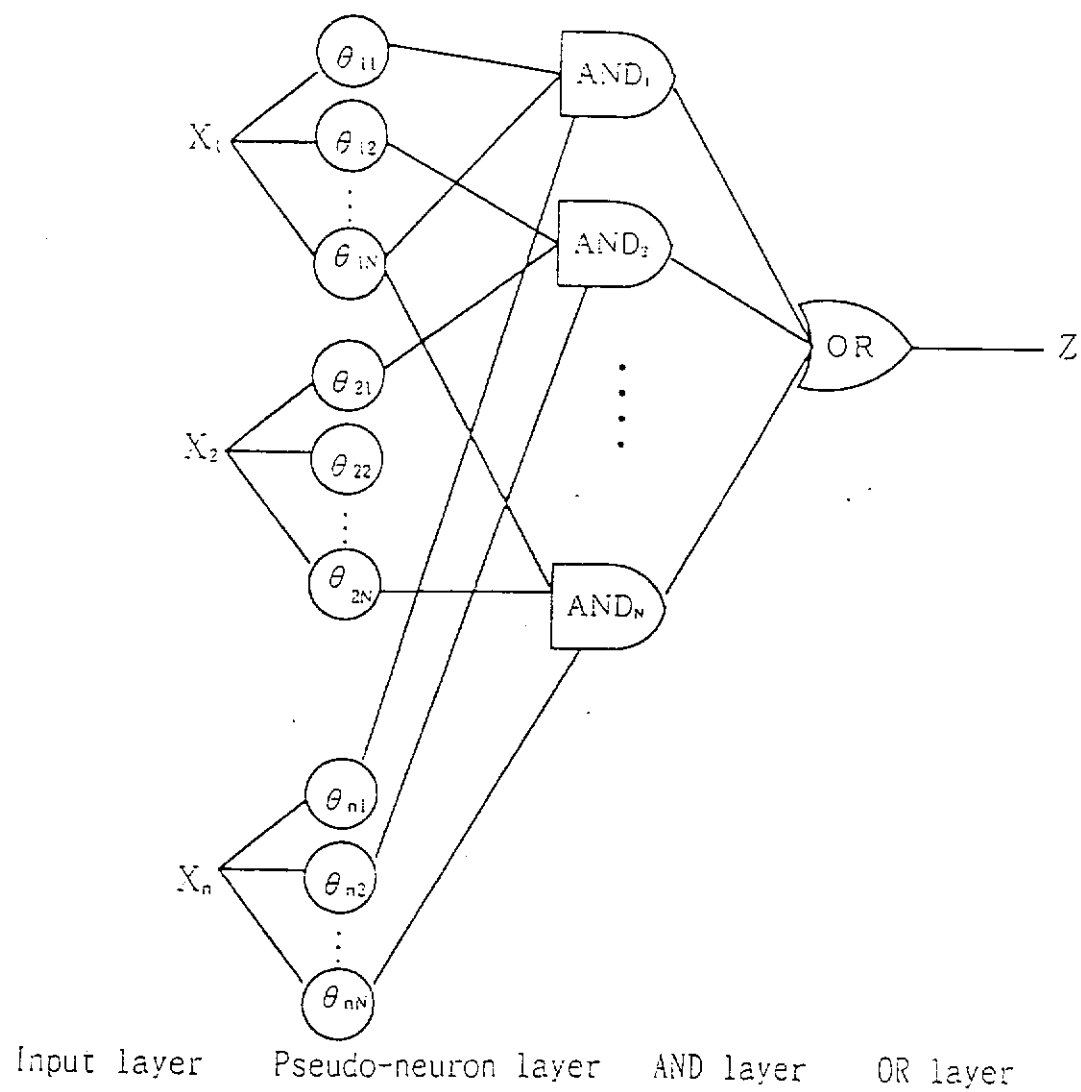


Fig. 16

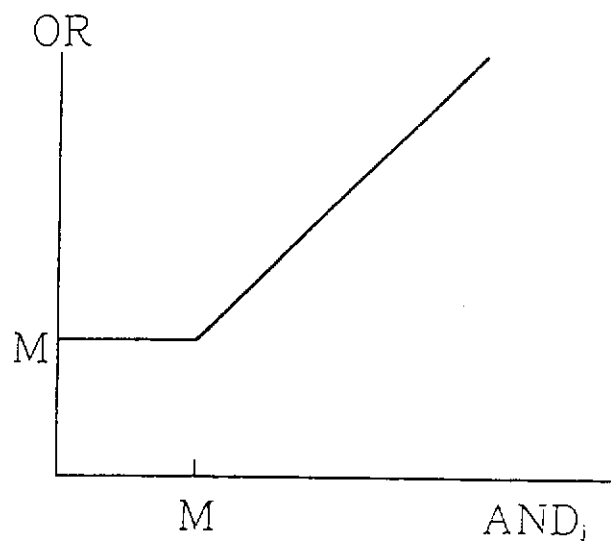


Fig. 17

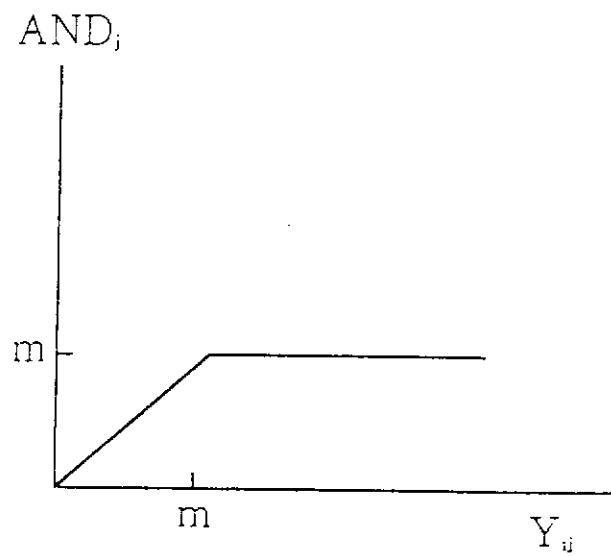


Fig. 18 Truth table of learning signals

Z	T	AND _i	M	m	Y _i	X _i	ΔW_{ij}	$\Delta \theta_{ij}$
0	0	0	0	0	0	0	HP	HP
0	0	1	1	1	1	1	HP	HP
0	1	0	0	0	0	0	HP	0
0	1	0	0	0	0	1	1	0
0	1	0	0	0	1	0	HP	HP
0	1	0	0	0	1	1	HP	HP
0	1	0	0	1	0	0	HP	0
0	1	0	0	1	0	1	1	0
0	1	0	0	1	1	0	impossible	
0	1	0	0	1	1	1		
0	1	0	1	0	0	0	impossible	
0	1	0	1	0	0	1		
0	1	0	1	0	1	0		
0	1	0	1	0	1	1		
0	1	0	1	1	0	0		
0	1	0	1	1	0	1		
0	1	0	1	1	1	0		
0	1	0	1	1	1	1		
0	1	1	0	0	0	0	imposibbble	
0	1	1	0	0	0	1		
0	1	1	0	0	1	0		
0	1	1	0	0	1	1		
0	1	1	0	1	0	0		
0	1	1	0	1	0	1		
0	1	1	0	1	1	0		
0	1	1	0	1	1	1		
0	1	1	1	0	0	0		
0	1	1	1	0	0	1		
0	1	1	1	0	1	0		
0	1	1	1	0	1	1		
0	1	1	1	1	0	0		
0	1	1	1	1	0	1		
0	1	1	1	1	1	0		
0	1	1	1	1	1	1		

Fi.19 Truth table of learning signals

Z	T	AND _{ij}	M	m	Y _{ij}	X _i	ΔW_{ij}	$\Delta \theta_{ij}$
1	0	0	0	0	0	0	impossible	
1	0	0	0	0	0	1		
1	0	0	0	0	1	0		
1	0	0	0	0	1	1		
1	0	0	0	1	0	0		
1	0	0	0	1	0	1		
1	0	0	0	1	1	0		
1	0	0	0	1	1	1		
1	0	0	1	0	0	0	HP	HP
1	0	0	1	0	0	1	HP	HP
1	0	0	1	0	1	0	HP	HP
1	0	0	1	0	1	1	HP	HP
1	0	0	1	1	0	0	HP	HP
1	0	0	1	1	0	1	HP	HP
1	0	0	1	1	1	0	impossible	
1	0	0	1	1	1	1		
1	0	1	0	0	0	0	impossible	
1	0	1	0	0	0	1		
1	0	1	0	0	1	0		
1	0	1	0	0	1	1		
1	0	1	0	1	0	0	impossible	
1	0	1	0	1	0	1		
1	0	1	0	1	1	0	HP	1
1	0	1	0	1	1	1	0	1
1	0	1	1	0	0	0	impossible	
1	0	1	1	0	0	1		
1	0	1	1	0	1	0		
1	0	1	1	0	1	1		
1	0	1	1	1	0	0	impossible	
1	0	1	1	1	0	1		
1	0	1	1	1	1	0	HP	1
1	0	1	1	1	1	1	0	1
1	1	0	0	0	0	0	HP	HP
1	1	0	0	0	0	0	HP	HP

Fig20 Karnaugh map of the threshold update $\Delta \theta_{ij}$

Z T AND M m Y _{ij}	000	001	011	010	110	111	101	100
000	HP	HP	—	0	HP	HP	—	—
001	HP	HP	—	HP	HP	HP	—	—
011	HP	HP	—	—	HP	HP	1	—
010	HP	HP	—	0	HP	HP	—	—
110	HP	HP	—	—	HP	HP	—	HP
111	HP	HP	—	—	HP	HP	1	—
101	HP	HP	—	—	HP	HP	—	HP
100	HP	HP	—	—	HP	HP	—	HP

Fig. 21 State assignment of connection states by pseudo-neuron

weights	Threshold	Input X_i	Output Y_{ij}	connection states	connection assignment	Q_3 Q_2 Q_1
1	-1.5	0	1	1-connect	S_0	0 0 0
		1	1			
1	-0.5	0	1	1-connect	S_1	0 0 1
		1	1			
1	0.5	0	0	direct-connect	S_2	0 1 0
		1	1			
1	1.5	0	0	0-connect	S_3	0 1 1
		1	0			
-1	-1.5	0	1	1-connect	S_4	1 0 0
		1	1			
-1	-0.5	0	1	Inverter Connect	S_5	1 0 1
		1	0			
-1	0.5	0	0	0-connect	S_6	1 1 0
		1	0			
-1	1.5	0	0	o-connect	S_7	1 1 1
		1	0			

Fig. 22 Karnaugh map of pseudo-neuron output Y_{ij} with input X_i and state assignment $Q_3 Q_2 Q_1$

X_i Q_3		Q_2 Q_1		Q_3 Q_2		X_i Q_3 Q_1	
Q_2 Q_1	X_i Q_3	0 0	0 1	1 1	1 0	Q_2 Q_1	Q_3 Q_2
		0 0	0 1	1 1	1 0		
0 0	0 0	1	1	1	1	$\overline{X_i} \overline{Q_2}$	$\overline{X_i} \overline{Q_2}$
0 1	0 1	1	1		1		
1 1	1 1						
1 0	1 0				1		$X_i Q_3 Q_1$

Fig. 23 Circuit implementation of learning algorithm

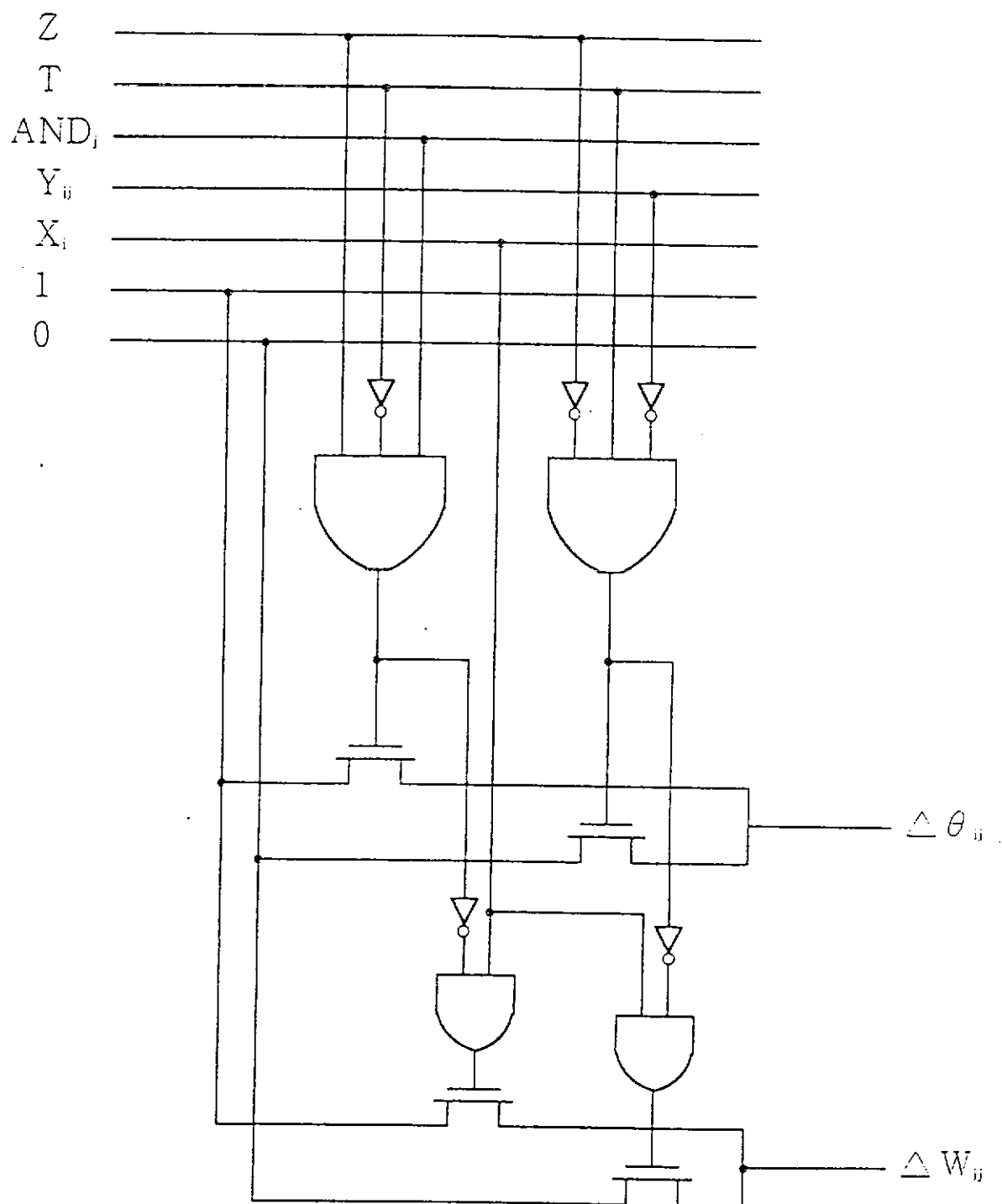
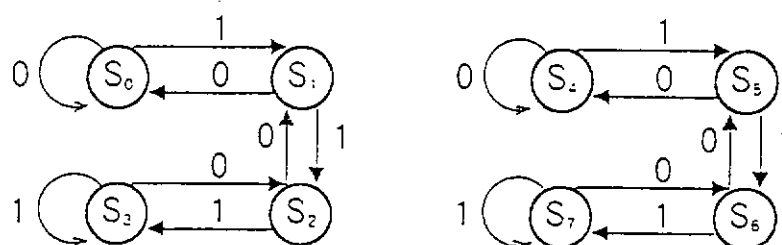


Fig. 24

(a)



(b)

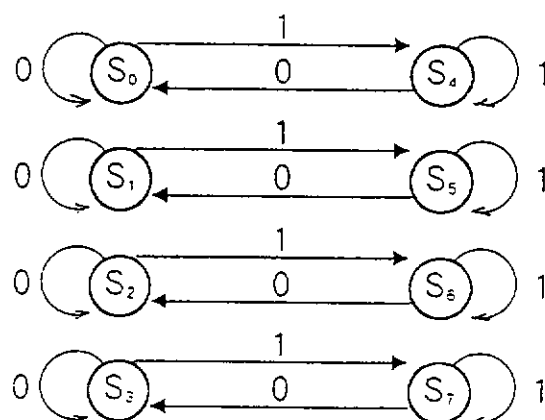


Fig. 25

(a) State transition table of threshold learning $\Delta \theta$

Input States	Next states	
	0	1
S0	S0	S1
S1	S0	S2
S2	S1	S3
S3	S2	S3
S4	S4	S5
S5	S4	S6
S6	S5	S7
S7	S6	S7

(b) State transition table of weight Δw

Input States	Next states	
	0	1
S0	S0	S4
S1	S1	S5
S2	S2	S6
S3	S3	S7
S4	S0	S4
S5	S1	S5
S6	S2	S6
S7	S3	S7

Fig. 26

Truth table for threshold learning circuit

$\Delta \theta$	q_3	q_2	q_1	q_3'	q_2'	q_1'
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	1	0	0	0	1
0	0	1	1	0	1	0
0	1	0	0	1	0	0
0	1	0	1	1	0	0
0	1	1	0	1	0	1
0	1	1	1	1	1	0
1	0	0	0	0	0	1
1	0	0	1	0	1	0
1	0	1	0	0	1	1
1	0	1	1	0	1	1
1	1	0	0	1	0	1
1	1	0	1	1	1	0
1	1	1	0	1	1	1
1	1	1	1	1	1	1

Fig. 27

Truth table for weight learning circuit

ΔW	q_3	q_2	q_1	q_3'	q_2'	q_1'
0	0	0	0	0	0	0
0	0	0	1	0	0	1
0	0	1	0	0	1	0
0	0	1	1	0	1	1
0	1	0	0	0	0	0
0	1	0	1	0	0	1
0	1	1	0	0	1	0
0	1	1	1	0	1	1
1	0	0	0	1	0	0
1	0	0	1	1	0	1
1	0	1	0	1	1	0
1	0	1	1	1	1	1
1	1	0	0	1	0	0
1	1	0	1	1	0	1
1	1	1	0	1	1	0
1	1	1	1	1	1	1

Fig. 28 Truth table of weight and threshold modification circuits

ΔW_{ij}	$\Delta \theta_{ij}$	q_3	q_2	q_1	q_3'	q_2'	q_1'
0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0
0	0	0	1	0	0	0	1
0	0	0	1	1	0	1	0
0	0	1	0	0	0	0	0
0	0	1	0	1	0	0	0
0	0	1	1	0	0	0	1
0	0	1	1	1	0	1	0
0	1	0	0	0	0	0	1
0	1	0	0	1	0	1	0
0	1	0	1	0	0	1	1
0	1	0	1	1	0	1	1
0	1	1	0	0	0	0	1
0	1	1	0	1	0	1	0
0	1	1	1	0	0	1	1
0	1	1	1	1	0	1	1
1	0	0	0	0	1	0	0
1	0	0	0	1	1	0	0
1	0	0	1	0	1	0	1
1	0	0	1	1	1	1	0
1	0	1	0	0	1	0	0
1	0	1	0	1	1	0	0
1	0	1	1	0	1	0	1
1	0	1	1	1	1	1	0
1	1	0	0	0	1	0	1
1	1	0	0	1	1	1	0
1	1	0	1	0	1	1	1
1	1	0	1	1	1	1	1
1	1	1	0	0	1	0	1
1	1	1	0	1	1	1	0
1	1	1	1	0	1	1	1
1	1	1	1	1	1	1	1

Fig. 29 karnaugh map of next state

$\Delta W_{ij} \Delta \theta_{ij}$ $q_3 \ q_2 \ q_1$	0 0	0 1	1 1	1 0
0 0 0			1	1
0 0 1			1	1
0 1 1			1	1
0 1 0			1	1
1 1 0			1	1
1 1 1			1	1
1 0 1			1	1
1 0 0			1	1

ΔW_{ij}

Fig. 30

$\Delta W_{ij} \Delta \theta_{ij}$ $q_3 \ q_2 \ q_1$	0 0	0 1	1 1	1 0
0 0 0				
0 0 1		1	1	
0 1 1	1	1	1	1
0 1 0		1	1	
1 1 0		1	1	
1 1 1	1	1	1	1
1 0 1		1	1	
1 0 0				

$q_2 \ q_1$

$\Delta \theta_{ij} q_1 + \Delta \theta_{ij} q_2$

Fig. 31

$\Delta W_{ij} \Delta \theta_{ij}$ $q_3 \ q_2 \ q_1$	0 0	0 1	1 1	1 0
0 0 0		1	1	
0 0 1				
0 1 1		1	1	
0 1 0	1	1	1	1
1 1 0	1	1	1	1
1 1 1		1	1	
1 0 1				
1 0 0		1	1	

$\Delta \theta_{ij} \ q_2$ (points to the 1s in the 0 1 and 1 1 columns)
 $q_2 \ q_1$ (points to the 1s in the 0 1 and 1 1 columns)
 $\Delta \theta_{ij} \ q_2 \ q_1$ (points to the 1s in the 0 1 and 1 1 columns)

Fig. 37 Truth table of connection function

X	q_2	q_1	Y_{ij}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

Fig. 32 Modification circuit diagram

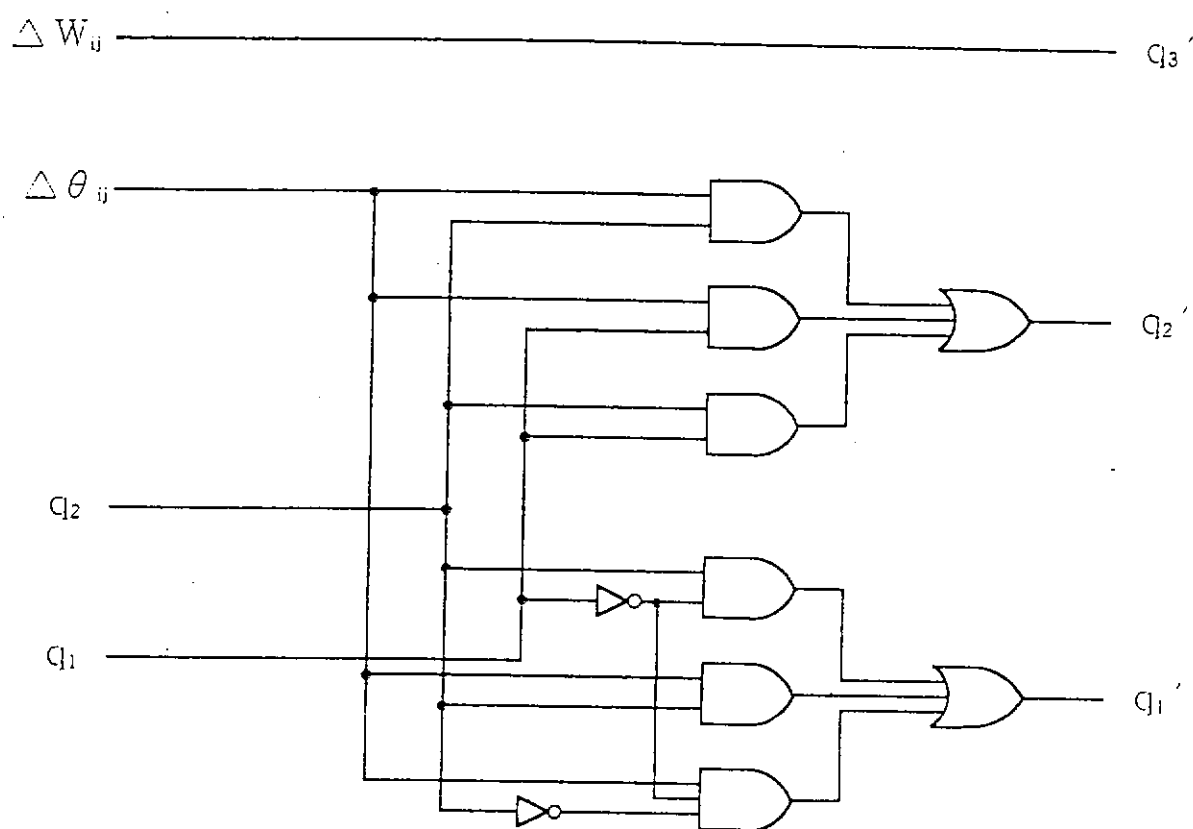


Fig. 33

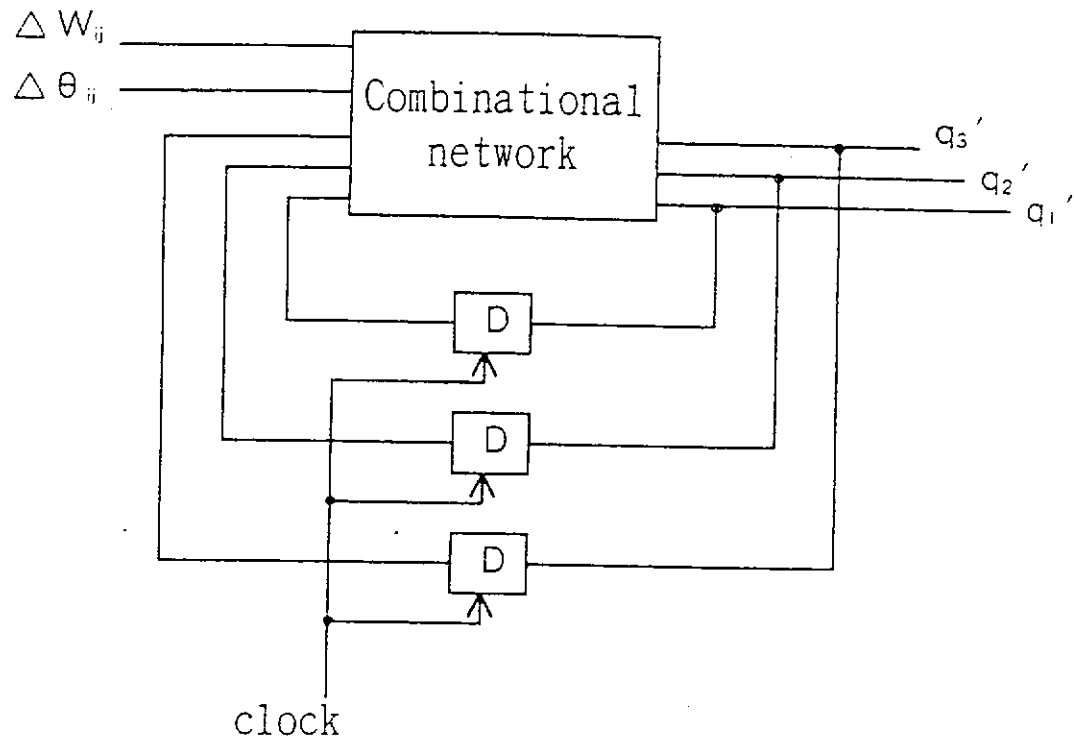


Fig. 34

	q_3	q_2	q_1	$S(1)$	$S(X)$	$S(1-X)$	$S(0)$
S_0	0	0	0	1			
S_1	0	0	1	1			
S_2	0	1	0		1		
S_3	0	1	1				1
S_4	1	0	0	1			
S_5	1	0	1			1	
S_6	1	1	0				1
S_7	1	1	1				1

Fig. 35

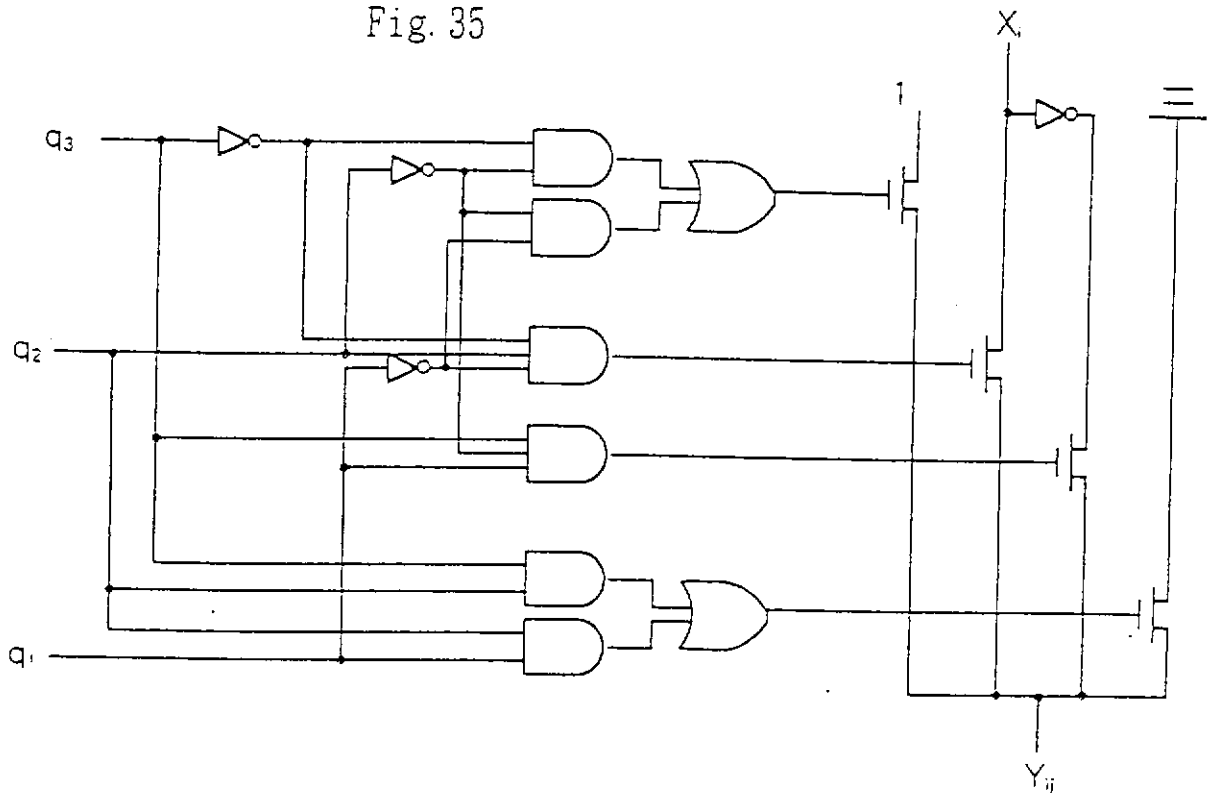


Fig. 36

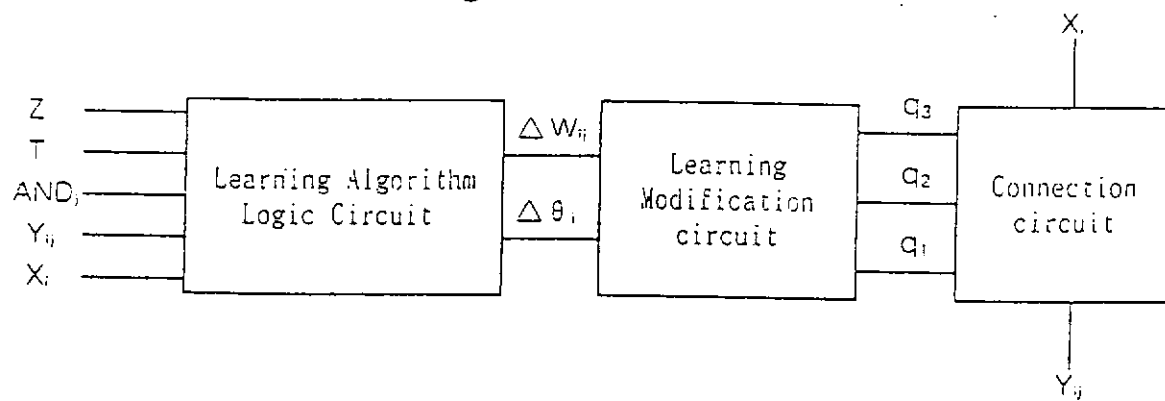


Fig. 38 Learning algorithm Circuit

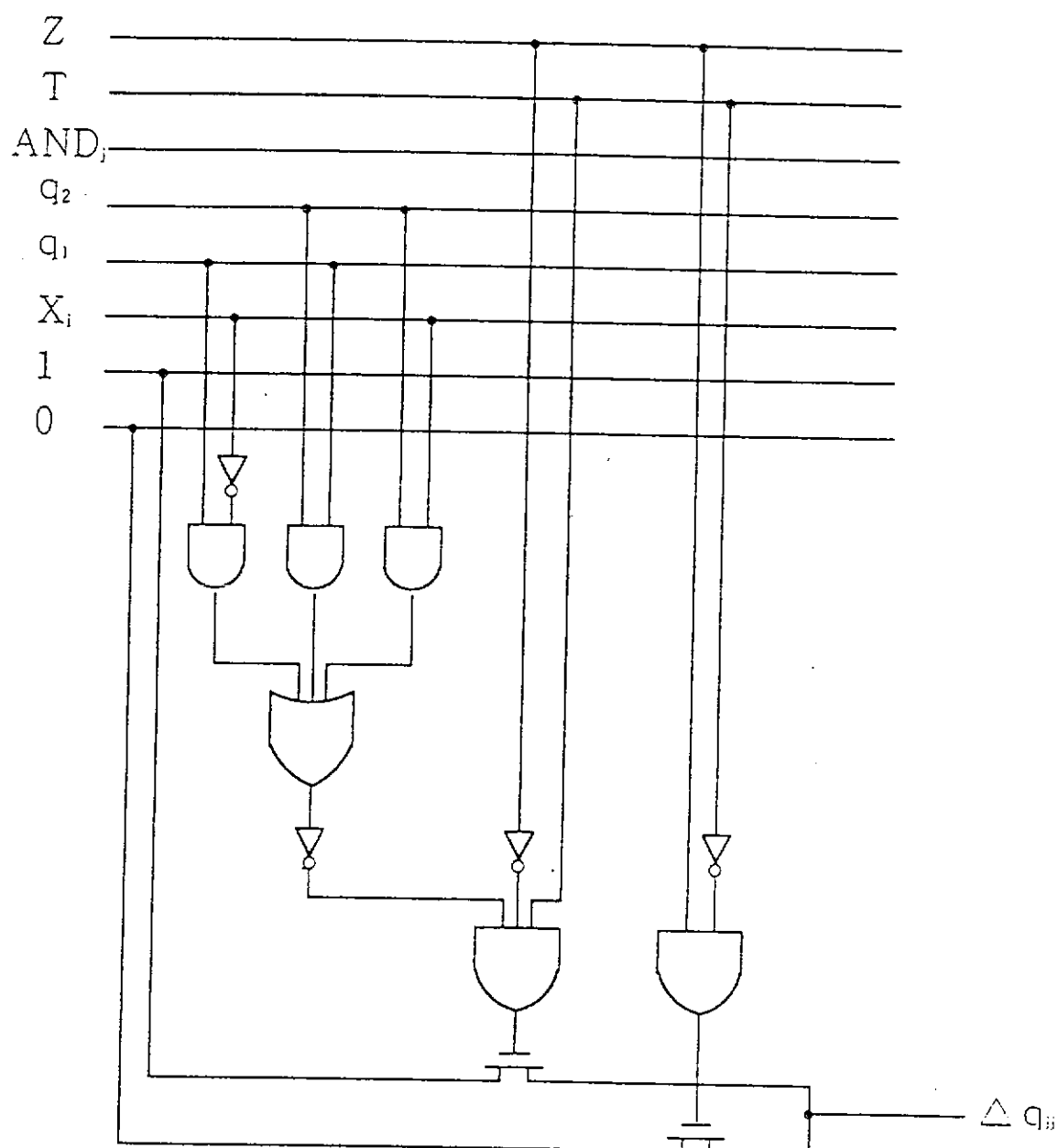


Fig. 39 Truth table of connection state learning circuit

X_i	Δq_{ij}	q_2	q_1	q_2'	q_1'
0	0	0	0	0	0
0	0	0	1	1	0
0	0	1	0	0	0
0	0	1	1	0	1
0	1	0	0	1	0
0	1	0	1	1	1
0	1	1	0	0	1
0	1	1	1	1	1
1	0	0	0	0	0
1	0	0	1	0	0
1	0	1	0	0	1
1	0	1	1	1	0
1	1	0	0	0	1
1	1	0	1	1	0
1	1	1	0	1	1
1	1	1	1	1	1

Fig. 40 Learning modification circuit by sequen
by sequential network

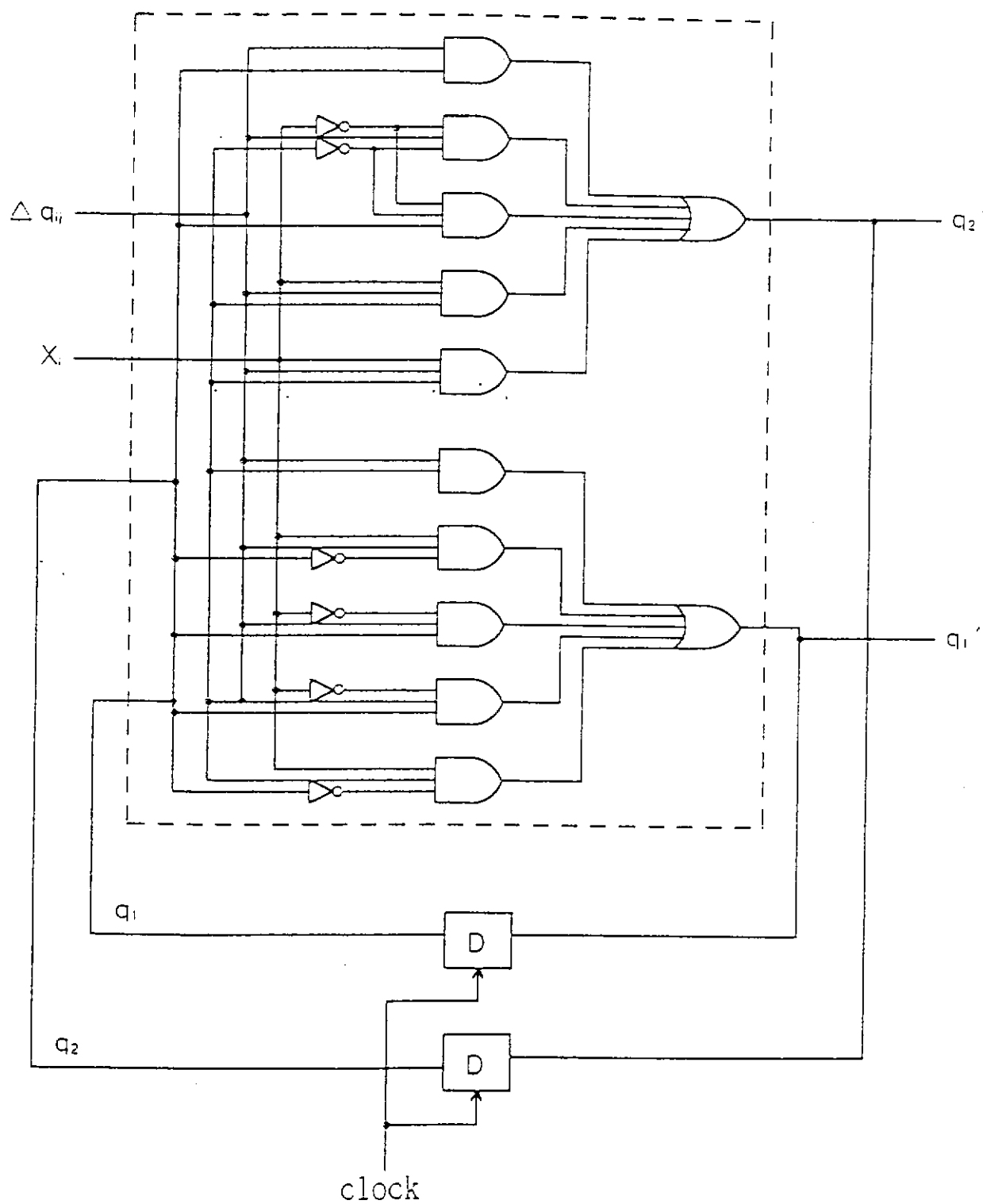


Fig. 41 Connection circuit diagram

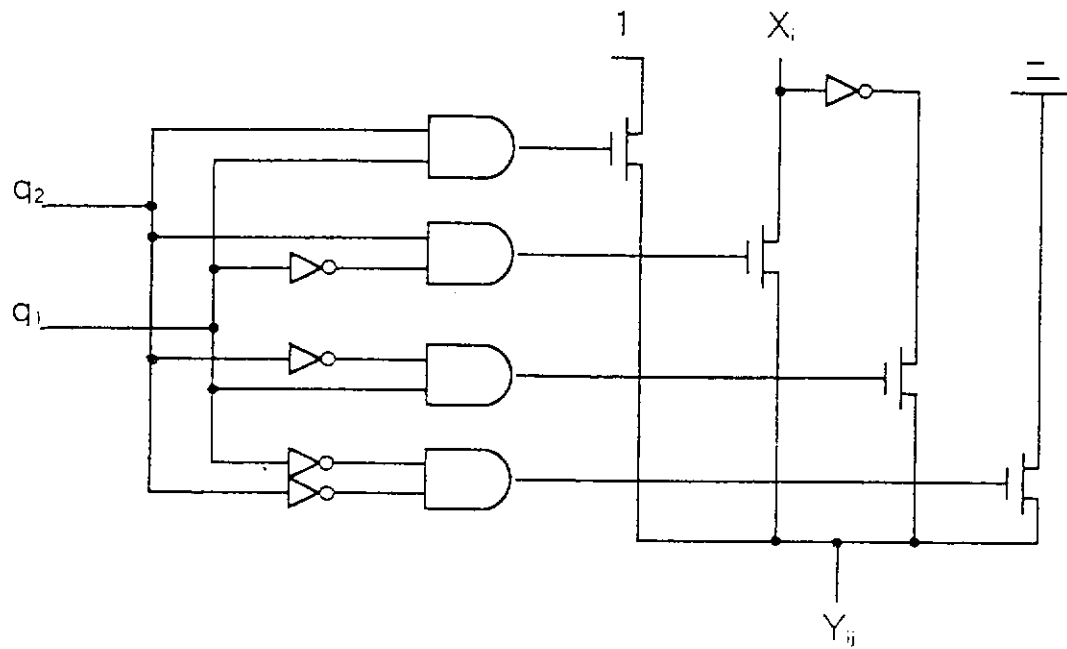


Fig. 42 Block diagram of the whole learning circuit by pseudo-potential energy method

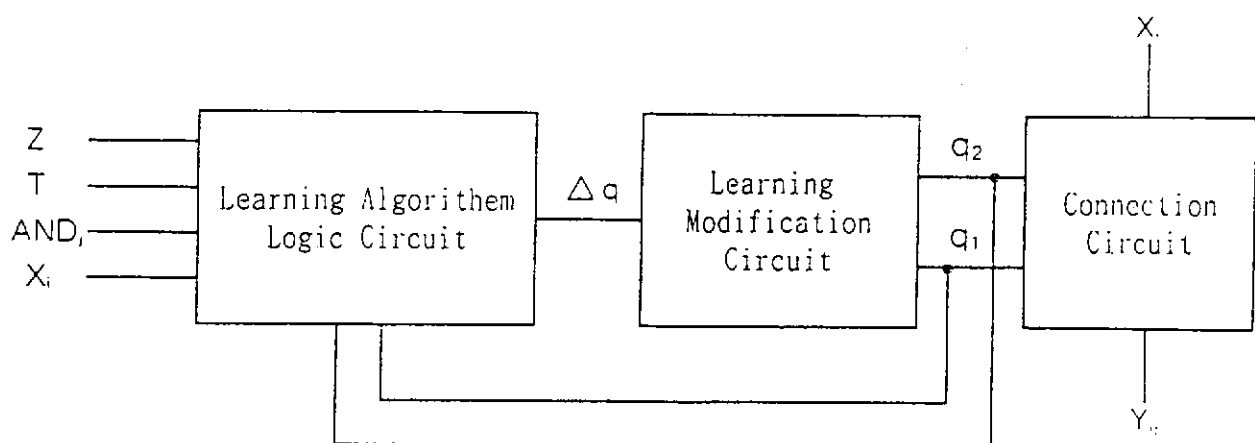


Fig. 43 Learning in sequential network

