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(A)

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2001 11 14

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(86) 1999 12 10

(87)
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(81) : , , 가 , , , , , , , , -
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AP ARIPO : , , , , , , , , , 가 ,
EA : , , , , , , , , , , , , , ,
EP : , , , , , , , , , , , , , , ,
OA OAPI : , , , , , , , , , , , , , , , , 가 ,

(30) 09/211,351 1998 12 15 (US)

(71)

10504

6 3

41

(72)

가

78727

4803

78730

3610

78759

10703

(74)

:

(54)

(NUMA)

, . , . , . , . , .

1

y access:NUMA)
NUMA

NUMA

(non - uniform memor

가

(MP)

(topology)

가

.가

(symmetric multi - processor:SMP)

(I/O)

SMP

(latency) 가

SMP

(scalability)
가)

SMP

(I/O)

(, ,

SMP

SMP , SMP , SMP 가 SMP

(NUMA) SMP 가 NUMA " " 가 (coherency) NUMA(CC - NUMA) 가 , NUMA SMP

NUMA 가 SMP

CC - NUMA

, 가

2

1

2

(22)

1 NUMA

2 1

3a 3b

4a 4d 3a 3b

1 NUMA 가 , NUMA

(8a - 8n) (6) M(M 0) (22) (10) (16) (8a - 8n)(N 2) (17) , NUMA

(18) IBM PowerPC™ (10a - 10m) (10a

- 10m) (12) (18) (12) (10a

2(L2) (14) , 8 - 32 KB 1(L1) , 1 - 16 MB

(8a - 8n) (16) (22) (2

0) (20) 가 (8) (snoop)

(8) (16) (20) (22) (16)

(arbiter)(24) (24) (10) (16)

(16) (16) (compile)

(16) (26) (26) (10)가 (PCI) / I/O

(30) (34) I/O (32)

(34) I/O (32)가 (18) . I/O (32)
 , , (34)

NUMA (6) (10) , 가
 (18)
 NUMA (6) (10) , 4 (8)
 (18) , NUMA 16 GB 가
 . 500 MB , 4 (8) 4
 . 2 GB , (8) I/O
 , (8a - 8n) (18) (8)

(18) , NUMA NUMA (6) (6) (10) ,
 , NUMA (6) . , NUMA
 (6) CC - NUMA .
 , (Modified, Exclusive, Shared, Invalid:MESI) .
 , (14) (24) (20)가 M, S I E M
 가 , 가 가 . (20)

(16) (22) , ,
 (22) IBM 가 6xx . , ,
 (16) (22) (split) ,
 가 , (16) (22)
 ,
 (sourcing)

), (snooper) 가 3가 " " (8) (16) 1 2 (22)

[1]

< 0:7>	(thru)
< 8:15>	
< 16:63>	,가 I/O
A < 0:2>	< 0:63>
T	

[2]

< 0:127>	
< 0:15>	< 0:127>
D	
D	가 D

1 2 , 가 가
 가
 (8) , (24)
 (16) 3

[3]

AStatOut < 0:1>	(assert)
AStatIn < 0:1>	AStatOut (tally)
ARespOut < 0:2>	
ARespIn < 0:2>	ARespOut

(16) AResp 가 AStat 가 (16)
 AStatOut (vote)가 2
 가 (24) AStatOut , 가 AStat 가 4
 가 (, 1) AStatIn . 가 AStat 가

[4]

AStat	
(Null)	(idle)
(Ack)	
(Error)	가
(Retry)	, 가

AStatIn , ARespOut , 가 (, 2)
 (24) AStatOut ,
 ARespIn . 가 AResp 5 .

[5]

(Retry)	, 가
(Modified intervention)	
(Shared)	
(Null)	
(ReRun)	가

(20) ReRun AResp 가 , ReRun
 ReRun (가) , Retry AResp , ReRun

2 1 NUMA (6) (20) 2
 (16) (22) (20) (TRU)
 (40), (TSU)(42), (DRU)(44) (DSU)(46) . T
 RU(40), TSU(42), DRU(44) DSU(46) ,
 (ASIC) (20)
 () TRU(40) TSU(42) , DRU(44) DSU(46)

(22) TRU(40) (22)
 (16) , TSU(42) . TRU
 (40) (mux)(52) (52) (22)
 (54) TSU(42) (56)
 (52) (54) (16)

(22) (conduit) TSU(42)
 (22) (60) (60)

) ,
 가 Null , ReRun
 TSU(42) (22) , TRU(40)
 , DRU(44) DSU(46) (16) (22)
 , TSU(42) (56) (22) (,
 MSI) (58) (50)
 (50) (,
)
 (50) 가 가 6

[6]

	가	가	
(Modified)(M)	I	M, E I	
(Shared)(S)	S I	S I	
(Invalid)(I)	M, E, S I	I	
- (Pending - shared)	S I	S I	
- (Pending - modified)	I	M, E I	

6 , (20) S I , E I
 E M

3a 3b

3a , 70 72 , 72 , (8a)
 (10a) (10) (16)
 (8a) (16) (20) 74
 AStatOut (24)가
 AStatIn (18) (20) Ack AStatOut (60) (write - with - clean)
 (20)
 (8a) AResp

76 , 74 AStatIn 가 (Retry) ,
 (60) , 72

(10a) , 76 78 , 78 , 74 AStatIn 가 가
 , (8)가 , 80 , (20) (8)가 100
 .

80 , (8a) ARespOut , ARespOut
 (24)가 ARespln (50)가 (20)
 가 (8) (8) , (ReRun) , (20)
 (50)가 (8) (8) , (50)가
 (8) , (read - with - intent - modify:RWITM)
 Kill (8)

90 , ARespln 82 , ARespln 가 84 .

84 , (20) (22) , [, (Kill)]
 (8) , 86 가 84
 (16) , (10a) (10a) (20) (ReRun) 88 ,
 AResp (10a) 90 , (16) (20)가 (8) . AStat
 (14)]가 , (8a) [, (17)
 150 .

100 , (8a) (20) , (8a)가 가
 , (20) (2) (8)
 0) , 3a , ARespln ARespIn (24) AStatIn (2
 , (60) (ReRun) , 102
 , ARespOut , ARespOut (24)가
 ARespln , 110 (20) (8a) ARespln ,

ARespln 가 (Retry) , (8a) , ARes
 pln , 110 112 114 , 112 114 , (Null)
 , (60) (Null) (20)

150

ARespIn 가 (Modified Intervention) , [(stale)]
 (8a) , ARespIn 102 110 120
 (60) (Null)
 122 , ARespOut
 (8a) (16)
 (Modified) (Shared) , 124
 (10a) (14) , 126
 (20) (16)
 (write - with - clean)
 (18) , 112

(6) (Shared Intervention),
 (14)
 (6) ARespIn 가 (,
) , 132 (16)
 , 134 (10a)
 (14) (18) (60)
 (Null) , 150

(8a) ARespIn 가 (ReRun) , (60)
 (Null) ,
 102 110, 120, 130 142 (8a) (20)
 (22)
 , 144 (20) (16)
 (10a) (10a) , 146
 (10a) (14) , 150

3b 가
 (22) , 160 162 , 162 , 가
 (8) , 162 (20)가
 (8) , 164 , 164 ,
 (20) 162 (16) , 170
 , (16) 172 , 17
 2 , (20)
 , 174 (20)
 (22) (8) , 190

164 가 , (16) (,)
 , 170 180 184 , 184 , (17)
 (16) (18) , 190 , 182 ,
 , 190 (14)

4a 4d
 , 2 (10a, 10b) 2 (8a, 8b) (6)
 (50) (10) (8a)

4a , (8b) (10b) (14) (Invalid) (,
) (8b)
 (20) (8a) (10a) ARespOut (8a) (Modified Interve
 ntion) (8b) ARespOut (14) ARespIn (8b)

4b , (8a) (20) ,
 (16) (8b) (Modified) 4b (20) ARespOut
 (Null) 4d , (50)

4c , (8a) (, , (1
) , (8b) (10a) (16))
 4) (Shared) (10b) (8b) (20)
 (Shared) (8a) (16) (8a)
 (20) (18) (8a)

4a (, ,) , (8a) (18)
 가 (16) (8a) (20)
 8b) (20) , (8a) (60) (Null) (

NUMA

, NUMA

(,)

가

NUMA

(57)

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10.

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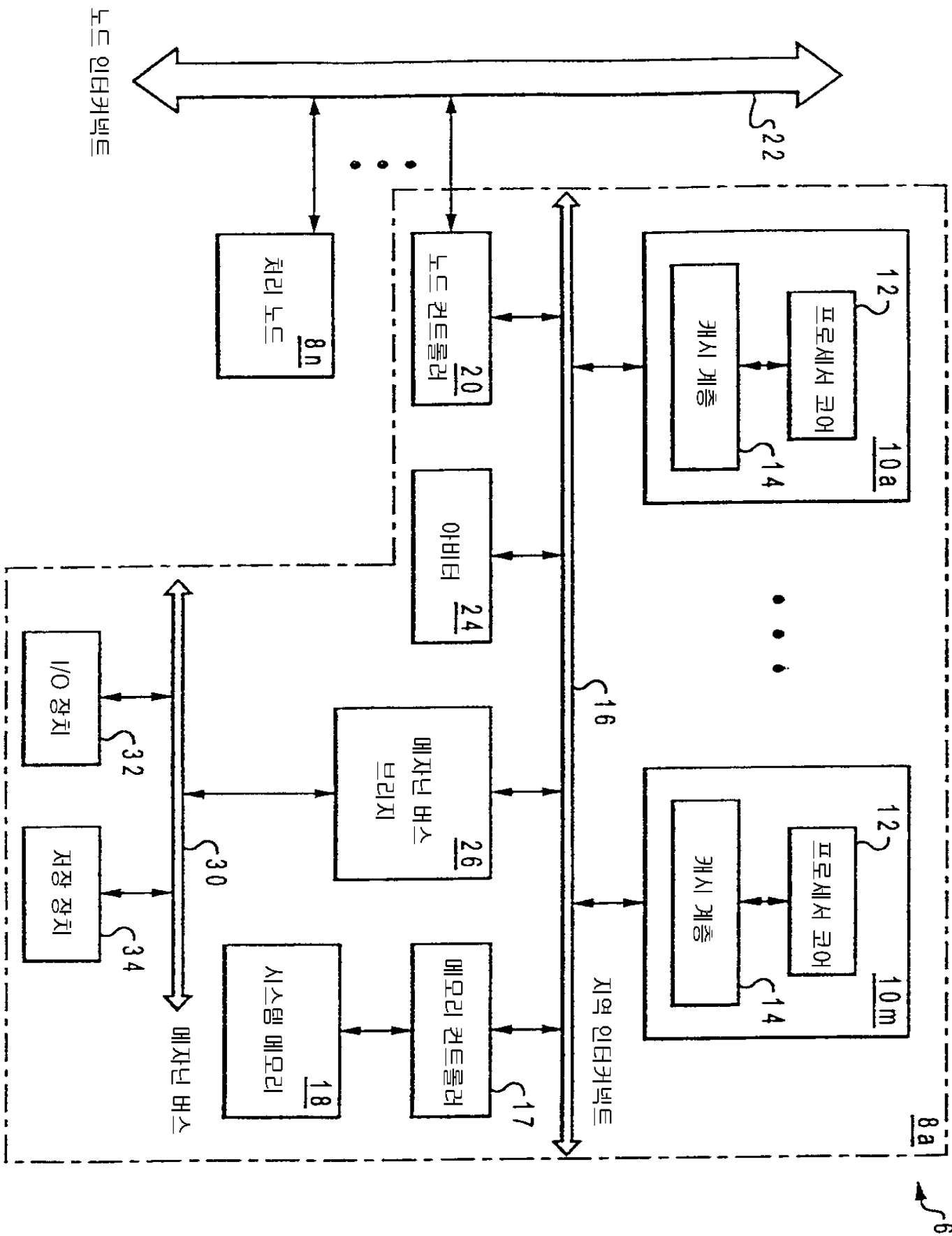
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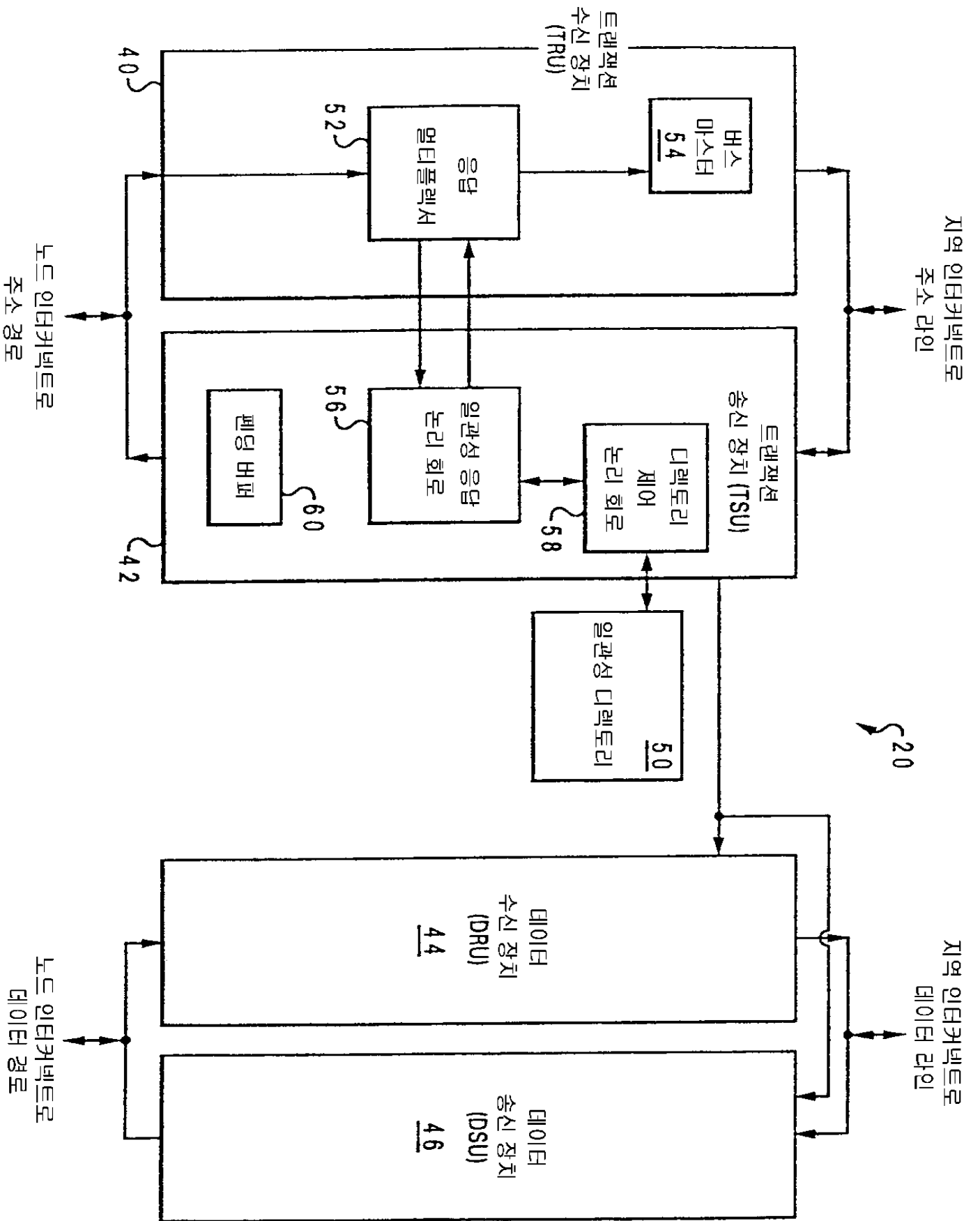
12.

7 ,

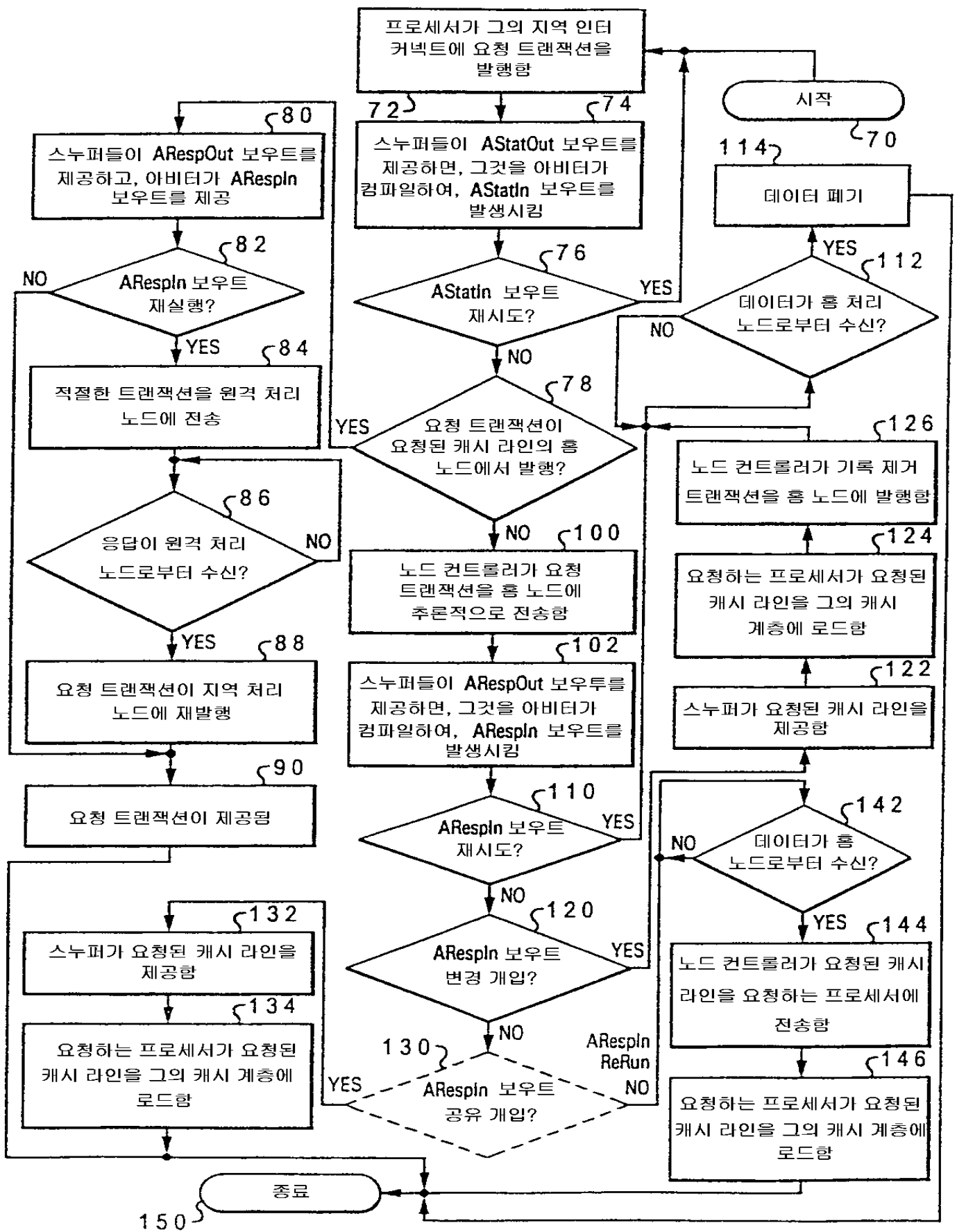
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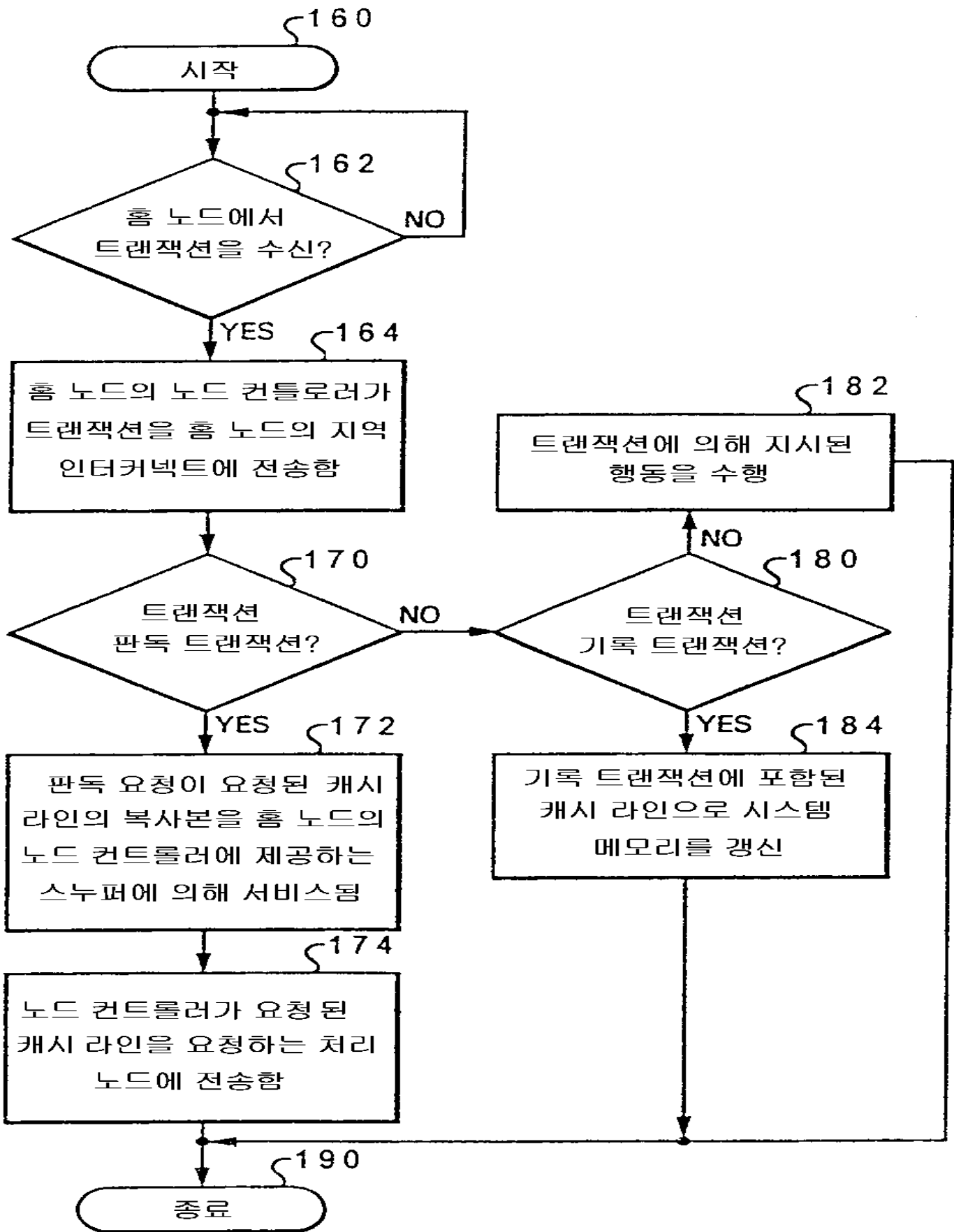
2



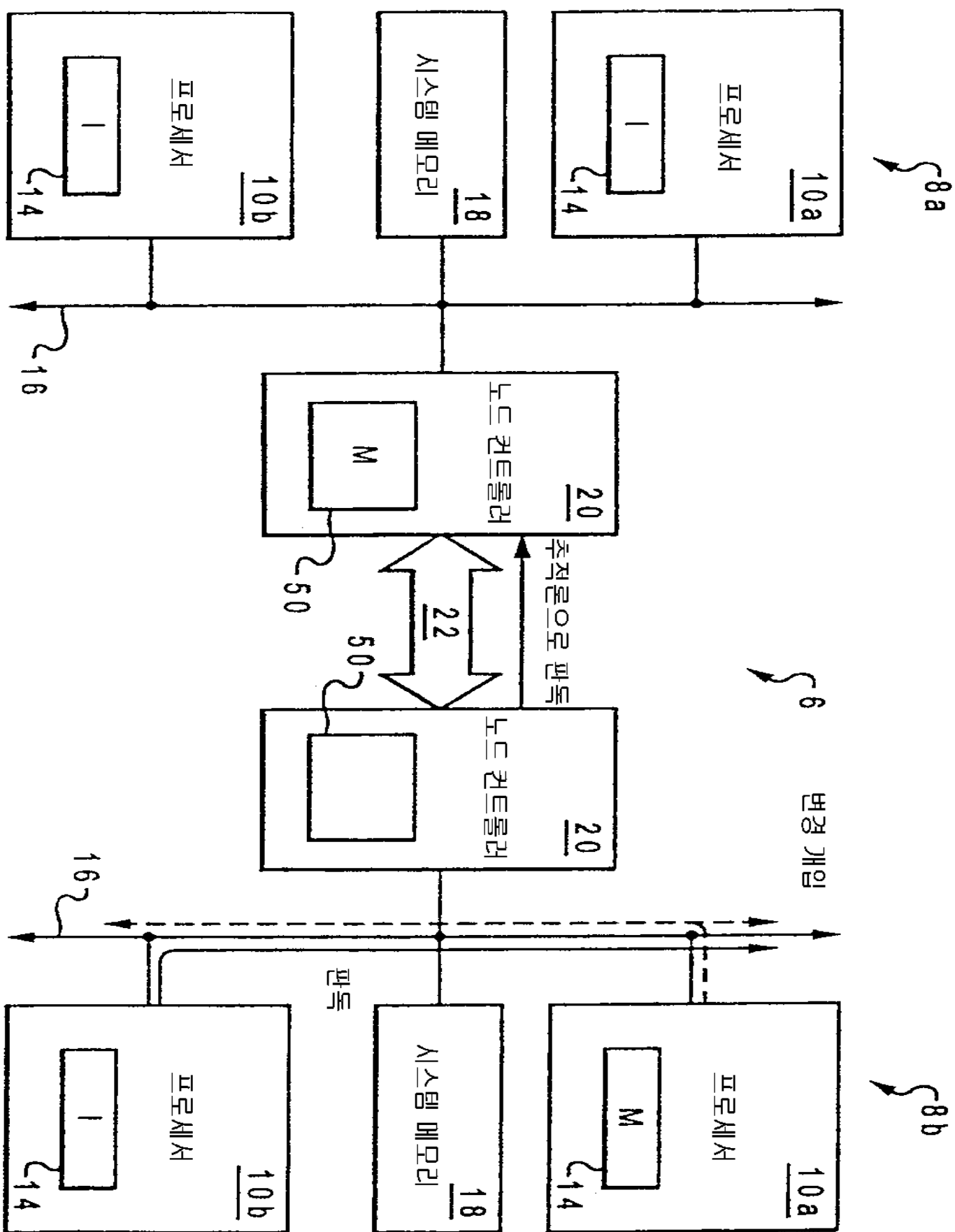
3a



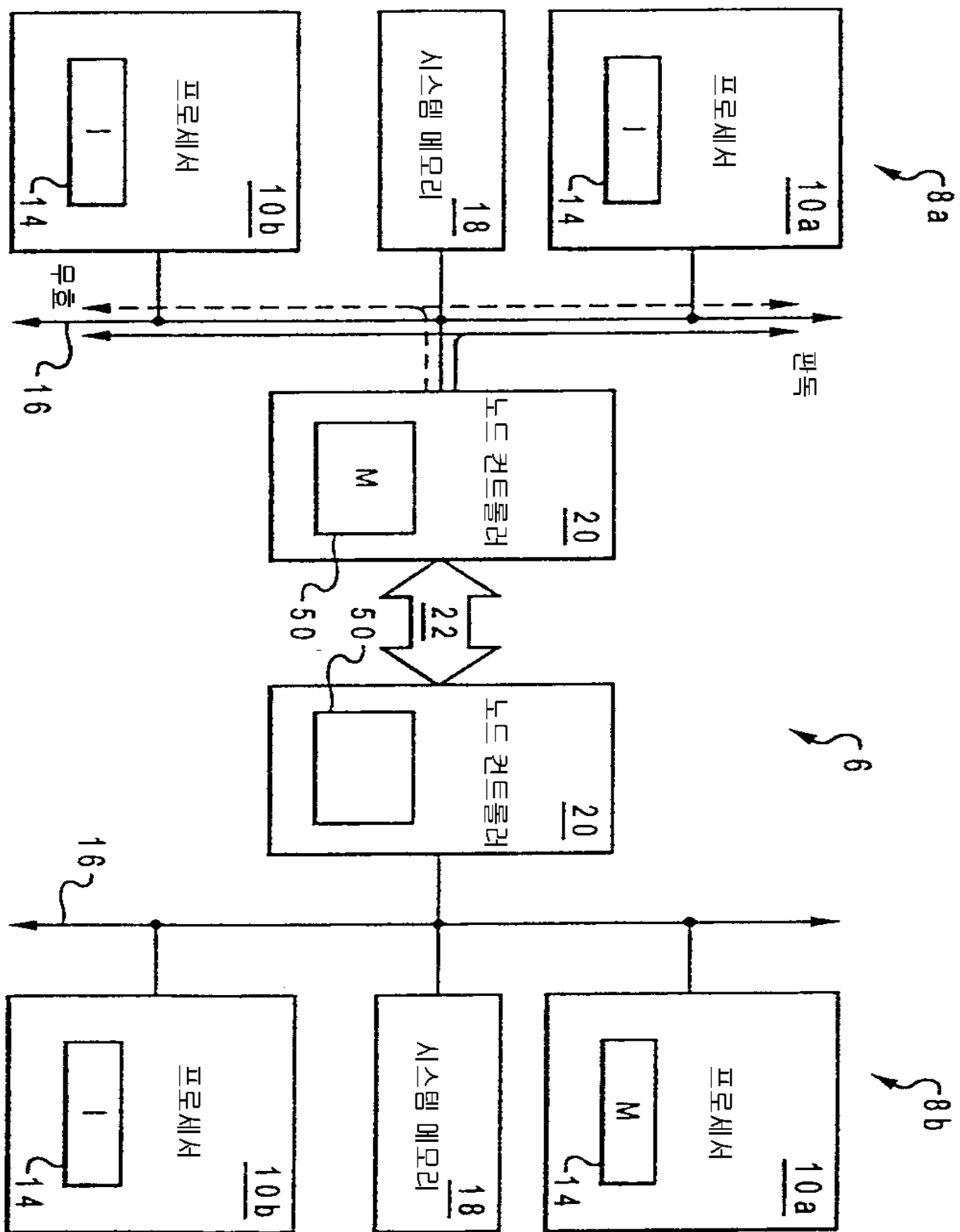
3b



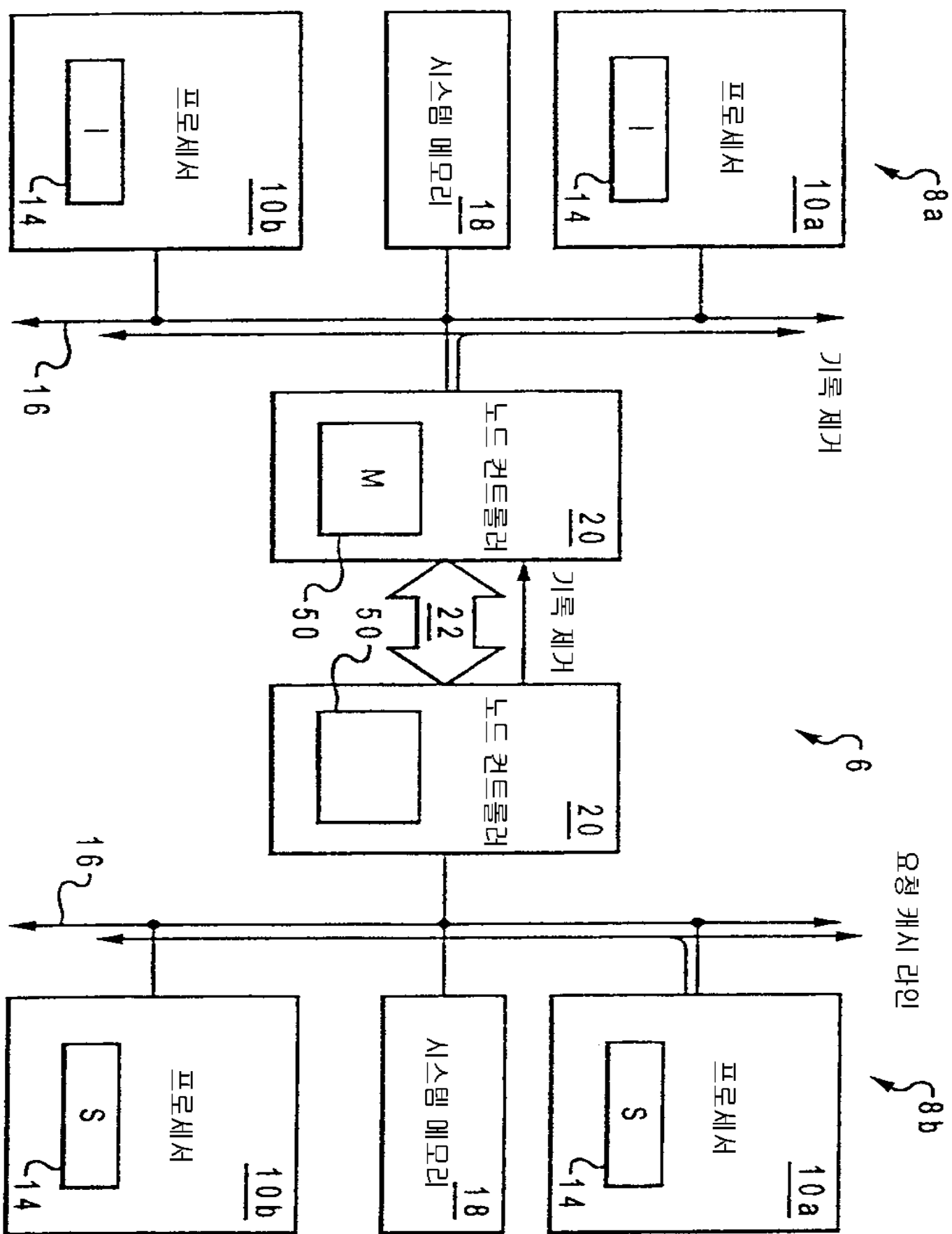
4a



4b



4c



4d

