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(54) METHOD OF SECTOR PROBE DRIVING AND ULTRASOUND DIAGNOSTIC APPARATUS

(76) Inventor: Shinichi Amemiya, Tokyo (JP)

Correspondence Address:
PATRICK W. RASCHE
ARMSTRONG TEASDALE LLP
ONE METROPOLITAN SQUARE, SUITE 2600
ST. LOUIS, MO 63102-2740 (US)

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(57) ABSTRACT

The transmitter/receiver for a convex probe and linear probe are used to drive a sector probe. Usually, when an ultrasound diagnostic apparatus using a convex probe and linear probe uses a sector probe, it selects vibration elements of N in number, which is equal to the number of channels of the sector probe, out of vibration elements of L in number (N is smaller than L), so that the selected elements are distributed at a virtually constant pitch in the alignment of vibration elements, and turns on only high voltage switches which are connected with the selected vibration elements to implement the sector scanning with the transmitter/receiver. It becomes possible to implement the sector scanning by using the transmitter/receiver having channels less than the number of vibration elements of the sector probe.

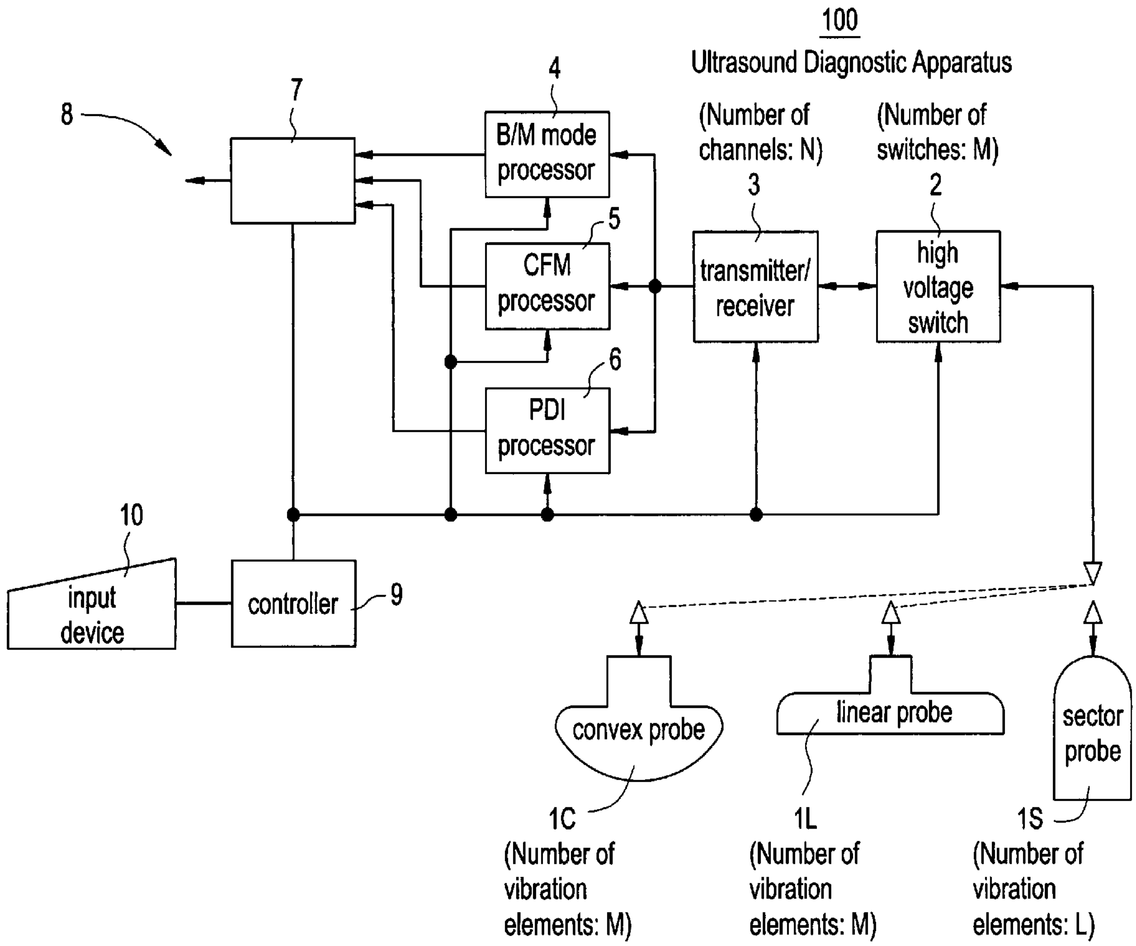


FIG. 1

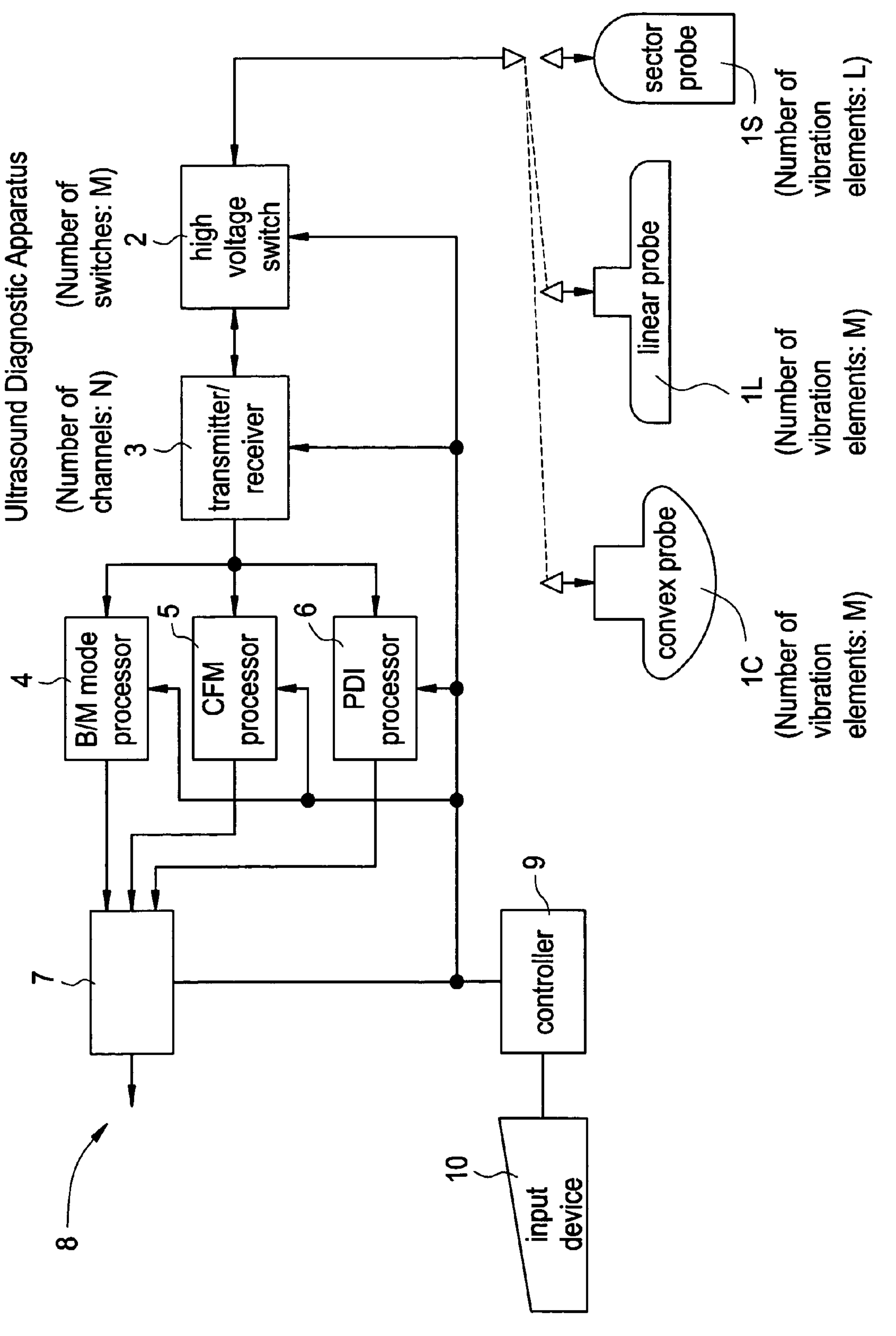
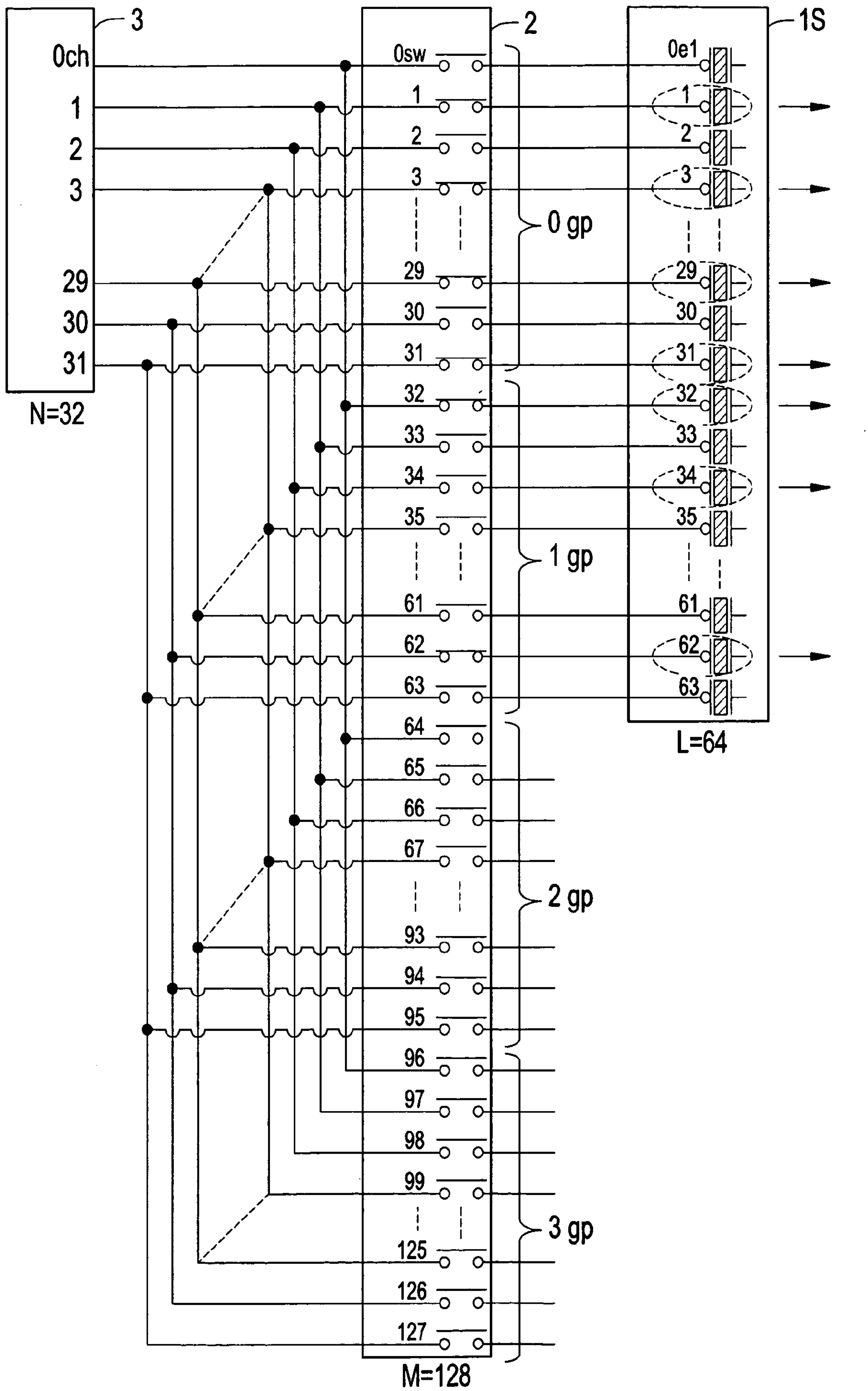

100
Ultrasound Diagnostic Apparatus
1S
sector probe
(Number of vibration elements: L)
1L
linear probe
(Number of vibration elements: M)
1C
convex probe
(Number of vibration elements: M)
2
high voltage switch
(Number of switches: M)
3
transmitter/receiver
(Number of channels: N)
4
B/M mode processor
5
CFM processor
6
PDI processor
7
8
9
controller
10
input device

FIG. 2



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29
30
31
N=32
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0sw
1
2
3
29
30
31
32
33
34
35
61
62
63
64
65
66
67
93
94
95
96
97
98
99
125
126
127
M=128
0 gp
1 gp
2 gp
3 gp
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30
31
32
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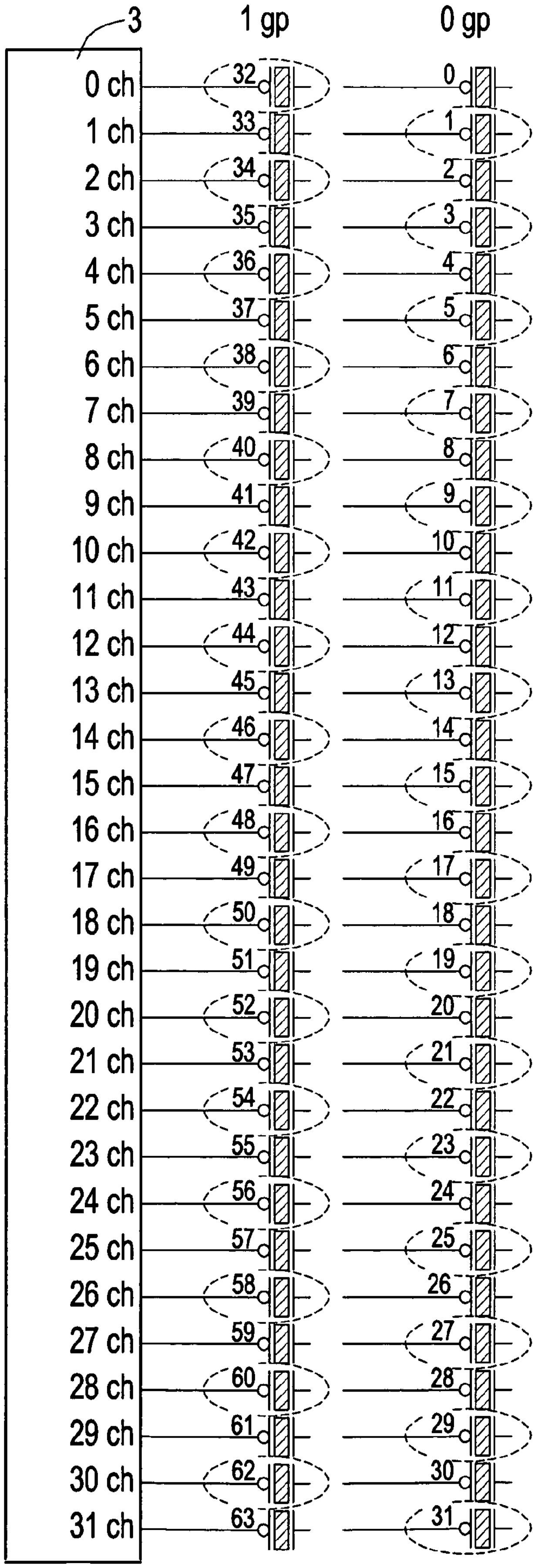
34
35
61
62
63
L=64

FIG. 3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13 ch
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15 ch
16 ch
17 ch
18 ch
19 ch
20 ch
21 ch
22 ch
23 ch
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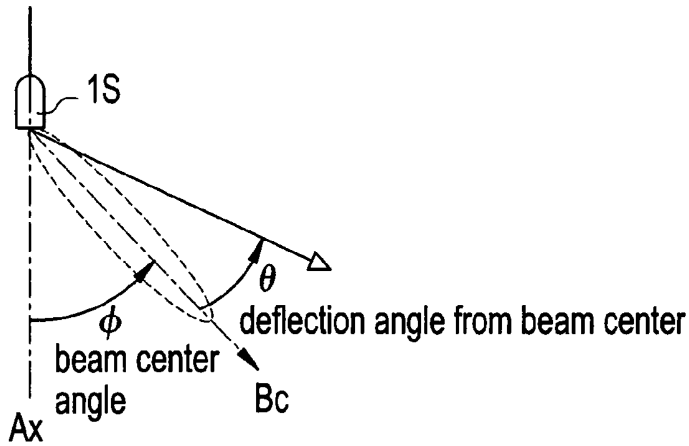
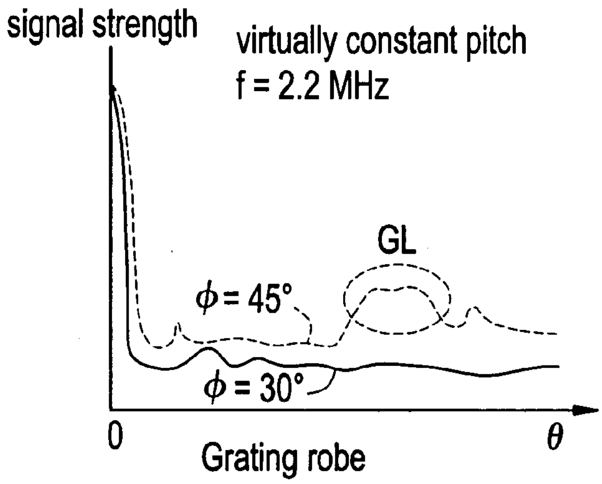
25 ch
26 ch
27 ch
28 ch
29 ch
30 ch
31 ch
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

# FIG. 4




# FIG. 5




# FIG. 6

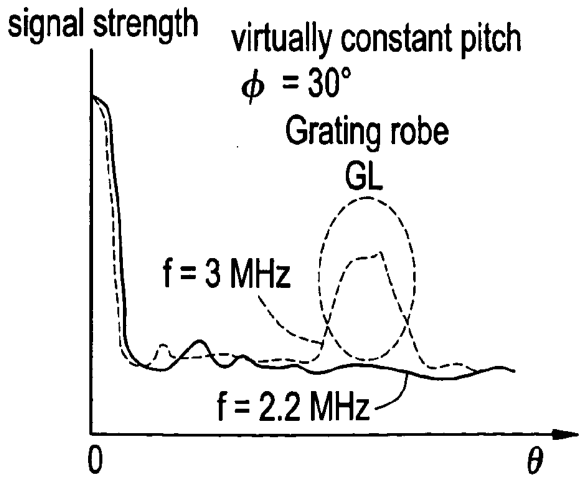
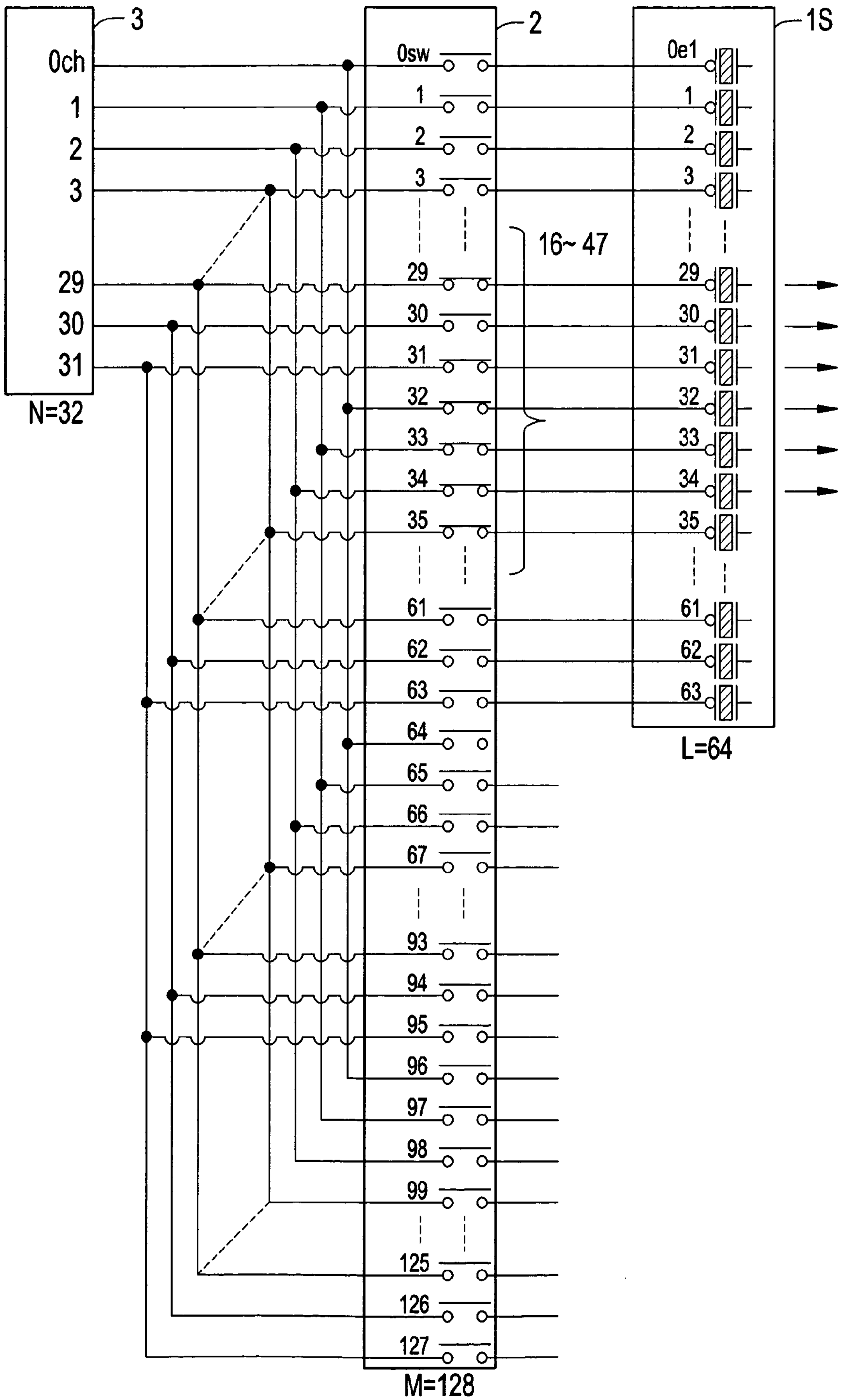


FIG. 7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34
35
61
62
63
64
65
66
67
93
94
95
96
97
98
99
125
126
127
M=128
16~ 47
1S
0e1
1
2
3
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30
31
32
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34
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62
63
L=64

FIG. 8

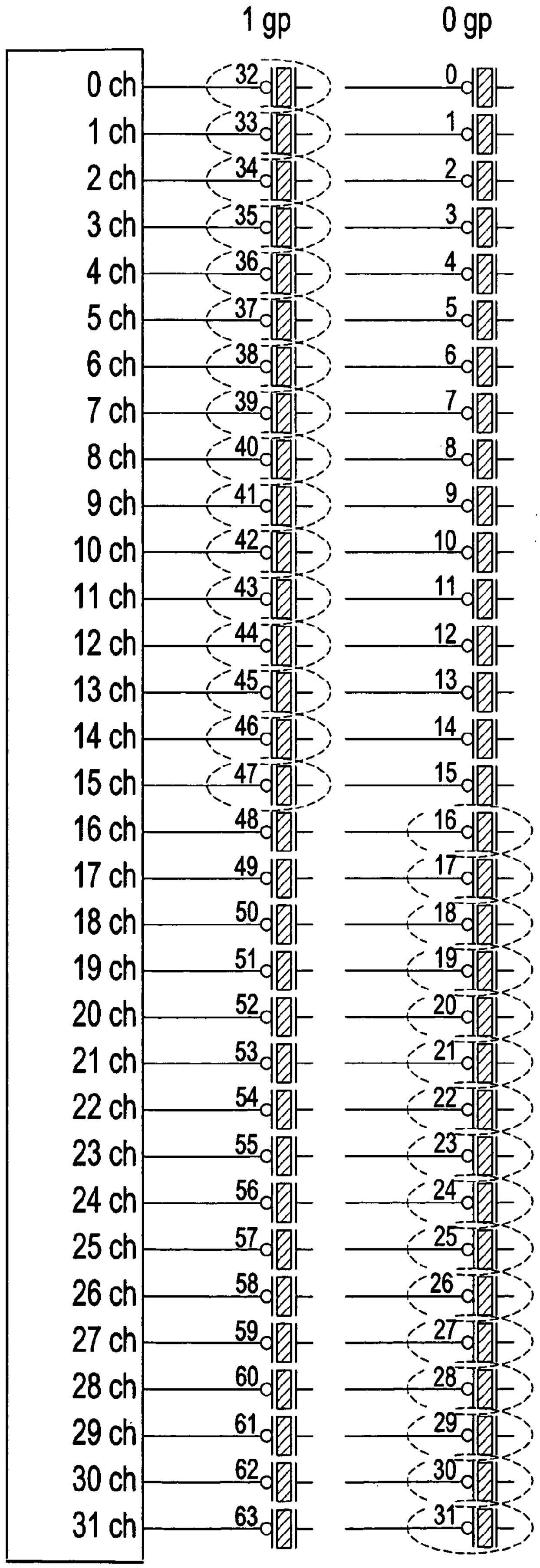
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FIG. 9

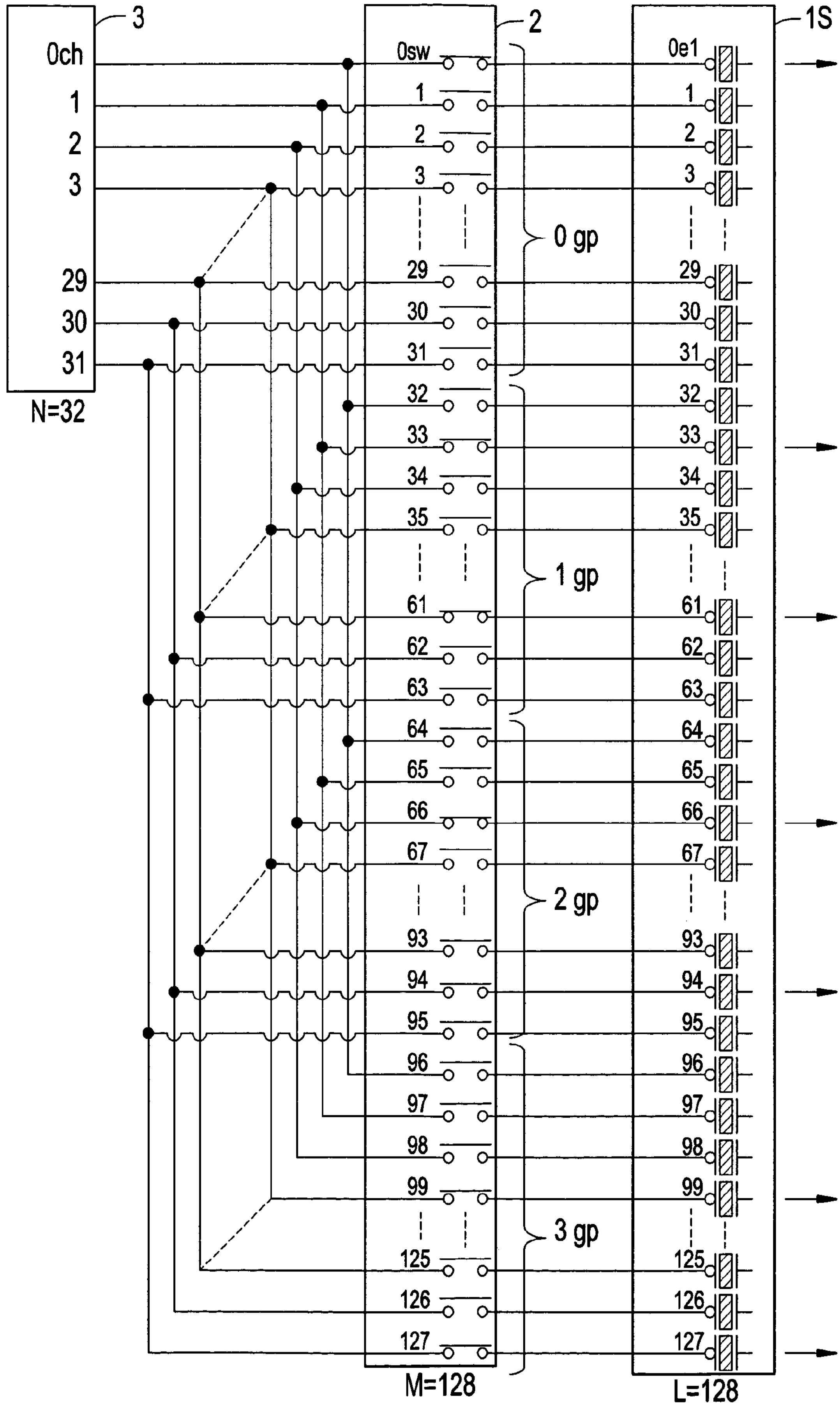
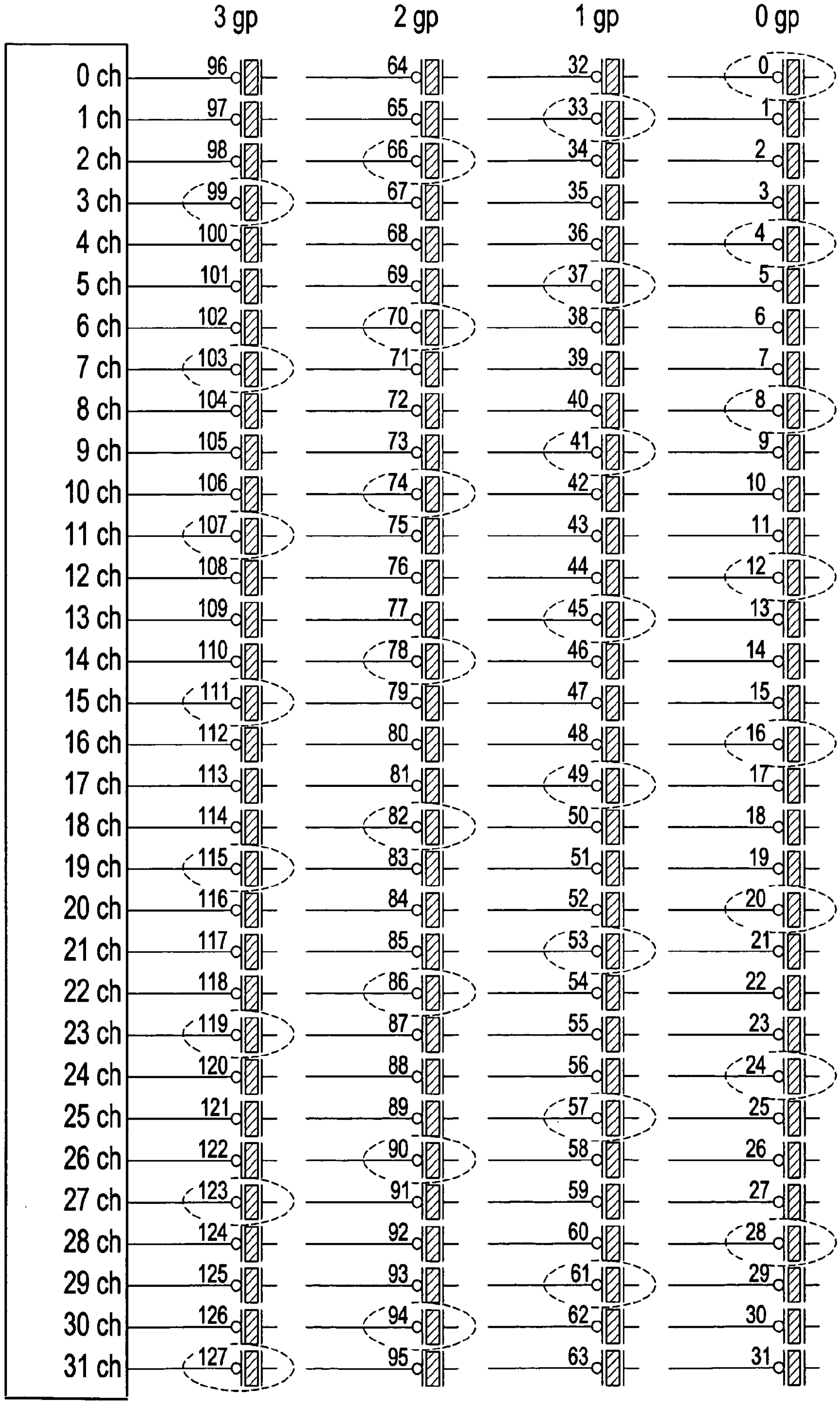


FIG. 10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15 ch
16 ch
17 ch
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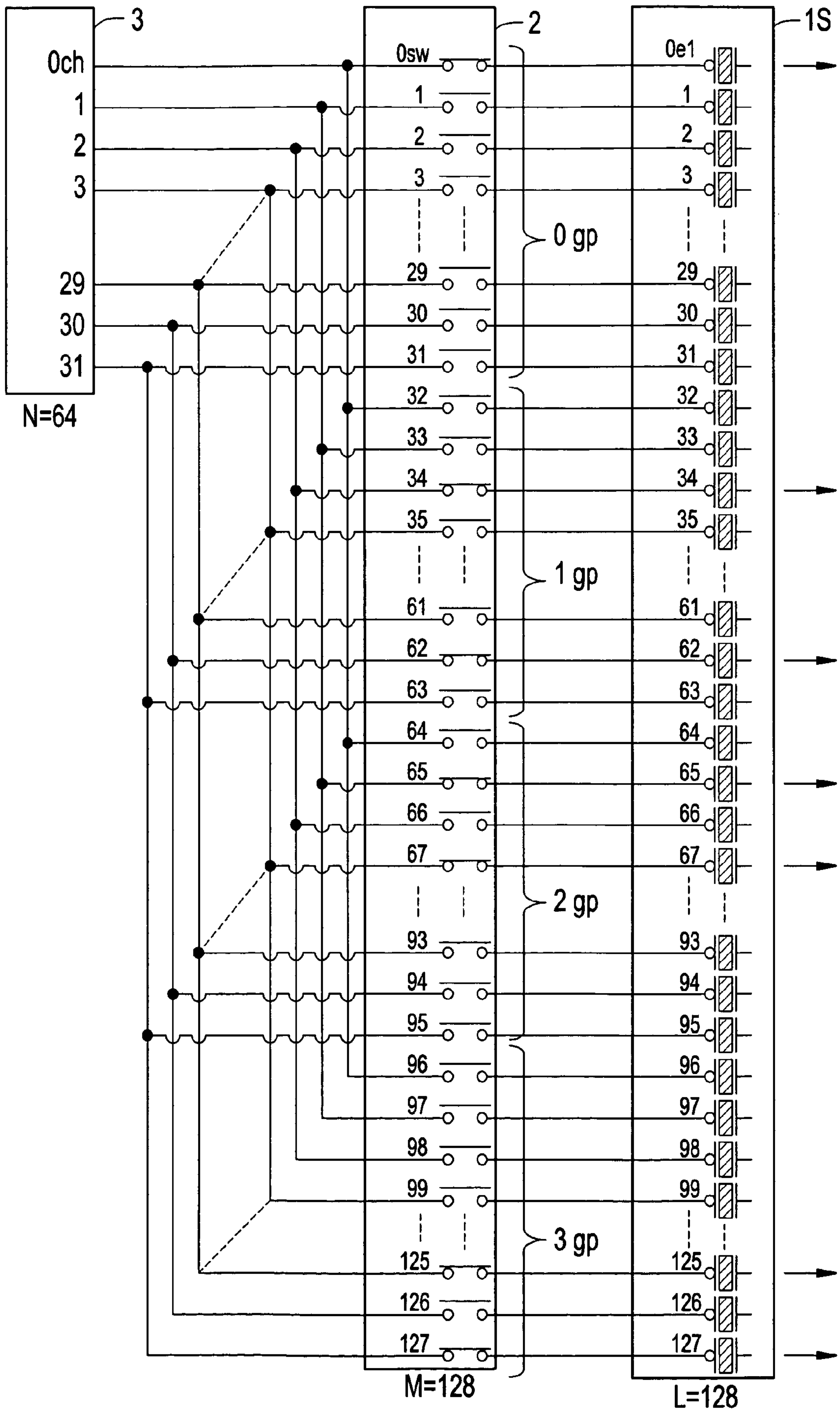
31 ch

FIG. 11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94
95
96
97
98
99
125
126
127
M=128
0 gp
1 gp
2 gp
3 gp
1S
0e1
1
2
3
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31
32
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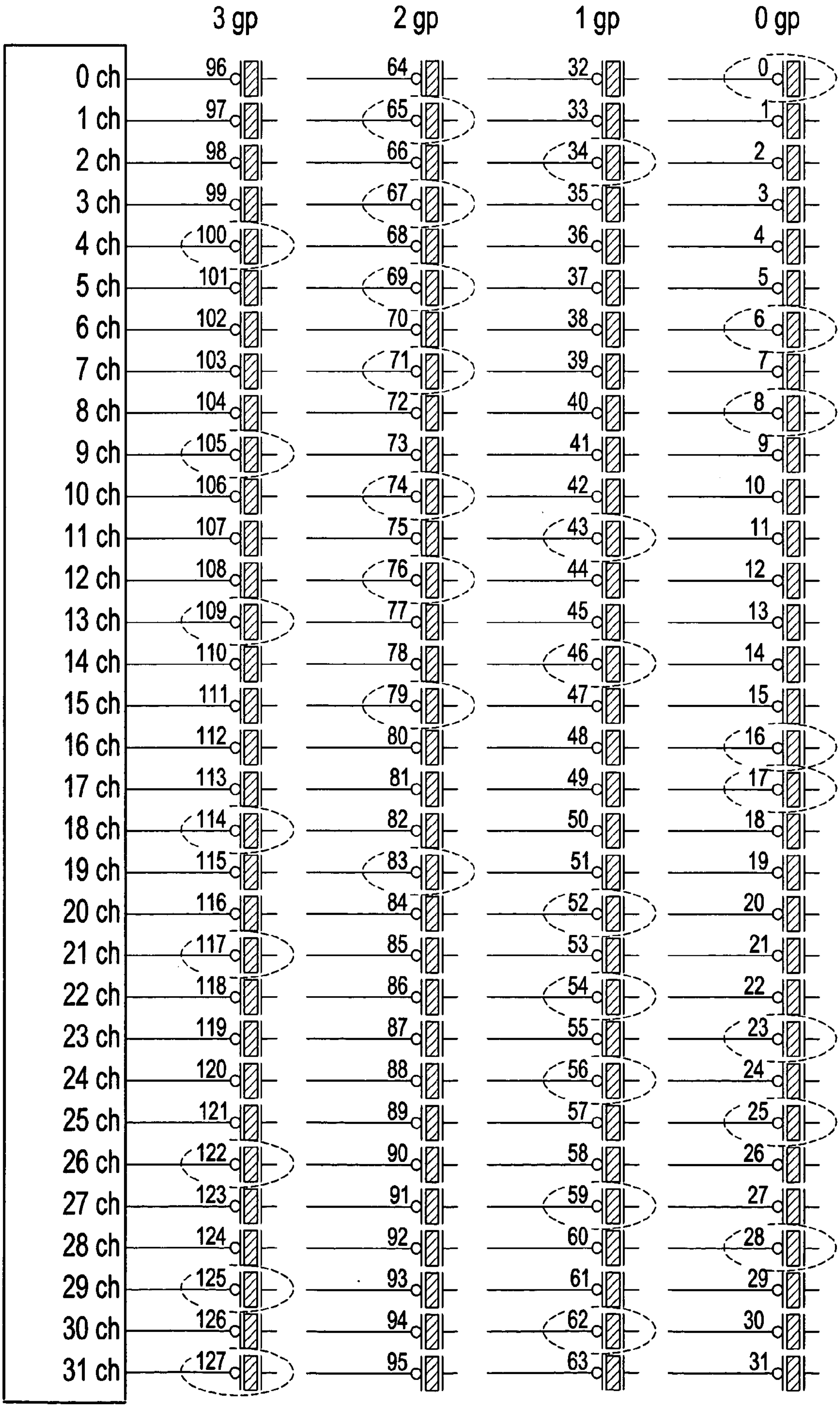
L=128

FIG. 12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12 ch
13 ch
14 ch
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27 ch
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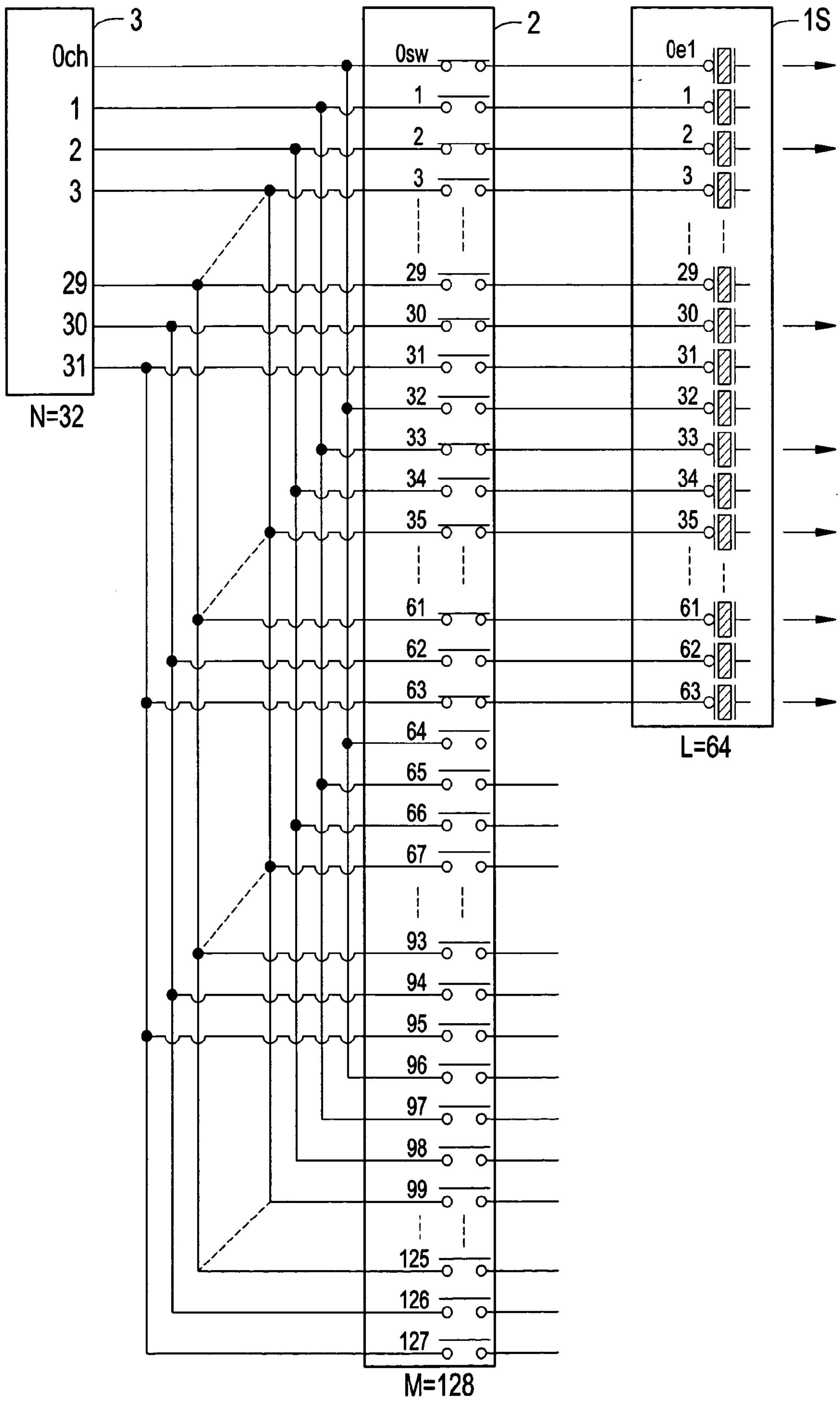
29 ch
30 ch
31 ch

FIG. 13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125
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M=128
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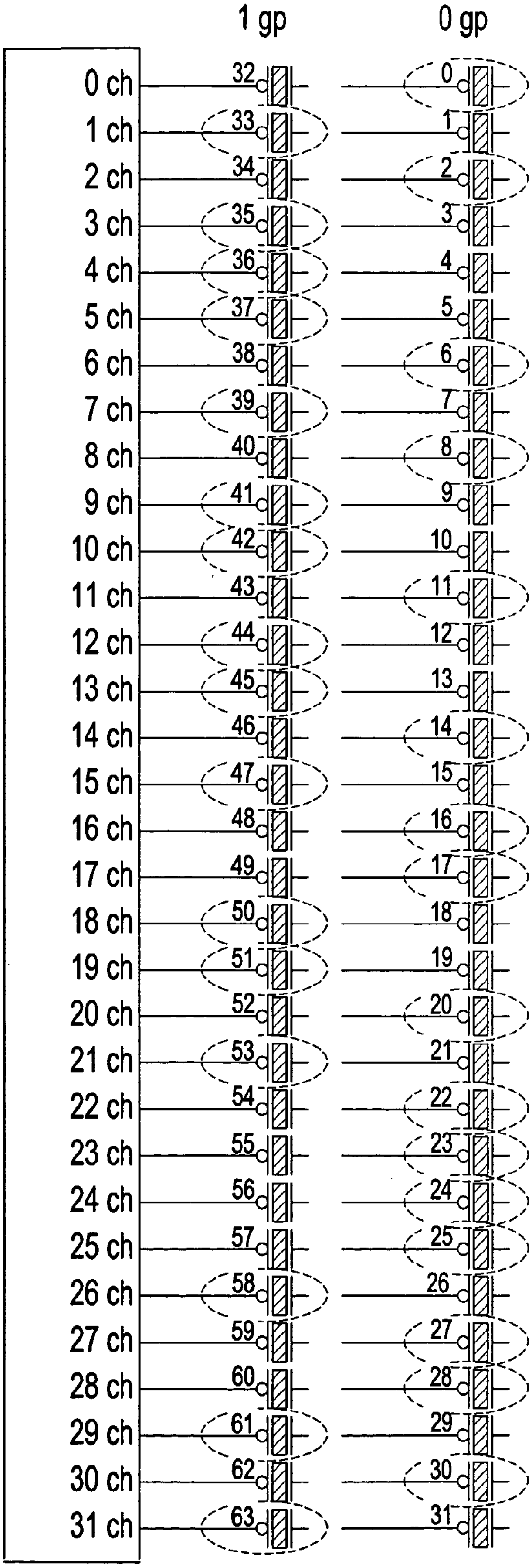
L=64

FIG. 14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# FIG. 15

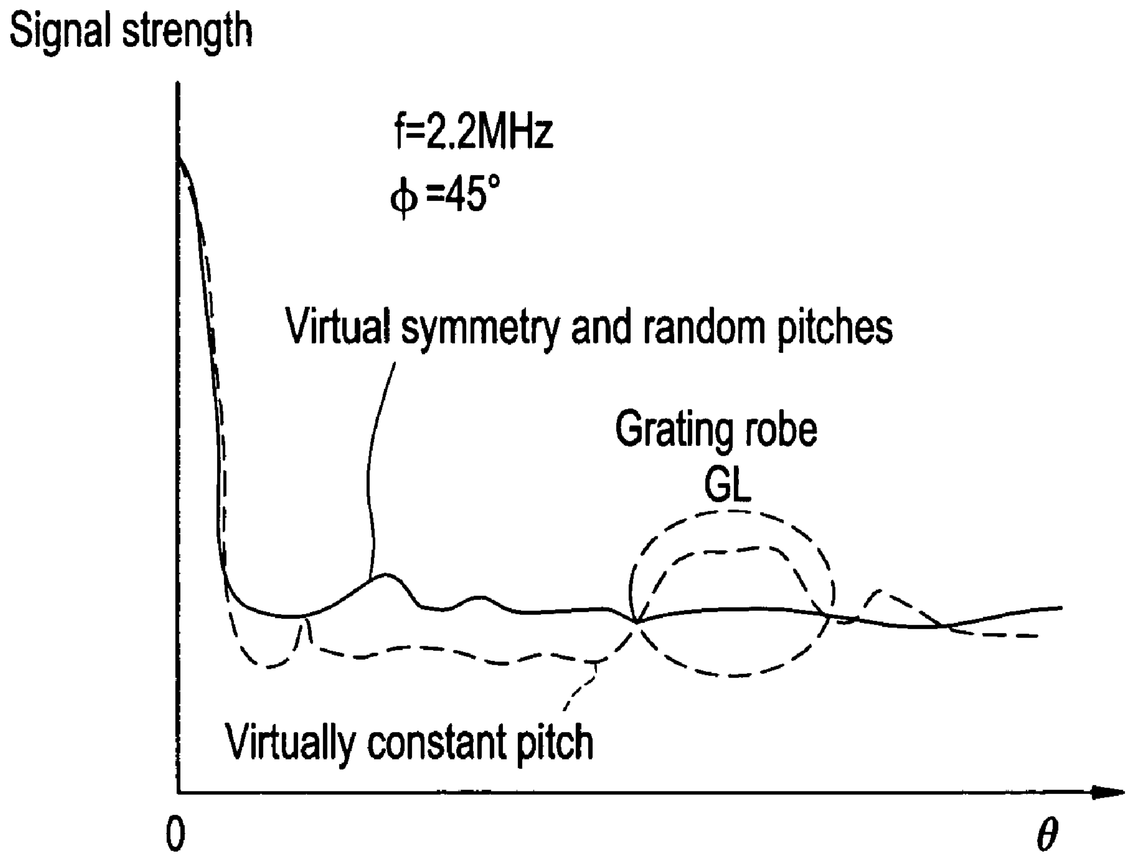
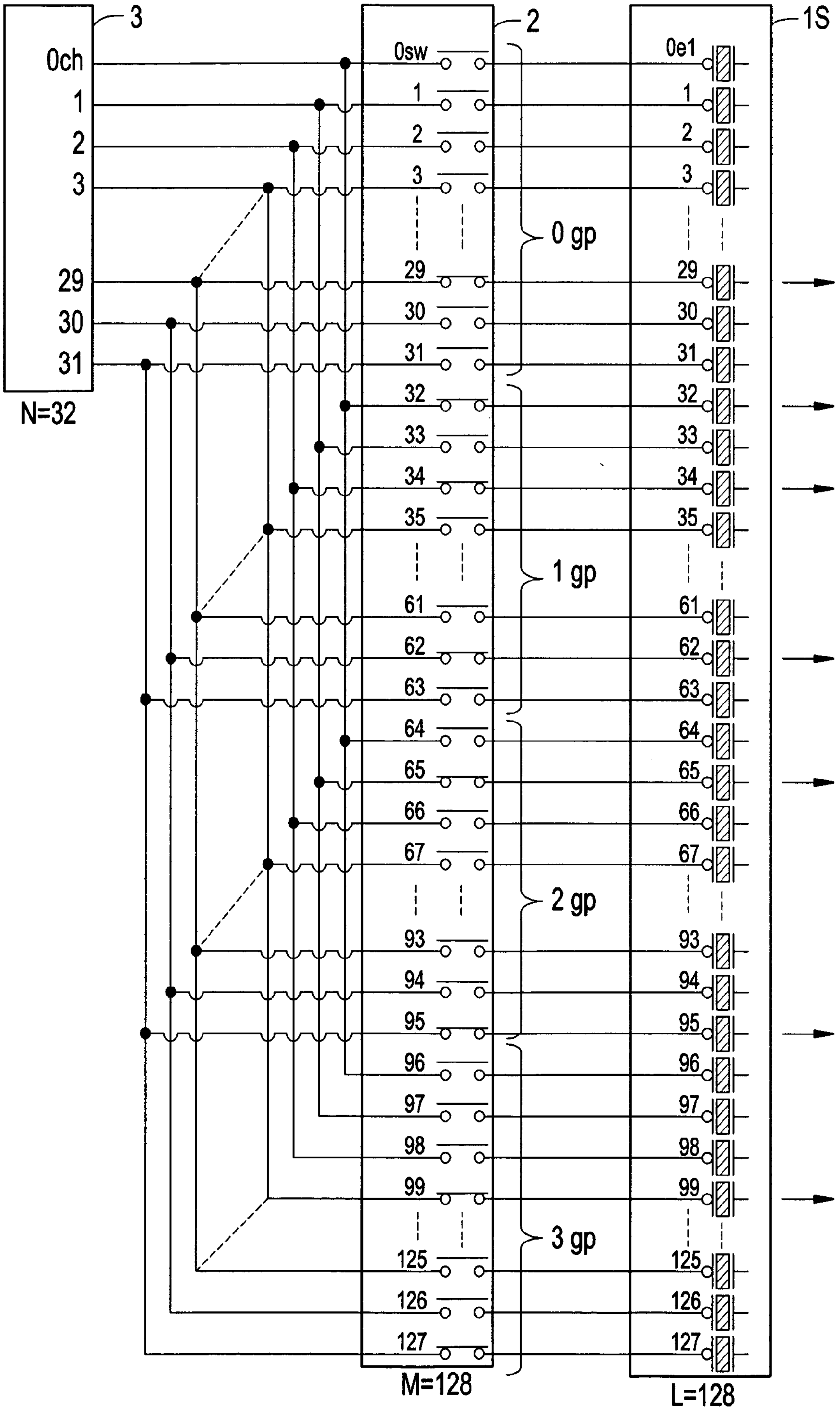

Signal strength
f=2.2MHz
$\phi$=45°
Virtual symmetry and random pitches
Grating robe
GL
Virtually constant pitch
0
$\theta$

FIG. 16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0 gp
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2 gp
3 gp
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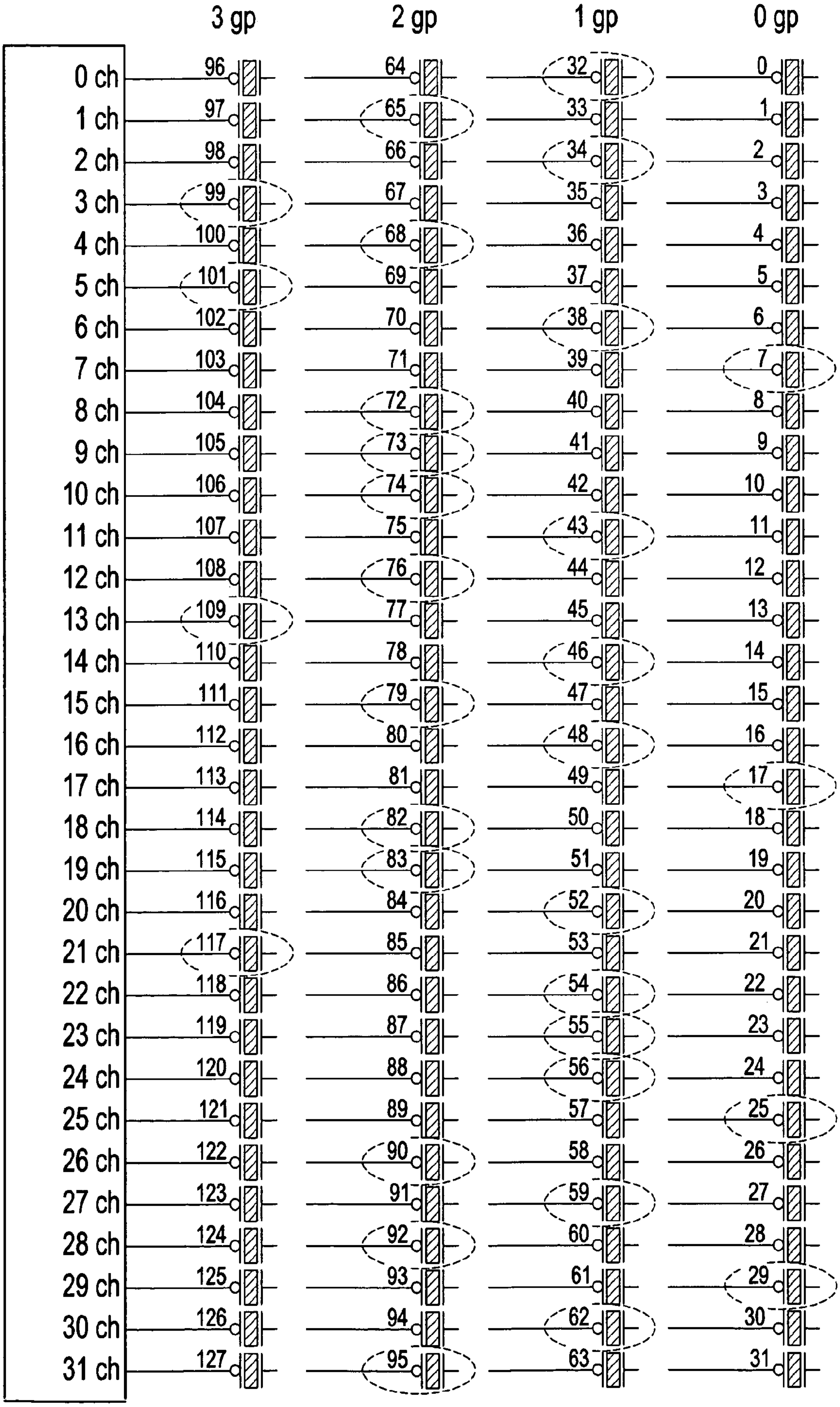
# FIG. 17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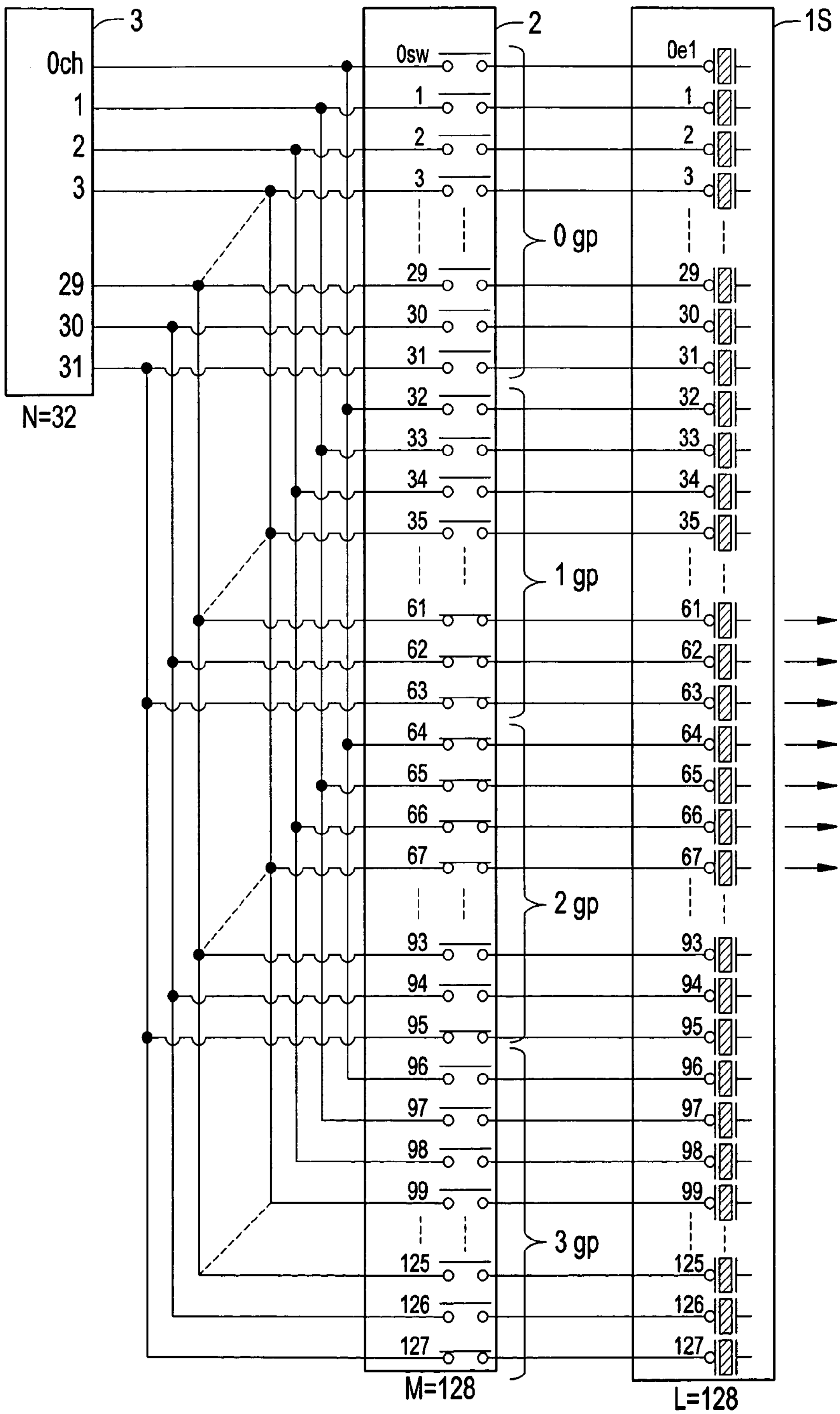
28 ch
29 ch
30 ch
31 ch

FIG. 18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127
M=128
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2 gp
3 gp
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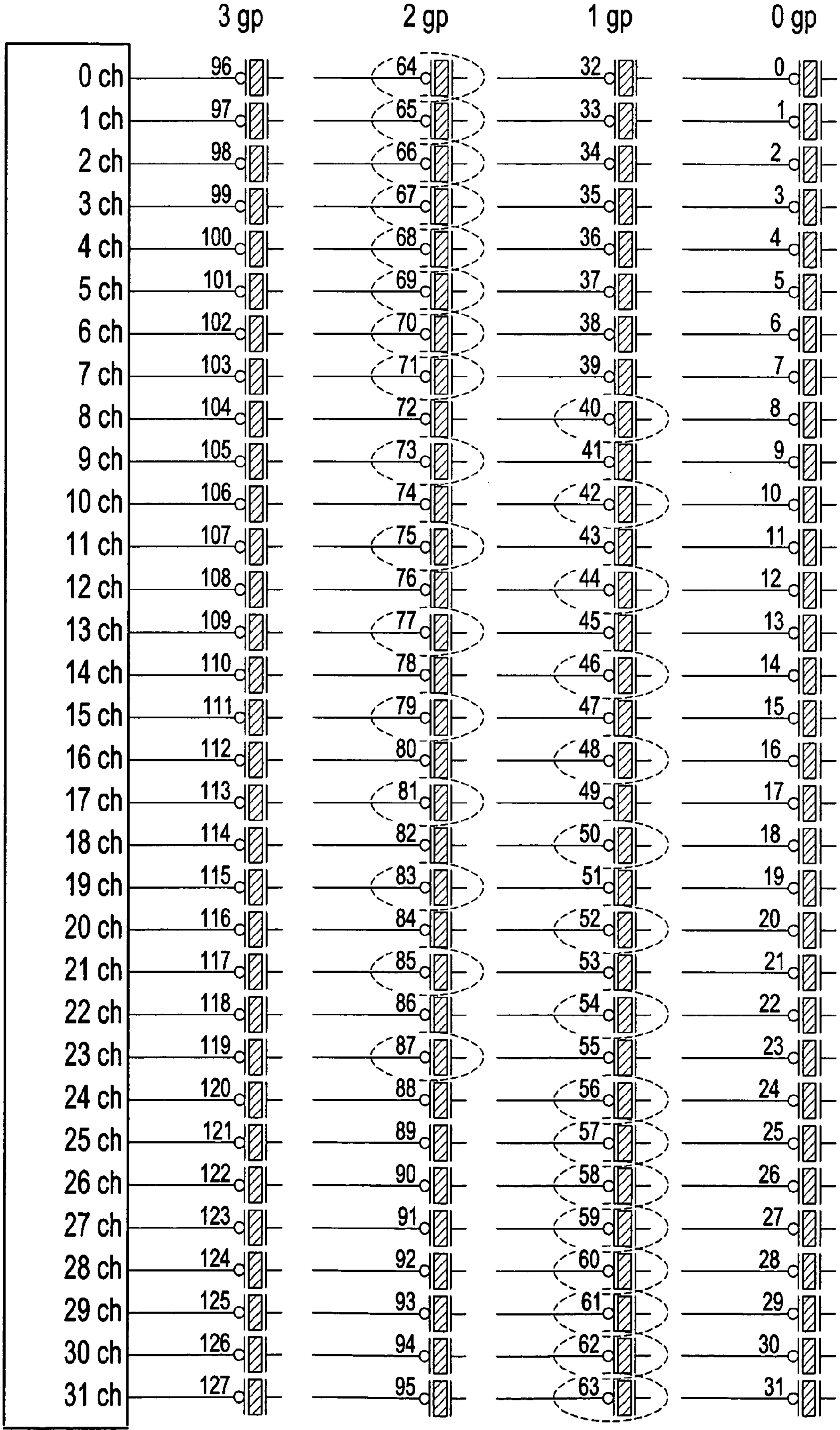
L=128

FIG. 19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0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

# METHOD OF SECTOR PROBE DRIVING AND ULTRASOUND DIAGNOSTIC APPARATUS

## BACKGROUND OF THE INVENTION

**[0001]** The present invention relates to a method of sector probe driving and an ultrasound diagnostic apparatus, and particularly to a method of sector probe driving and an ultrasound diagnostic apparatus which are capable of driving a sector probe by using the transmitter/receiver for a convex probe and linear probe.

**[0002]** An ultrasound diagnostic apparatus using a convex probe and linear probe is equipped with a transmitter/receiver having a 0th through 31st channels and a high voltage switch including a 0th through 127th switches, for example, with each n-th channel, where n takes 0 through 31, being connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch. The 0th through 127th switches are connected to the 0th through 127th vibration elements, respectively, of the convex probe and linear probe. Only the 0th through 31 st switches are turned on to drive the 0th through 31st vibration elements, and next, only the 1st through 32nd switches are turned on to drive the 1st through 32nd vibration elements, and next, only the 2nd through 33rd switches are turned on to drive the 2nd through 33rd vibration elements, and so on, so that 32 vibration elements are driven at a time in turn, thereby implementing the linear scanning or convex scanning. An ultrasound diagnostic apparatus using a sector probe is equipped with a transmitter/receiver having a 0th through 63rd channels, for example, with the 0th through 63rd channels being connected to the 0th through 63rd vibration elements, respectively, of the sector probe. The 0th through 63rd channels drive the 0th through 63rd vibration elements by being timed with different delay times, thereby implementing the sector scanning. (Refer to non-patent publication 1, for example.)

**[0003]** [Non-patent publication 1]

**[0004]** "Medical Ultrasound Apparatus Handbook", FIG.3.59 on p.94, FIG.3.64 on p.97, and FIG.3.76 on p.102, edited by Electronic Industries Association of Japan, published by Corona Corp. for the first revision on Jan. 20, 1997.

**[0005]** The transmitter/receiver for a convex probe and linear probe has a smaller number of channels than the number of vibration elements of the convex probe and linear probe, as mentioned previously. Whereas, the transmitter/receiver for a sector probe has channels larger than or equal in number to the vibration elements of the sector probe. Due to this difference, the conventional ultrasound diagnostic apparatus has a problem of incapacity for driving a sector probe by using the transmitter/receiver for a convex probe and linear probe.

**[0006]** Specifically, an ultrasound diagnostic apparatus intended for the diagnosis of internal medicine and superficial tissue has a transmitter/receiver of 32 channels for example and uses a convex probe and linear probe of 128 vibration elements for example. Whereas, an ultrasound diagnostic apparatus intended for the diagnosis of circulatory organs has a transmitter/receiver of 64 channels for example and uses a sector probe of 64 vibration elements for example. It has not been possible for the former ultrasound diagnostic apparatus to use the sector probe of the latter apparatus.

## SUMMARY OF THE INVENTION

**[0007]** Accordingly, it is an object of the present invention is to provide a method of sector probe driving and an ultrasound diagnostic apparatus which are capable of driving a sector probe by using the transmitter/receiver for a convex probe and linear probe.

**[0008]** At a first viewpoint, the present invention resides in a method of driving a sector probe having vibration elements of L in number through channels of N in number of a transmitter or receiver for a convex probe and linear probe, where L is larger than N, the method being characterized by selecting and driving vibration elements of N in number which are located at a constant pitch or virtually constant pitch in the alignment of vibration elements.

**[0009]** The sector probe driving method of the first viewpoint selects and drives vibration elements of N in number, which is equal to the number of channels of the transmitter or receiver, located at a constant pitch or virtually constant pitch in the alignment of L vibration elements of the sector probe. The resulting ability of sector scanning enables the sector probe driving by use of the transmitter/receiver for the convex probe and linear probe. A wide distribution of vibration elements allows a large aperture.

**[0010]** At a second viewpoint, the present invention resides in a method of driving a sector probe having vibration elements of L in number through channels of N in number of a transmitter or receiver for a convex probe and linear probe, where L is larger than N, the method being characterized by selecting and driving vibration elements of N in number which are located at the middle or nearly middle of the alignment of vibration elements.

**[0011]** The sector probe driving method of the second viewpoint selects and drives vibration elements of N in number, which is equal to the number of channels of the transmitter or receiver, located at the middle or nearly middle of the alignment of L vibration elements of the sector probe. The resulting ability of sector scanning enables the sector probe driving by use of the transmitter/receiver for the convex probe and linear probe. A dense distribution of vibration elements suits for imaging of a shallow portion.

**[0012]** At a third viewpoint, the present invention resides in a method of driving a sector probe having vibration elements of L in number through channels of N in number of a transmitter or receiver for a convex probe and linear probe, where L is larger than N, the method being characterized by selecting and driving vibration elements of N in number at random out of the L vibration elements.

**[0013]** The sector probe driving method of the third viewpoint selects and drives vibration elements of N in number, which is equal to the number of channels of the transmitter or receiver, at random out of the L vibration elements of the sector probe.

**[0014]** The resulting ability of sector scanning enables the sector probe driving by use of the transmitter/receiver for the convex probe and linear probe. An irregular distribution of vibration elements alleviates the emergence of grating robe.

**[0015]** At a fourth viewpoint, the present invention resides in a method of driving a sector probe having vibration elements of L in number through channels of N in number of a transmitter or receiver for a convex probe and linear probe, where L is larger than N, the method being characterized by selecting and driving vibration elements of N/2 in number at random out of vibration elements of L/2 in number which are located on one side of the middle of the alignment of vibration elements and vibration elements of N/2 in number which are located symmetrically or nearly symmetrically to the first-selected vibration elements across the middle of the alignment of vibration elements.

[0016] The sector probe driving method of the fourth viewpoint selects and drives vibration elements of N/2 in number, which is half the number of channels of the transmitter or receiver, at random out of the L/2 vibration elements which are located on one side of the middle of the alignment of vibration elements of the sector probe.

[0017] The method also selects and drives vibration elements of N/2 in number which are located symmetrically or nearly symmetrically to the first-selected vibration elements across the middle of the alignment of vibration elements. The resulting ability of sector scanning enables the sector probe driving by use of the transmitter/receiver for the convex probe and linear probe. An irregular distribution of the half vibration elements alleviates the emergence of grating robe. In addition, a virtually symmetric distribution of vibration elements to be driven simplifies the setting of delay times for sector scanning.

[0018] At a fifth viewpoint, the present invention resides in a method of sector probe driving, which is derived from the above-mentioned arrangement and is characterized by raising the probability of selection of vibration elements which are located at the middle or nearly middle of the alignment of vibration elements.

[0019] A fairly dense distribution of vibration elements to be driven at the middle or nearly middle of the alignment of vibration elements, which is achieved by the sector probe driving method of the fifth viewpoint, suits for imaging of a shallow portion.

[0020] At a sixth viewpoint, the present invention resides in a method of sector probe driving, which is derived from the above-mentioned arrangement and is characterized by lowering the probability of selection in contiguous order of vibration elements which are located far from the middle of the alignment of vibration elements.

[0021] The sector probe driving method of the sixth viewpoint has a scarce distribution of vibration elements to be driven at positions far from the middle of the alignment of vibration elements. In other words, a relatively dense element distribution nearly at the middle suits for imaging of a shallow portion.

[0022] At a seventh viewpoint, the present invention resides in a method of driving a sector probe having vibration elements of L in number through channels of N in number of a transmitter or receiver for a convex probe and linear probe, where L is larger than N, the method being characterized by selecting and driving contiguous vibration elements of C in number which are located at the middle or nearly middle of the alignment of vibration elements and every b-th element among vibration elements of N-C in number which are located on both sides of the C vibration elements.

[0023] The sector probe driving method of the seventh viewpoint selects and drives vibration elements of C in number which are located at the middle or nearly middle of the alignment of L vibration elements of the sector probe. The method also selects and drives every b-th element among vibration elements of N-C in number which are located on both sides of the C vibration elements. The resulting ability of sector scanning enables the sector probe driving by use of the transmitter/receiver for the convex probe and linear probe. A dense distribution of C vibration elements at the middle or nearly middle of the alignment of vibration elements suits for imaging of a shallow portion. In addition, a relatively large aperture is allowed.

[0024] At an eighth viewpoint, the present invention resides in a method of sector probe driving, which is characterized by selecting one of at least two of the sector probe driving methods derived from the above-mentioned arrangement depending on at least one of the ultrasound diagnostic mode, scanning depth, scanning angle, and ultrasound frequency.

[0025] The sector probe driving method of the eighth viewpoint can select one of the above-mentioned sector probe driving methods of the first through sixth viewpoints which matches with the ultrasound diagnostic mode, scanning depth, scanning angle, or ultrasound frequency.

[0026] At a ninth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where $N<L\leqq M$, which are aligned in the order from the 0th through (L−1)th vibration elements, each n-th channel, where n takes 0 through N-1, being connected in parallel fashion to the n-th switch, the switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively, each set of a m-th through (m+N−1)th switches, where m takes 0, N, . . . , (k−1)N, being united to be a (m/N)th switch group.

[0027] The ultrasound diagnostic apparatus further comprises a switch control means which selects two switch groups in which all switches are connected with vibration elements, turns on only odd-numbered switches for one switch group, turns on only even-numbered switches for another switch group, and turns off switches which are of other switch groups and connected with vibration elements.

[0028] The ultrasound diagnostic apparatus of the ninth viewpoint selects consecutive vibration elements of 2N in number out of the L vibration elements, and is capable of implementing the sector probe driving method of the first viewpoint for the 2N consecutive vibration elements.

[0029] At a tenth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where $N<L\leqq M$, which are aligned in the order from the 0th through (L−1)th vibration elements, each n-th channel, where n takes 0 through N-1, being connected in parallel

fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L-1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively. The ultrasound diagnostic apparatus further comprises a switch control means which turns on the (L/2−N/2)th through (L/2+N/2−1)th switches, and turns off other switches which are connected with vibration elements.

**[0030]** The ultrasound diagnostic apparatus of the tenth viewpoint is capable of implementing the sector probe driving method of the second viewpoint properly.

**[0031]** At an eleventh viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where N<L≦M, which are aligned in the order from the 0th through (L−1)th vibration elements, each n-th channel, where n takes 0 through N-1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively. The ultrasound diagnostic apparatus further comprises a switch control means which selects, out of the 0th through (L-I)th switches, vibration elements of N in number which are located at a constant pitch or virtually constant pitch and are not connected to same channels and turns on the N switches only, and turns off other switches which are connected with vibration elements.

**[0032]** The ultrasound diagnostic apparatus of the eleventh viewpoint is capable of implementing the sector probe driving method of the first viewpoint properly.

**[0033]** At a twelfth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where N<L≦M, which are aligned in the order from the 0th through (L−1)th vibration elements, each n-th channel, where n takes 0 through N−1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively. The ultrasound diagnostic apparatus further comprises a switch control means which selects, out of the 0th through (L−1)th switches, vibration elements of N in number which are located at random and are not connected to same channels and turns on the N switches only, and turns off other switches which are connected with vibration elements.

**[0034]** The ultrasound diagnostic apparatus of the twelfth viewpoint is capable of implementing the sector probe driving method of the third viewpoint properly.

**[0035]** At a thirteenth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where N<L≦M, which are aligned in the order from the 0th through (L−1)th vibration elements, each n-th channel, where n takes 0 through N-1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively. The ultrasound diagnostic apparatus further comprises a switch control means which selects, out of the 0th through (L/2-1)th switches, vibration elements of N/2 in number which are located at random and are not connected to same channels and turns on the associated N/2 switches only, and selects, out of the (L/2)th through (L−1)th switches, switches of N/2 in number which correspond to vibration elements located symmetrically or nearly symmetrically to the vibration elements which correspond to the turned-on switches among the 0th through (L/2−1)th switches across the middle of the alignment of vibration elements and are not connected to same channels and to the channels used by the turned-on switches among the 0th through (L/2−1)th switches and turns on these N/2 switches only.

**[0036]** The ultrasound diagnostic apparatus of the thirteenth viewpoint is capable of implementing the sector probe driving method of the fourth viewpoint properly.

**[0037]** At a fourteenth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is derived from the above-mentioned arrangement, the apparatus being characterized in that the switch control means selects switches which correspond to vibration elements located at the middle or nearly middle of the alignment of vibration elements at higher probabilities than probabilities of selection of switches which correspond to vibration elements located far from the middle of the alignment of vibration elements.

**[0038]** The ultrasound diagnostic apparatus of the fourteenth viewpoint is capable of implementing the sector probe driving method of the fifth viewpoint properly.

**[0039]** At a fifteenth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is derived from the above-mentioned arrangement, the apparatus being characterized in that the switch control means selects, out of switches corresponding to vibration elements which are located far from the middle of the alignment of vibration elements, one set of odd-numbered switches or even-numbered switches at higher probabilities than probabilities of selection of another set of switches.

**[0040]** The ultrasound diagnostic apparatus of the fifteenth viewpoint is capable of implementing the sector probe driving method of the sixth viewpoint properly.

**[0041]** At a sixteenth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where N<L≦M, which are aligned in the order from the 0th

through (L−1)th vibration elements, each n-th channel, where n takes 0 through N-1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively. The ultrasound diagnostic apparatus further comprises a switch control means which turns on a (L/2-C/2)th through (L/2+C/2−1)th switches, turns on every b-th switch among the (L/2-C/2-(b+1)(N−C)/2)th through (L/2−C/2−1 )th switches, turns on every b-th switch among the (L/2-C/2+b)th through (L/2+C/2−1+(b+1)(N−C)/2)th switches, and turns off other switches which are connected with vibration elements.

[0042] The ultrasound diagnostic apparatus of the sixteenth viewpoint is capable of implementing the sector probe driving method of the seventh viewpoint properly.

[0043] At a seventeenth viewpoint, the present invention resides in an ultrasound diagnostic apparatus which is characterized by comprising: a transmitter or receiver having a 0th through (N−1)th channels; a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and a sector probe having vibration elements of L in number, where $N<L\leqq M$, which are aligned in the order from the 0th through (L−1)th vibration elements, each n-th channel, where n takes 0 through N-1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch, the 0th through (L-1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively. The ultrasound diagnostic apparatus further comprises: at least two of the switch control means of the above-mentioned arrangement; and a switch control mode selection means which selects one of the two switch control means depending on at least one of the ultrasound diagnostic mode, scanning depth, scanning angle, and ultrasound frequency.

[0044] The ultrasound diagnostic apparatus of the seventeenth viewpoint is capable of implementing the sector probe driving method of the eighth viewpoint properly.

[0045] According to the inventive sector probe driving method and ultrasound diagnostic apparatus, it is possible to implement the sector scanning properly by driving the sector probe by use of the transmitter/receiver for the convex probe and linear probe.

[0046] Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

## BRIEF DESCRIPTION OF DRAWINGS

[0047] **FIG. 1** is a block diagram showing the arrangement of the ultrasound diagnostic apparatus of the first embodiment.

[0048] **FIG. 2** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the first embodiment.

[0049] **FIG. 3** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the first embodiment.

[0050] **FIG. 4** is an explanatory diagram of the beam center angle $\phi$ and deflection angle $\theta$.

[0051] **FIG. 5** is a characteristic graph of the signal strength with respect to the deflection angle $\theta$ when the beam center angle $\phi$ is 30° and the signal strength with respect to the deflection angle $\theta$ when the beam center angle $\phi$ is 45°.

[0052] **FIG. 6** is a characteristic graph of the signal strength with respect to the deflection angle $\theta$ when the frequency f is 2.2 MHz and the signal strength with respect to the deflection angle $\theta$ when the frequency f is 3 MHz.

[0053] **FIG. 7** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the second embodiment.

[0054] **FIG. 8** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the second embodiment.

[0055] **FIG. 9** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the third embodiment.

[0056] **FIG. 10** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the third embodiment.

[0057] **FIG. 11** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the fourth embodiment.

[0058] **FIG. 12** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the fourth embodiment.

[0059] **FIG. 13** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the fifth embodiment.

[0060] **FIG. 14** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the fifth embodiment.

[0061] **FIG. 15** is a characteristic graph of the signal strength with respect to the deflection angle $\theta$ when vibration elements which are distributed at a virtually constant pitch in the alignment of vibration elements are driven and the signal strength with respect to the deflection angle $\theta$ when vibration elements which are distributed at random in a half of the alignment of vibration elements and distributed virtually symmetrically in the middle of the alignment of vibration elements are driven.

[0062] **FIG. 16** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the sixth embodiment.

[0063] **FIG. 17** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the sixth embodiment.

[0064] **FIG. 18** is an explanatory diagram showing the connection among the sector probe, high voltage switch, and transmitter/receiver based on the seventh embodiment.

[0065] **FIG. 19** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver and the vibration elements of the sector probe based on the seventh embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

[0066] The present invention will be explained in more detail in regard to illustrated embodiments. The present invention is not confined to these embodiments however.

[0067] First Embodiment:

[0068] **Fig. 1** is a block diagram showing an ultrasound diagnostic apparatus **100** based on a first embodiment.

[0069] The ultrasound diagnostic apparatus **100** includes a convex probe **1C** having vibration elements of M in number, a linear probe **1L** having vibration elements of M in number, a sector probe **1S** having vibration elements of L in number, a high voltage switch **2** including switches of M in number, a transmitter/receiver **3** of N channels, a B/M mode processor **4**, a CFM (Color Flow Mapping) processor **5**, a PDI (Power Doppler Image) processor **6**, a DSC (Digital Scan Converter) **7**, a display device **8**, a controller **9**, and an input device **10**.

[0070] **FIG. 2** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of the first embodiment.

[0071] The parameters are set to be N=32, M=128 and L=64 in this embodiment.

[0072] Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

[0073] The sector probe **1S** has its 0th through 63rd vibration elements connected to the 0th through 63rd switches, respectively.

[0074] The controller **9** unites each set of a m-th through (m+31)th switches, where m takes 0,32,64 and 96, into a (m/32)th switch group, selects two switch groups in which all switches are connected with vibration elements, turns on only odd-numbered switches for one switch group, turns on only even-numbered switches for another switch group, and turns off switches which are of other switch groups and connected with vibration elements. Specifically, the controller **9** selects the 0th switch group and 1st switch group, turns on only the odd-numbered switches for the 0th switch group, and turns on only the even-numbered switches for the 1 st switch group.

[0075] Consequently, only the vibration elements of odd numbers 1,3, . . . ,31 among the vibration elements corresponding to the 0th switch group are driven, and only the vibration elements of even numbers 32,34, . . . ,62 among the vibration elements corresponding to the 1 st switch group are driven.

[0076] **FIG. 3** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the first embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

[0077] Only the vibration elements of odd numbers 1,3, . . . ,31 among the vibration elements corresponding to the 0th switch group are driven, and only the vibration elements of even numbers 32,34, . . . ,62 among the vibration elements corresponding to the 1 st switch group are driven.

[0078] **FIG. 3** reveals that 32 vibration elements located at a virtually constant pitch are driven selectively, and it becomes possible for the transmitter/receiver **3** to implement the sector scanning by using the sector probe **1S**. In addition, the apparatus can have a large aperture.

[0079] **FIG. 4** is an explanatory diagram of the beam center angle $\phi$ and the deflection angle $\theta$ from the beam center.

[0080] The beam center angle $\phi$ is the angle of beam center measured from the central axis Ax of the sector probe **1S**.

[0081] The deflection angle $\theta$ from the beam center is the angle of sound beam measured from the beam center Bc.

[0082] **FIG. 5** is a characteristic graph of the signal strength with respect to the deflection angle $\theta$ when the beam center angle $\phi$ is 30° and the signal strength with respect to the deflection angle $\theta$ when the beam center angle $\theta$ is 45°. The frequency fis 2.2 MHz.

[0083] **FIG. 5** reveals that no grating robe emerges when the beam center angle $\phi$ is 30°, while a grating robe GL emerges when the beam center angle $\phi$ is 45°. The graph reveals that the range of scanning angle is preferably set to be: beam center angle $|\phi| \leqq 37.5°$(middle of 300 and 45°) in order to prevent the emergence of grating robe.

[0084] **FIG. 6** is a characteristic graph of the signal strength with respect to the deflection angle $\theta$ when the frequency f is 2.2 MHz and the signal strength with respect to the deflection angle $\theta$ when the frequency is 3 MHz. The beam center angle $\phi$ is 30°.

[0085] **FIG. 6** reveals that no grating robe emerges when the frequency is 2.2 MHz, while a grating robe GL emerges when the frequency is 3 MHz. The graph reveals that the frequency is preferably set below 2.6 MHz (middle of 2.2 MHz and 3 MHz) in order to prevent the emergence of grating robe.

[0086] In harmonic imaging, in which a low transmission frequency is used and harmonic components scarcely arise at the sound pressure of grating robe, the range of scanning angle can be set to be: beam center angle $|\phi| \leqq 45°$ Second embodiment:

[0087] **FIG. 7** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of a second embodiment.

[0088] The parameters are set to be N=32, M=128 and L=64 in this embodiment.

[0089] Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

[0090] The sector probe **1S** has its 0th through 63rd vibration elements connected to the 0th through 63rd switches, respectively.

[0091] The controller **9** turns on the 16th through 47th switches and turns off other switches which are connected with vibration elements. Consequently, only the 16th through 47th vibration elements located in the central section of the alignment of vibration elements are driven.

[0092] **FIG. 8** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the second embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

[0093] Only the 16th through 47th vibration elements located in the central section of the alignment of vibration elements are driven.

[0094] **FIG. 8** reveals that selective driving of 32 contiguous vibration elements enables the sector scanning by use of the sector probe **1S**. In the B/M mode which uses the fundamental wave, an image of less grating robe can be obtained. Due to a small aperture, a deep portion has a low resolution. Therefore, this apparatus is preferably used for the observation of a shallow portion (e.g., in a depth of 12 cm or smaller) or for the CFM or PDI which do not require a high resolution.

[0095] Third embodiment:

[0096] **FIG. 9** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of a third embodiment.

[0097] The parameters are set to be N=32, M=128 and L=128 in this embodiment.

[0098] Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

[0099] The sector probe **1S** has its 0th through 127th vibration elements connected to the 0th through 127th switches, respectively.

[0100] Each set of a m-th through (m+31)th switches, where m takes 0,32,64 and 96), are united to be a (m/32)th switch group.

[0101] The controller **9** selects 32 vibration elements which are located at a constant pitch or virtually constant pitch and are not connected to same channels, turns on the 32 switches only, and turns off other switches which are connected with vibration elements. Consequently, only 32 vibration elements which are distributed at a constant pitch or virtually constant pitch in the alignment of vibration elements are driven.

[0102] **FIG. 10** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the third embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

[0103] **FIG. 10** reveals that for each n-th channel, where n takes 0 through 31, only a switch which belongs to a mod{n/4}th switch group is turned on to drive a corresponding vibration element, where mod {$\alpha$, $\beta$} is a function which gives the modulus of $\alpha/\beta$.

[0104] More generally, for each n-th channel, where n takes 0 through N, only a switch which belongs to a mod{n/k}th switch group, where k=M/N, is turned on.

[0105] The third embodiment has the similar operational characteristics as the first embodiment.

[0106] Fourth Embodiment:

[0107] **Fig. 11** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of a fourth embodiment.

[0108] The parameters are set to be N=32, M=128 and L=128 in this embodiment.

[0109] Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

[0110] The sector probe **1S** has its 0th through 127th vibration elements connected to the 0th through 127th switches, respectively.

[0111] Each set of a m-th through (m+31)th switches, where m takes 0,32,64 and 96) are united to be a (m/32)th switch group.

[0112] The controller **9** selects, out of the 0th through 127th switches,32 vibration elements which are located at random and are not connected to same channels, turns on the 32 switches only, and turns off other switches which are connected with vibration elements. Consequently, only 32 vibration elements which are distributed at random in the alignment of vibration elements are driven.

[0113] **FIG. 12** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the fourth embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

[0114] **FIG. 12** reveals that one of the four switch groups is selected at random for each channel, and only a switch which belongs to the selected switch group is turned on to drive the corresponding vibration element.

[0115] As shown in **FIG. 12**, selective driving of 32 vibration elements which are distributed at random in the alignment of vibration elements enables the sector scanning by use of the sector probe **1S**. Based on the irregularity in pitch of the vibration elements to be driven, an image of less grating robe can be obtained.

[0116] Fifth embodiment:

[0117] **FIG. 13** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of a fifth embodiment.

[0118] The parameters are set to be N=32, M=128 and L=64 in this embodiment.

[0119] Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

[0120] The sector probe **1S** has its 0th through 63rd vibration elements connected to the 0th through 63rd switches, respectively Each set of a m-th through (m+31)th switches, where m takes 0,32,64 and 96), are united to be a (m/32)th switch group.

[0121] The controller **9** selects, out of the 0th through 31st switches,16 vibration elements which are located at random and are not connected to same channels, and turns on the associated 16 switches only. Next, the controller **9** selects, out of the 32nd through 63rd switches,16 switches which correspond to vibration elements located symmetrically or nearly symmetrically to the vibration elements which correspond to the turned-on switches among the 0th through 31st switches across the middle of the alignment of vibration elements and are not connected to same channels and to the channels used by the turned-on switches among the 0th through 31st switches, and turns on only these 16 switches. Consequently, only 32 vibration elements which are distributed at random in a half of the alignment of vibration elements and distributed virtually symmetrically in the middle of the alignment of vibration elements are driven.

**[0122]** **FIG. 14** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the fifth embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

**[0123]** **FIG. 14** reveals that 16 vibration elements are selected at random out of the vibration elements of the 0th switch group, and only the switches corresponding to these vibration elements are turned on to drive the corresponding vibration elements.

**[0124]** In addition, switches which correspond to the channels of the turned-off switches of the 0th switch group are selected out of the vibration elements of the 1 st switch group, and only these switches are turned on to drive the corresponding vibration elements.

**[0125]** As shown in **FIG. 14**, selective driving of 32 vibration elements, which are distributed at random in a half of the alignment of vibration elements and distributed virtually symmetrically in the middle of the alignment of vibration elements, enables the sector scanning by use of the sector probe **1S**.

**[0126]** **FIG. 15** is a characteristic graph of the signal strength with respect to the deflection angle θ when vibration elements distributed at a virtually constant pitch in the alignment of vibration elements are driven (virtually constant pitch: first embodiment), and the signal strength with respect to the deflection angle θ when vibration elements, which are distributed at random in a half of the alignment of vibration elements and distributed virtually symmetrically in the middle of the alignment of vibration elements, are driven (virtual symmetry and random pitches: fifth embodiment). The frequency f is 2.2 MHz and the beam center angle φ is 45°.

**[0127]** **FIG. 15** reveals that although the case of “virtual symmetry and random pitches” is inferior to the case of “virtually constant pitch” in the floor section of boom profile, it does not create a grating robe. Accordingly, the vibration element selection at “virtuall symmetry and random pitches” is found to be useful without problems for any imaging mode.

**[0128]** Sixth embodiment:

**[0129]** **FIG. 16** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of a sixth embodiment.

**[0130]** The parameters are set to be N=32, M=128 and L=128 in this embodiment.

**[0131]** Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

**[0132]** The sector probe **1S** has its 0th through 127th vibration elements connected to the 0th through 127th switches, respectively.

**[0133]** Each set of a m-th through (m+31)th switches, where m takes 0,32,64 and 96), are united to be a (m/32)th switch group.

**[0134]** The controller **9** selects, out of the 0th through 63rd switches,16 vibration elements which are located at random and are not connected to same channels, and turns on these 16 switches only. At this time, switches corresponding to vibration elements which are located at the middle or nearly middle of the alignment of vibration elements are selected at higher probabilities than probabilities of selection of switches corresponding to vibration elements which are located far from the middle of the alignment of vibration elements. Among the switches corresponding to the vibration elements which are located far from the middle of the alignment of vibration elements, odd-numbered switches are selected at high probabilities than probabilities of selection of even-numbered switches. Next, the controller **9** selects, out of the 64th through 127th switches,16 switches which correspond to vibration elements located symmetrically or nearly symmetrically to the vibration elements which correspond to the turned-on switches among the 0th through 63rd switches across the middle of the alignment of vibration elements and are not connected to same channels and to the channels used by the turned-on switches among the 0th through 63rd switches, and turns on only these 16 switches. Consequently, only 32 vibration elements which are distributed at random in a half of the alignment of vibration elements and distributed virtually symmetrically in the middle of the alignment of vibration elements are driven.

**[0135]** **FIG. 17** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the sixth embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

**[0136]** **FIG. 17** reveals that four vibration elements are selected at random out of the odd-numbered vibration elements of the 0th switch group,12 vibration elements are selected at random out of the vibration elements of the 1st switch group, and only the switches corresponding to these vibration elements are turned on to drive the corresponding vibration elements. Out of the switches of the 2nd switch group, switches which correspond to vibration elements located symmetrically or nearly symmetrically to the vibration elements which correspond to the turned-on switches of the 1 st switch group are selected, and only these switches are turned on. Out of the switches of the 3rd switch group, switches which correspond to vibration elements located symmetrically or nearly symmetrically to the vibration elements which correspond to the turned-on switches of the 0th switch group are selected, and only these switches are turned on. The vibration elements corresponding to these switches are driven.

**[0137]** As shown in **FIG. 17**, selective driving of 32 vibration elements, which are distributed at random (on condition that the distribution is more dense as the position is nearer to the middle) in a half of the alignment of vibration elements and distributed virtually symmetrically in the middle of the alignment of vibration elements, enables the sector scanning by use of the sector probe **1S**. Based on the dense distribution of vibration elements to be driven in the middle section of the alignment of vibration elements and the distribution of vibration elements to reach the ends of the alignment of vibration elements so that the aperture can be fairly large, the sixth embodiment is useful without problems for any imaging mode.

**[0138]** Seventh embodiment:

**[0139]** **FIG. 18** is an explanatory diagram showing the connection among the sector probe **1S**, high voltage switch **2**, and transmitter/receiver **3** of a seventh embodiment.

**[0140]** The parameters are set to be N=32, M=128 and L=128 in this embodiment.

**[0141]** Each n-th channel, where n takes 0 through 31, is connected in parallel fashion to the n-th switch, the (n+32)th switch, . . . , and the (n+96)th switch.

**[0142]** The sector probe **1S** has its 0th through 127th vibration elements connected to the 0th through 127th switches, respectively.

**[0143]** The controller **9** turns on the 56th through 71st switches, turns on every second of the 40th through 54th switches, turns on every second of the 73rd through 87th switches, and turns off other switches which are connected to vibration elements.

**[0144]** Consequently,16 contiguous vibration elements located at the middle or nearly middle of the alignment of vibration elements and every second of 16 vibration elements located on both sides of these middle elements only are driven.

**[0145]** **FIG. 19** is an explanatory diagram showing the correspondence between the channels of the transmitter/receiver **3** and the vibration elements of the sector probe **1S** of the seventh embodiment. Vibration elements to be driven are marked by dashed ellipsoids.

**[0146]** **FIG. 19** reveals that 16 contiguous vibration elements located at the middle or nearly middle of the alignment of vibration elements and every second of 16 vibration elements located on both sides of these middle elements only are driven.

**[0147]** As shown in **FIG. 19**, based on a dense distribution of vibration elements to be driven in the middle section of the alignment of vibration elements and the provision of a fairly large aperture, the seventh embodiment is useful for any imaging mode without significant problems.

**[0148]** Eighth Embodiment:

**[0149]** It is preferable to make operative at least two of the first through seventh embodiments and carry out one of the two embodiments based on the selection by the controller **9** or the operator depending on at least one of the ultrasound diagnostic mode, scanning depth, scanning angle, and ultrasound frequency.

**[0150]** Other Embodiments:

**[0151]** Although the foregoing embodiments are on the assumption that the transmitter and receiver have equally N channels, the present invention can be applied to cases where the transmitter and receiver have different numbers of channels.

**[0152]** Specifically, the invention is applied by putting the number of channels of the transmitter to N, and, independently of this, the invention is applied by putting the number of channels of the receiver to N.

**[0153]** Many widely different embodiments of the invention may be configured without departing from the spirit and the scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.

**1**. A method of driving a sector probe having vibration elements of L in number through channels of N in number of a transmitter or receiver for a convex probe and linear probe, where L is larger than N, wherein said method selects and drives vibration elements of N in number at random out of the L vibration elements.

**2**. A sector probe driving method according to claim 1, wherein the probability of selection of vibration elements which are located at the middle or nearly middle of the alignment of vibration elements is raised.

**3**. A sector probe driving method according to claim 1, wherein the probability of selection in contiguous order of vibration elements which are located far from the middle of the alignment of vibration elements is lowered.

**4**. An ultrasound diagnostic apparatus comprising:

a transmitter or receiver having a 0th through (N−1)th channels;

a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and

a sector probe having vibration elements of L in number, where N<L<M, which are aligned in the order from the 0th through (L−1)th vibration elements,

each n-th channel, where n takes 0 through N-1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch,

the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively,

each set of a m-th through (m+N−1)th switches, where m takes 0, N, . . . , (k−1)N, being united to be a (m/N)th switch group,

said ultrasound diagnostic apparatus further comprising:

a switch control device which selects two switch groups in which all switches are connected with vibration elements, turns on only odd-numbered switches for one switch group, turns on only even-numbered switches for another switch group, and turns off switches which are of other switch groups and connected with vibration elements.

**5**. An ultrasound diagnostic apparatus comprising:

a transmitter or receiver having a 0th through (N−1)th channels;

a high voltage switch including a 0th through (M−1)th switches, where M has a value of N multiplied by a natural number k of 2 or larger; and

a sector probe having vibration elements of L in number, where N<L<M, which are aligned in the order from the 0th through (L−1)th vibration elements,

each n-th channel, where n takes 0 through N−1, being connected in parallel fashion to the n-th switch, the (n+N)th switch, . . . , and the (n+(k−1)N)th switch,

the 0th through (L−1)th vibration elements of the sector probe being connected to the 0th through (L−1)th switches, respectively,

said ultrasound diagnostic apparatus further comprising:

a switch control device which selects, out of the 0th through (L−1)th switches, vibration elements of N in number which are located at random and are not connected to same channels and turns on the N switches only, and turns off other switches which are connected with vibration elements.

**6**. An ultrasound diagnostic apparatus according to claim 5, wherein said switch control device selects switches which correspond to vibration elements located at the middle or nearly middle of the alignment of vibration elements at higher probabilities than probabilities of selection of switches which correspond to vibration elements located far from the middle of the alignment of vibration elements.

**7**. An ultrasound diagnostic apparatus according to claim 5, wherein said switch control device selects, out of switches corresponding to vibration elements which are located far from the middle of the alignment of vibration elements, one set of odd-numbered switches or even-numbered switches at higher probabilities than probabilities of selection of another set of switches.

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| [标]申请(专利权)人(译) | 雨宫SHINICHI | | |
| 申请(专利权)人(译) | 雨宫SHINICHI | | |
| 当前申请(专利权)人(译) | 通用电气医疗系统全球性技术公司，有限责任公司 | | |
| [标]发明人 | AMEMIYA SHINICHI | | |
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摘要(译)

凸探头和线性探头的发射器/接收器用于驱动扇形探头。通常，当使用凸探头和线性探头的超声诊断设备使用扇形探头时，它从数量为L的振动元件中选择数量为N的振动元件，其数量等于扇形探头的通道数（ N小于L），因此所选元件在振动元件的对准中以几乎恒定的间距分布，并且仅接通与所选振动元件连接的高压开关，以利用发射器实现扇形扫描/接收器。通过使用具有小于扇区探测器的振动元件的数量的信道的发送器/接收器，可以实现扇区扫描。