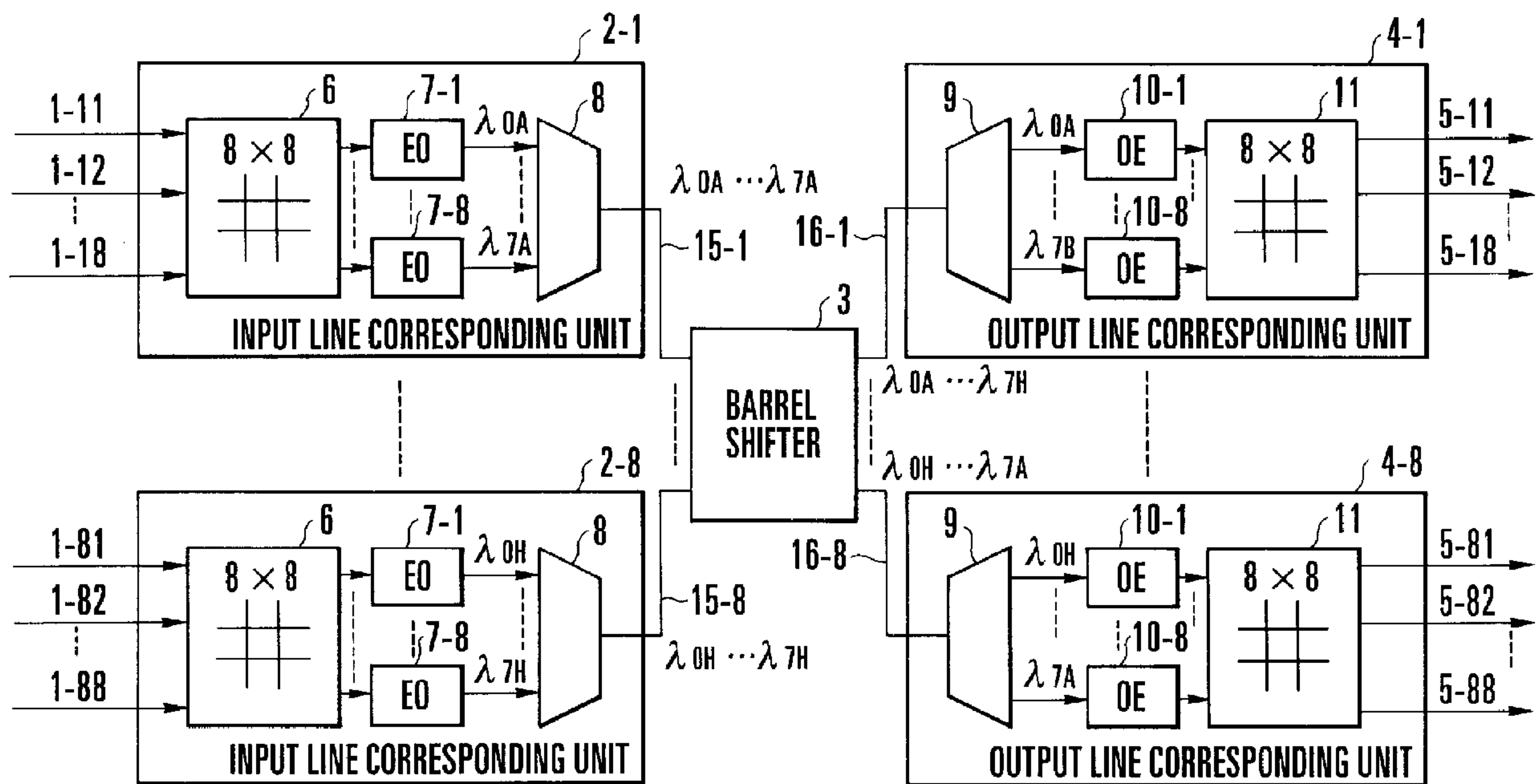




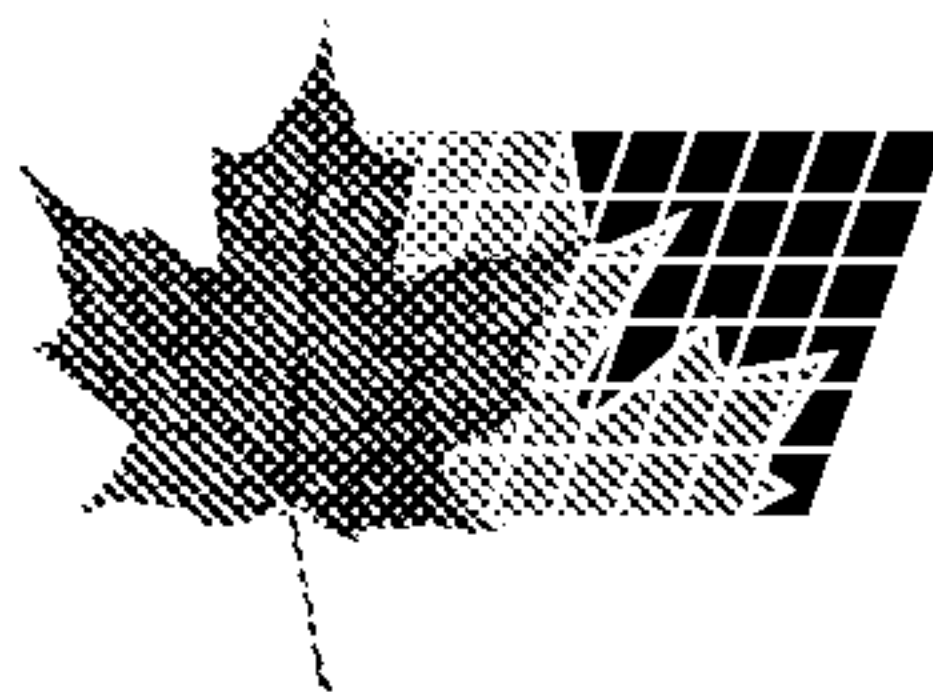
(72) YAMANAKA, Naoaki, JP
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(73) NIPPON TELEGRAPH AND TELEPHONE CORPORATION, JP
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(30) 1996/05/09 (115001/96) JP
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(54) **COMMUTATEUR ATM**
(54) **ATM SWITCH**



(57) Commutateur ATM comprenant un certain nombre d'unités homologues de lignes d'entrée, un certain nombre d'unités homologues de lignes de sortie, et une unité de décalage de longueur d'onde. L'unité de décalage de longueur d'onde est disposée entre les unités homologues de lignes d'entrée et les unités homologues de lignes de sortie. Elle décale des signaux optiques de différentes longueurs d'onde compris dans un groupe de signaux optiques multiplexés en longueur d'onde qui proviennent des unités homologues de lignes d'entrée, et produit en sortie les signaux optiques multiplexés en longueur d'onde. Chaque unité homologue de ligne

(57) An ATM switch includes a plurality of input line corresponding units, a plurality of output line corresponding units, and a wavelength shifting unit. The wavelength shifting unit is arranged between the input line corresponding units and the output line corresponding units to shift optical signals having different wavelengths in a plurality of wavelength-multiplexed optical signals arriving from the input line corresponding units and output the wavelength-multiplexed optical signals. Each input line corresponding unit includes an input-side basic switch for distributing N (N is a positive integer) cells





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d'entrée comprend un commutateur de base côté entrée pour distribuer N (N étant un entier positif) cellules entrées dans des ports d'entrée de N lignes, un convertisseur électro-optique pour convertir les cellules en signaux optiques de différentes longueurs d'onde dans les unités de N lignes, et un multiplexeur pour multiplexer les signaux optiques en un unique signal optique multiplexé en longueur d'onde. Chaque unité homologue de ligne de sortie comprend un démultiplexeur pour démultiplexer le signal optique multiplexé en longueur d'onde dans des unités de longueurs d'onde, un convertisseur opto-électrique pour convertir les sorties du démultiplexeur en signaux électriques, et un commutateur de base côté sortie pour distribuer à un certain nombre de ports de sortie les cellules converties en signaux électriques.

respectively input to input ports to N lines, an electro-optic converter for converting the cells into optical signals having different wavelengths in units of N lines, and a multiplexer for multiplexing the optical signals into one wavelength-multiplexed optical signal. Each output line corresponding unit includes a demultiplexer for demultiplexing the wavelength-multiplexed optical signal in units of wavelengths, an opto-electric converter for converting outputs from the demultiplexer into electrical signals, respectively, and an output-side basic switch for distributing the cells converted into the electrical signals to a plurality of output ports.

Abstract of the Disclosure

An ATM switch includes a plurality of input line corresponding units, a plurality of output line corresponding units, and a wavelength shifting unit. The wavelength shifting unit is arranged between the
5 input line corresponding units and the output line corresponding units to shift optical signals having different wavelengths in a plurality of wavelength-multiplexed optical signals arriving from the input line corresponding units and output the
10 wavelength-multiplexed optical signals. Each input line corresponding unit includes an input-side basic switch for distributing N (N is a positive integer) cells respectively input to input ports to N lines, an electro-optic converter for converting the cells into
15 optical signals having different wavelengths in units of N lines, and a multiplexer for multiplexing the optical signals into one wavelength-multiplexed optical signal. Each output line corresponding unit includes a demultiplexer for demultiplexing the
20 wavelength-multiplexed optical signal in units of wavelengths, an opto-electric converter for converting outputs from the demultiplexer into electrical signals, respectively, and an output-side basic switch for distributing the cells converted into the electrical
25 signals to a plurality of output ports.

Specification

Title of the Invention

ATM Switch

5 Background of the Invention

The present invention is used for ATM
(Asynchronous Transfer Mode) communication. The present
invention relates to a technique of simplifying
connection of the internal links of an ATM switch. The
10 present invention also relates to a technique of
constituting an ATM switch using an optical device. The
present invention also relates to a technique of coping
with traffic localization.

Figs. 16 to 18 explain a conventional ATM
15 switch. Fig. 16 shows the arrangement of a 4 x 4 (m
inputs and n outputs are represented by "m x n") basic
switch. Fig. 17 shows the detailed arrangement of a
cross point in the basic switch. Fig. 18 shows the
arrangement of a 16 x 16 ATM switch using eight 4 x 4
20 basic switches. The ATM switch is described in detail
in reference "Illustrated standard ATM textbook, ASCII
Shuppansha".

The arrangement of the basic switch will be
described with reference to Figs. 16 and 17. An input
25 buffer type basic switch will be described below. This
basic switch comprises input buffers 51-1 to 51-4 for
temporarily storing arriving cells, a controller 52 for

controlling the congestion of cells, cross points 53 for transferring ATM cells output from the input buffers 51-1 to 51-4 to desired output ports, and output highways 54-1 to 54-4 to which ATM cells are transferred. The controller 52 communicates with the respective input buffers 51-1 to 51-4 to permit cell transmission so as not to transfer the cells from the input buffers 51-1 to 51-4 to the same one of the output highways 54-1 to 54-4. The cross point 53 has an address filter AF, as shown in Fig. 17, and transfers an input cell to the corresponding one of the output highways 54-1 to 54-4 on the basis of the information in the header of the cell.

The conventional ATM switch is constituted using a plurality of basic switches shown in Figs. 16 and 17. Fig. 18 shows a 16 x 16 ATM switch constituted using eight 4 x 4 basic switches 71 to 78. The basic switches 71 to 74 are individually connected to the basic switches 75 to 78 through links so that a cell from an arbitrary input line can be output to an arbitrary output line.

When the ATM switch is to be constituted using a plurality of basic switches, a number of links are required to mutually connect the respective basic switches. In addition, wires for connection are intertwined with each other to result in a complex structure. In the example shown in Fig. 18, 16 links

are necessary. An actual large-scale ATM switch uses several ten or several hundred basic switches, and the number of links therebetween is enormous.

The links are constituted using optical
5 fibers. The process of connecting the wires requires a long time. In addition, the check process for preventing erroneous interconnection increases the apparatus cost and the work time. Every time the number of basic switches is increased/decreased,
10 interconnections between the wires must be changed for all the basic switches, so the degree of freedom in increasing/decreasing the number of basic switches is low.

When the traffics localize in routes from the
15 basic switch 71 to the basic switch 75 and from the basic switch 72 to the basic switch 76, the links connecting these switches congest. This situation is shown in Fig. 19. Fig. 19 shows the congestion situation of the 16 x 16 ATM switch. This largely
20 degrades the throughput of the switch.

Summary of the Invention

It is the principal object of the present invention to provide an ATM switch capable of flexibly coping with an increase/decrease in the number of
25 input/output lines.

It is another object of the present invention to provide an ATM switch capable of solving the

conventional complex link connection to reduce the quantity of hardware.

It is still another object of the present invention to provide an ATM switch capable of solving
5 traffic localization generated in the respective lines.

It is still another object of the present invention to provide an ATM switch applicable to a large-scale ATM switch structure.

In order to achieve the above objects of the
10 present invention, there is provided an ATM switch for distributing cells arriving from a plurality of input lines to a plurality of output lines, comprising a plurality of input line corresponding units each connected to the plurality of input lines, a plurality
15 of output line corresponding units each connected to the plurality of output lines, and wavelength shifting means, arranged between the input line corresponding units and the output line corresponding units, for shifting optical signals having different wavelengths
20 included in a plurality of wavelength-multiplexed optical signals arriving from the input line corresponding units and outputting the wavelength-multiplexed optical signals, wherein each of the input line corresponding units includes an
25 input-side basic switch for distributing N (N is a positive integer) cells which are respectively input to a plurality of input ports to N lines, electro-optic

conversion means for converting the cells distributed to the N lines into optical signals having different wavelengths in units of lines, and a multiplexer for multiplexing the optical signals converted in units of lines into one wavelength-multiplexed optical signal, and each of the output line corresponding units includes a demultiplexer for demultiplexing in units of wavelengths the wavelength-multiplexed optical signal obtained by wavelength-multiplexing the optical signals having N wavelengths, opto-electric conversion means for converting outputs from the demultiplexer into electrical signals, respectively, and an output-side basic switch for distributing the cells converted into the electrical signals to a plurality of output ports.

The present invention is characterized in that basic switches are connected through wavelength multiplexing links such that the basic switches are connected through wavelength shifting means for distributing signals on the respective multiplexing links in units of wavelengths. The present invention is different from the prior art in that the number of links is reduced by wavelength multiplexing, the output-side basic switch is selected in units of wavelengths, and one output-side basic switch is connected to the respective input-side basic switches through links with different wavelengths.

In addition, the present invention is characterized in that some output ports of the output line corresponding units are connected to the corresponding input ports of the input line

5 corresponding units, respectively, or some output ports of a certain input line corresponding unit are connected to input ports of another input line corresponding unit such that bypass routes for avoiding congestion can be set.

10 More specifically, the first gist of the present invention is an ATM switch for distributing cells arriving from a plurality of input lines to a plurality of output lines.

According to the present invention, there is
15 provided an ATM switch comprising a plurality of input line corresponding units each connected to the plurality of input lines, a plurality of output line corresponding units each connected to the plurality of output lines, each of the input line corresponding units including an
20 input-side basic switch for distributing cells which are respectively input to a plurality of input ports to N lines, electro-optic conversion means for converting the cells distributed to the N lines into optical signals having different wavelengths in units of lines, and a
25 multiplexer for multiplexing the optical signals converted in units of lines into one wavelength-multiplexed optical signal, and each of the

output line corresponding units including a demultiplexer for demultiplexing in units of wavelengths the wavelength-multiplexed optical signal obtained by wavelength-multiplexing the optical signals having N
5 wavelengths, opto-electric conversion means for converting outputs from the demultiplexer into electrical signals, respectively, and an output-side basic switch for distributing the cells converted into the electrical signals to a plurality of output ports,
10 and wavelength shifting means, arranged between the input line corresponding units and the output line corresponding units, for shifting the optical signals having different wavelengths included in a plurality of wavelength-multiplexed optical signals arriving from the
15 input line corresponding units and outputting the wavelength-multiplexed optical signals.

Preferably, the wavelength shifting means includes a barrel shifter which distributes an optical signal having a p th ($p = 0, 1, 2, \dots, (N - 1)$)
20 wavelength in an n th ($n = 0, 1, 2, \dots, (\text{the number of input line corresponding units} - 1)$) wavelength-multiplexed optical signal to the $(n + p)$ th output and distributes the optical signal to the output of an ordinal number obtained by subtracting the number
25 of output line corresponding units from $(n + p)$ when $n + p$ is equal to or larger than the number of output line corresponding units.

With this arrangement, the cells arriving from the plurality of input lines can be distributed to the output lines determined in units of wavelengths. At this time, use of the wavelength shifting means such as
5 a barrel shifter allows to omit complex interconnections and increases the degree of freedom in increasing/decreasing the number of lines. More specifically, one output-side basic switch is connected to the respective input-side basic switches through
10 links with different wavelengths when viewed from this output-side basic switch.

The number of input line corresponding units can be made equal to that of output line corresponding units. The numbers of input line corresponding units or
15 output line corresponding units can be arbitrarily set. For this reason, an ATM switch having a high degree of freedom in design can be realized.

Wavelength multiplexing links are preferably arranged between the output terminals of the
20 multiplexers and the wavelength shifting means and between the wavelength shifting means and the input terminals of the demultiplexers. With this arrangement, the number of links input/output to/from the wavelength shifting means can be reduced, so that an ATM switch
25 which can omit complex interconnections can be realized. The number of basic switches can be easily changed by increasing/decreasing the number of links input/output

to/from the wavelength shifting means. More specifically, the number of basic switches can be easily changed by increasing/decreasing not the number of outputs of the basic switches but the number of links
5 input/output to/from the wavelength shifting means in correspondence with the number of basic switches themselves.

At least some input ports of the plurality of input line corresponding units may be connected to lines
10 from any routes from other input line corresponding units to the plurality of output line corresponding units. With this arrangement, a plurality of routes via feedback routes can be selected as a route for transferring a cell from a certain input line to a
15 certain output line. Therefore, in case of traffic localization, a bypass route can be formed to cope with the traffic localization.

To obtain simple and regular interconnections, at least some output ports of each output-side basic
20 switch are preferably connected to input ports of an input-side basic switch corresponding to the output-side basic switch. Alternatively, at least some output ports of each input-side basic switch may be connected to input ports of the input-side basic switch of another
25 input line corresponding unit.

Alternatively, for a combination of at least one input line corresponding unit and an output line

corresponding unit corresponding to this input line
corresponding unit, the output ports of the output line
corresponding unit may be connected to the input ports
of the input line corresponding unit. The combination
5 of an input line corresponding unit and an output line
corresponding unit corresponding to this input line
corresponding unit is specialized to form bypass routes,
and the remaining input line corresponding units and
output line corresponding units can have the basic
10 arrangement. With this arrangement, the degree of
freedom in increasing/decreasing the number of
input/output lines can be increased.

Electro-optic conversion means for converting
cells into optical signals having different wavelengths
15 in units of inputs and a multiplexer for multiplexing
the optical signals converted in units of inputs into
one wavelength-multiplexed optical signal may be
arranged. This multiplexer is connected to the input
side of the wavelength shifting means. The plurality of
20 output line corresponding units may include at least one
output line corresponding unit whose output ports are
connected to the input ports of the electro-optic
converters. With this arrangement, in the above
specialized arrangement, the arrangement corresponding
25 to the input line corresponding units can be simplified.

The second gist of the present invention is a large-scale ATM switch in which the above ATM switches are multiple-connected.

Brief Description of the Drawings

5 Fig. 1 is a block diagram of an ATM switch according to the first embodiment of the present invention;

 Fig. 2 is a view showing the situation of optical signal distribution by a barrel shifter;

10 Fig. 3 is a view showing the concept of an arrayed-waveguide grating;

 Fig. 4 is a view showing the situation of input/output of the barrel shifter;

 Fig. 5 is a block diagram of an ATM switch
15 according to the second embodiment of the present invention;

 Fig. 6 is a view for explaining an operation performed when traffic localization occurs in the ATM switch according to the second embodiment of the present
20 invention;

 Fig. 7 is a block diagram of an ATM switch according to the third embodiment of the present invention;

 Fig. 8 is a view for explaining an operation
25 performed when traffic localization occurs in the ATM switch according to the third embodiment of the present invention;

Fig. 9 is a block diagram of an ATM switch according to the fourth embodiment of the present invention;

Fig. 10 is a view for explaining an operation performed when traffic localization occurs in the ATM switch according to the fourth embodiment of the present invention;

Fig. 11 is a block diagram of an ATM switch according to the fifth embodiment of the present invention;

Fig. 12 is a view for explaining an operation performed when traffic localization occurs in the ATM switch according to the fifth embodiment of the present invention;

Fig. 13 is a block diagram of the sixth embodiment of the present invention;

Fig. 14 is a block diagram of the seventh embodiment of the present invention;

Fig. 15 is a block diagram of a multiple ATM switch according to the eighth embodiment of the present invention;

Fig. 16 is a view showing the arrangement of a 4 x 4 basic switch;

Fig. 17 is a view showing the detailed arrangement of a cross point;

Fig. 18 is a view showing the arrangement of a 16 x 16 ATM switch using eight 4 x 4 basic switches; and

Fig. 19 is a view showing the link congestion situation.

Description of the Preferred Embodiments

(First Embodiment)

5 The arrangement of the first embodiment of the present invention will be described below with reference to Fig. 1. Fig. 1 shows the arrangement of an ATM switch according to the first embodiment of the present invention.

10 In the present invention, an ATM switch which distributes arriving cells from 64 input lines to 64 output lines will be described.

 The present invention has the following characteristic features. The ATM switch comprises input
15 line corresponding units 2-1 to 2-8 (2-2 to 2-7 are not illustrated) each connected to eight lines of a total of 64 input lines, and output line corresponding units 4-1 to 4-8 (4-2 to 4-7 are not illustrated) each connected to eight lines of a total of 64 output lines. Each of
20 the input line corresponding units 2-1 to 2-8 includes an 8 x 8 input-side basic switch 6 for distributing cells input to eight input ports 1-11 to 1-18, ..., or 1-81 to 1-88 to the eight lines, electro-optic
converters 7-1 to 7-8 for converting the cells
25 distributed to the eight lines into optical signals having different wavelengths in units of lines, and a multiplexer 8 for multiplexing the optical signals

converted in units of lines into one wavelength-multiplexed optical signal. Each of the output line corresponding units 4-1 to 4-8 includes a demultiplexer 9 for demultiplexing the

5 wavelength-multiplexed optical signal formed by wavelength-multiplexing eight optical signals into optical signals having wavelengths different from each other, opto-electric converters 10-1 to 10-8 for converting outputs from the demultiplexer 9 into

10 electrical signals, respectively, and an 8×8 output-side basic switch 11 for distributing the cells converted into the electrical signals to eight output ports 5-11 to 5-18, ..., or 5-81 to 5-88. A barrel shifter 3 serving as a wavelength shifting means for

15 shifting the optical signals having different wavelengths included in a plurality of wavelength-multiplexed optical signals arriving from the input line corresponding units 2-1 to 2-8 and outputting the wavelength-multiplexed optical signals is arranged

20 between the input line corresponding units 2-1 to 2-8 and the output line corresponding units 4-1 to 4-8.

The barrel shifter 3 distributes an optical signal having the p th ($p = 0, \dots, N - 1$) wavelength in the n th ($n = 0, 1, \dots, (\text{the number of input line}$

25 corresponding units - 1)) wavelength-multiplexed optical signal to the $(n + p)$ th output. When $n + p$ is equal to or larger than the number of output line corresponding

units, the optical signal is distributed to the output of an ordinal number obtained by subtracting (the number of output line corresponding units) from $(n + p)$.

In the first embodiment of the present invention, the number of the input line corresponding units 2-1 to 2-8 equals that of the output line corresponding units 4-1 to 4-8.

Wavelength multiplexing links 15-1 to 15-8 and wavelength multiplexing links 16-1 to 16-8 are arranged between the output terminals of the multiplexers 8 and the barrel shifter 3 and between the barrel shifter 3 and the input terminals of the demultiplexers 9, respectively.

The electro-optic converters 7-1 to 7-8 output optical signals having wavelengths λ_0 to λ_7 , respectively. Suffixes A to H are added to clarify the input line corresponding units 2-1 to 2-8 in which the optical signals are converted. More specifically, the wavelengths of optical signals in the input line corresponding unit 2-1 are represented by λ_{0A} to λ_{7A} , and the wavelengths of optical signals in the input line corresponding unit 2-8 are represented by λ_{0H} to λ_{7H} .

The barrel shifter will be described with reference to Fig. 2. Fig. 2 shows the situation of optical signal distribution by the barrel shifter. As shown in Fig. 2, a description will be made assuming two input lines #0 and #1 and four output lines #0 to #3.

Optical signals each having wavelengths λ_0 to λ_3 are transmitted to input lines #0 and #1, respectively. Output lines #0, #1, #2, and #3 are set as output lines of the optical signals having wavelengths λ_0 , λ_1 , λ_2 , and λ_3 in input line #0, respectively. Output lines #1, #2, #3, and #0 are set as output lines of the optical signals having wavelengths λ_0 , λ_1 , λ_2 , and λ_3 in input line #1, respectively. Output line #1 is used to output the wavelength λ_1 of the optical signals transmitted through input line #0. Output line #1 is also used to output the wavelength λ_0 of the optical signals transmitted through input line #1. In the ATM switch shown in Fig. 1, a cell to be output to the output line corresponding unit 4-1 may be input to the electro-optic converter 7-1 for converting the cell into an optical signal having the wavelength λ_{0A} . The cell input to the electro-optic converter 7-1 is converted into the optical signal having the wavelength λ_{0A} and input to the barrel shifter 3 through the wavelength multiplexing link 15-1. The cell is then output to the wavelength multiplexing link 16-1 and arrives at the output line corresponding unit 4-1.

The barrel shifter is a known technique. It is not directly associated with the present invention, and a detailed description thereof will be omitted. The barrel shifter will be briefly described below (reference: Hiroshi Takahashi et al.,

"Polarization-insensitive arranged waveguide grating wavelength multiplexer on silicon", OPTICS LETTERS, Vol. 17, No. 7, April 1 1992, pp. 499-501.

The optical device used in the present invention, i.e., the optical device called a barrel shifter is one of optical devices generally called "arrayed-waveguide gratings". Fig. 3 shows the concept of the arrayed-waveguide grating. Normally, the arrayed-waveguide grating is integrated on a substrate together with input and output waveguides and two slab waveguides each functioning as a collimator/condenser lens, and manufactured as a multiplexer/demultiplexer.

As shown in Fig. 3, the arrayed-waveguide grating is constituted by a plurality of waveguides arranged at an equal interval and having different lengths. The phase shift between the waveguides generates the same dispersion properties as those of a diffraction grating. Therefore, wavelength-multiplexed light from the input waveguide is demultiplexed and extracted from different output waveguides. This device is used as a multiplexer in a reverse direction. The slab waveguide has a sectorial shape whose center of curvature is at the end of the input or output waveguide. The slab waveguide also has a condenser function, like a concave mirror, because the axis of the waveguide of the arrayed-waveguide grating is directed to the center of curvature. To reduce the connection

loss, a tapered waveguide is generally inserted between the channel waveguide and the slab waveguide, which constitute the arrayed-waveguide grating.

5 A wavelength interval $\Delta\lambda$ as one of the most important parameters of the multiplexer/demultiplexer using the arrayed-waveguide grating is represented as follows:

$$\Delta\lambda = \Delta x / (f \cdot m / n_x \cdot d) \quad \dots(1)$$

$$m = (n_c \cdot \Delta L) / \lambda_0 \quad \dots(2)$$

10 where ΔL is the difference between a pitch d of the arrayed-waveguide grating and the length of the waveguides constituting the arrayed-waveguide grating, f is the focal length (= radius of curvature) of the slab waveguide, Δx is the interval of the input and output
15 waveguides, and n_x is the effective refractive index of the slab waveguide. The denominator $(f \cdot m / n_x \cdot d)$ on the right-hand side of equation (1) represents a linear dispersion and the proportional constant of the relationship between the wavelength and the condensing
20 position, n_c is the effective refractive index of the waveguide, λ_0 is the center wavelength of the arrayed-waveguide grating, i.e., the wavelength obtained from the central output waveguide, and m is the degree of diffraction of the arrayed-waveguide grating, i.e., a
25 numerical value representing the phase shift of light between adjacent waveguides. As the value m becomes large, the angular dispersion becomes large. For this

reason, wavelengths having a small interval can be multiplexed/demultiplexed (the wavelength resolving power is high). For a conventional diffraction grating, the pitch must be reduced to increase the resolving power, though there is a process limitation. In the arrayed-waveguide grating, the waveguide can be elongated to increase the degree of diffraction, thereby easily realizing a high resolving power. This is the largest difference between the arrayed-waveguide grating and the conventional diffraction grating.

As is represented by equation (2), since m is an arbitrary integer, a plurality of center wavelengths λ_0 are present in one arrayed-waveguide grating. For example, when the optical path difference $\Delta L = 126 \mu\text{m}$, and $n_c = 1.45$, $\lambda_0 = 1548.3 \text{ nm}$ for $m = 118$, and $\lambda_0 = 1535.3 \text{ nm}$ for $m = 119$. That is, light components having a plurality of wavelengths λ_0 including 1548.3 nm and 1535.3 nm are output from the central output port. Therefore, a band usable without overlapping the wavelengths is 13 nm . For wavelength division multiplexing at a wavelength interval of 0.8 nm , the maximum number of wavelengths is "16". When the value m increases, the wavelength resolving power increases. However, the band usable without overlapping the wavelengths becomes narrow, so the value m must be carefully set.

The barrel shifter used in the present invention is an arrayed-waveguide grating which positively utilizes its nature (circulation properties) that light components having the same wavelength are repeatedly output in units of bands usable without overlapping the wavelengths, as shown in Table 1.

Table 1

I/O	O1	O2	O3	O4	O5
i1	λ_0	λ_1	λ_2	λ_3	λ_4
i2	λ_4	λ_0	λ_1	λ_2	λ_3
i3	λ_3	λ_4	λ_0	λ_1	λ_2
i4	λ_2	λ_3	λ_4	λ_0	λ_1
i5	λ_1	λ_2	λ_3	λ_4	λ_0

Fig. 4 shows the situation of input/output of the barrel shifter 3 shown in Fig. 1. One output-side basic switch is connected to the respective input-side basic switches through links with different wavelengths when viewed from this output-side basic switch.

The operation of the first embodiment of the present invention will be described next. Cells input to the input line corresponding units 2-1 to 2-8 are switched by the input-side basic switches 6. The output line corresponding units 4-1 to 4-8 as destinations are determined in accordance with output lines switched by the input-side basic switches 6. For example, when one of cells input to the input line corresponding unit 2-1 is to use the output line corresponding unit 4-1 as an output line, the cell may be input to the electro-optic

converter 7-1 for converting the cell into an optical signal having the wavelength λ_{0A} . The cell input to the electro-optic converter 7-1 is converted into the optical signal having the wavelength λ_{0A} and input to the barrel shifter 3 through the wavelength multiplexing link 15-1 and arrives at the output line corresponding unit 4-1 through the wavelength multiplexing link 16-1.

The operation of the input line corresponding unit 2-1 will be described in more detail. Cells output from the input-side basic switch 6 are converted into optical signals having the wavelengths λ_{0A} to λ_{7A} by the electro-optic converters 7-1 to 7-8, respectively. These optical signals are multiplexed by the multiplexer 8 into one serial signal and output to the wavelength multiplexing link 15-1. The barrel shifter 3 selectively distributes the optical signals having the wavelengths λ_{0A} to λ_{7A} to the wavelength multiplexing links 16-1 to 16-8. On the other hand, when attention is paid to one wavelength multiplexing link, e.g., 16-1, optical signals from the input line corresponding units 2-1 to 2-8 are wavelength-multiplexed and transferred to the wavelength multiplexing link 16-1.

The demultiplexer 9 demultiplexes the wavelength-multiplexed optical signal from the input line corresponding units 2-1 to 2-8. The opto-electric converters 10-1 to 10-8 convert the optical signals into cells of electrical signals. The cells are output to

the output lines by the output-side basic switch 11 through the desired output ports 5-11 to 5-18, respectively.

In connection between the input port 1-12 of the input-side basic switch 6 of the input line corresponding unit 2-1 and the output port 5-14 of the output-side basic switch 11 of the output line corresponding unit 4-1, the electro-optic converter 7-1 at the uppermost stage is selected by the input-side basic switch 6. The optical signal having the wavelength λ_{0A} is transferred to the output line corresponding unit 4-1 through the barrel shifter 3, demultiplexed by the demultiplexer 9 to the output-side basic switch 11, and connected to the output port 5-14 by the basic switch 11.

As described above, cells arriving from the plurality of input lines can be distributed to the output lines which are determined in units of wavelengths. When the barrel shifter 3 is used, the internal links of the ATM switch can be simplified.

When a plurality of ATM switches of the present invention are connected, a large-scale ATM switch having, e.g., three or five stages can be constituted.

(Second Embodiment)

The arrangement of the second embodiment of the present invention will be described with reference

to Figs. 5 and 6. Fig. 5 shows an ATM switch according to the second embodiment of the present invention. In the second embodiment, output ports 5-11 to 5-18, ..., 5-81 to 5-88 of output-side basic switches 11 of output line corresponding units 4-1 to 4-8 are connected to input ports 1-11 to 1-18, ..., 1-81 to 1-88 of input-side basic switches 6 of input line corresponding units 2-1 to 2-8 through lines 12-1 to 12-8. With this arrangement, when partial congestion occurs in the ATM switch, a bypass route for avoiding the congested route can be set.

Fig. 6 explains an operation performed when traffic localization occurs in the ATM switch according to the second embodiment of the present invention and shows a case wherein the traffic of the input line corresponding unit 2-1 concentrates to the output line corresponding unit 4-1. To transfer a cell from the input line corresponding unit 2-1 to the output line corresponding unit 4-1, a wavelength λ_{0A} is selected, and the cell is automatically transferred by a barrel shifter 3. However, when the transfer rate of the input ports 1-11 to 1-18, ..., 1-81 to 1-88 is 1 Gb/s, traffics of 8 Gb/s may localize between the input line corresponding unit 2-1 and the output line corresponding unit 4-1 at maximum. Assume that the throughput at which a cell can be transferred via one wavelength of wavelength multiplexing links 15-1 to 15-8 or 16-1 to

16-8 is 1 Gb/s. When a cell is to be directly transferred from the input line corresponding unit 2-1 to the output line corresponding unit 4-1, only cells of 1 Gb/s of the cells of 8 Gb/s can be transferred. The remaining cells of 7 Gb/s are handled as a call loss. To avoid this, a feedback route is used. In the example shown in Fig. 6, in addition to a route A for directly transferring a cell from the input line corresponding unit 2-1 to the output line corresponding unit 4-1, a route B is arranged to select λ_{1A} for some cells to be transferred to the output line corresponding unit 4-1, and transfer the cells to the output line corresponding unit 4-2. The cell from the output line corresponding unit 4-2 is fed back to the input line corresponding unit 2-2 via the feedback loop and transferred from the input line corresponding unit 2-2 to the output line corresponding unit 4-1. Therefore, congestion between the input line corresponding unit 2-1 and the output line corresponding unit 4-1 can be avoided.

Although one bypass route has been exemplified above, seven bypass routes can be additionally ensured between the input line corresponding unit 2-1 and the output line corresponding unit 4-1. Consequently, a total of eight routes can be used. In addition, not one but a plurality of feedback routes can be set between the input line corresponding units 2-1 to 2-8 and the output line corresponding units 4-1 to 4-8.

(Third Embodiment)

The third embodiment of the present invention will be described with reference to Figs. 7 and 8. Fig. 7 shows an ATM switch according to the third
5 embodiment of the present invention. The third embodiment of the present invention includes a circuit in which each of input line corresponding units 2-1 to 2-8 has a 9 x 9 input-side basic switch 13 for distributing cells input to nine input ports 1-11 to
10 1-19, 1-21 to 1-29, ..., or 1-81 to 1-89, and one of the output ports of each input-side basic switch 13 is connected to the input port 1-19, 1-29, ..., or 1-89 of the corresponding one of the input line corresponding units 2-1 to 2-8 without interposing electro-optic
15 converters 7-1 to 7-8.

According to the third embodiment, no bypass route need be set for the subsequent paths. Only by increasing the number of input/output ports of the input-side basic switch 13 by one, an ATM switch having
20 a 64 x 64 arrangement can be constituted.

More specifically, in the third embodiment of the present invention, eight input lines are connected to each of the input line corresponding units 2-1 to 2-8, and eight output lines are connected to each of
25 output line corresponding units 4-1 to 4-8. Instead of the 8 x 8 input-side basic switch 6 in the first and second embodiments of the present invention, each of the

input line corresponding units 2-1 to 2-8 has the 9 x 9 basic switch, i.e., the input-side basic switch 13 for distributing cells input to the nine input ports to the nine lines. Of these nine lines, eight lines are
5 connected to the electro-optic converters 7-1 to 7-8, respectively, as in the first and second embodiments of the present invention. The remaining one line of each input-side basic switch 13 is connected such that the line of the input-side basic switch 13 of the input line
10 corresponding unit 2-(8-k) ($k = 1, 2, \dots, 8$) is connected to an input port of the input-side basic switch 13 of the input line corresponding unit 2-(8-(k+1)) (when $k = 8$, the input line corresponding unit 2-1). The remaining arrangement in each of the
15 input line corresponding units 2-1 to 2-8, and the arrangement of a barrel shifter 3 and the output line corresponding units 4-1 to 4-8 are the same as those in the first embodiment of the present invention.

Fig. 8 explains an operation performed when
20 traffic localization occurs in the ATM switch according to the third embodiment of the present invention. Assume that the traffic localizes between the input line corresponding unit 2-1 and the output line corresponding unit 4-1, as in the description of Fig. 6. In this
25 case, in addition to a route A for directly transferring a cell from the input line corresponding unit 2-1 to the output line corresponding unit 4-1, a route B is set.

With this route B, some cells to be transferred to the output line corresponding unit 4-1 are transferred to the input line corresponding unit 2-2 by using the line 14-1, and λ_{7B} is selected to transfer the cells to the
5 output line corresponding unit 4-1. When traffics also concentrate between the input line corresponding unit 2-2 and the output line corresponding unit 4-1, some cells from the input line corresponding unit 2-1 can be further transferred to the input line corresponding unit
10 2-3. With this arrangement, a plurality of routes can be used to transfer cells from the input line corresponding unit 2-1 to the output line corresponding unit 4-1. In addition, not only one but a plurality of routes can be set among the input line corresponding
15 units 2-1 to 2-8.

In the third embodiment of the present invention, an arrangement which includes a regular wire structure and can be easily practiced has been described. However, the present invention can be
20 practiced even for another connection form. For example, outputs from some opto-electric converters 10-k of the output line corresponding units 4-1 to 4-8 can be connected to the input line corresponding units 2-1 to 2-8. Alternatively, some outputs from the input-side
25 basic switch 13 can be connected to a common input line corresponding unit 2-k.

(Fourth Embodiment)

The fourth embodiment of the present invention will be described with reference to Figs. 9 and 10.

Fig. 9 shows an ATM switch according to the fourth

5 embodiment of the present invention. In the fourth embodiment of the present invention, output ports 5-81 to 5-88 of an output-side basic switch 11 of an output line corresponding unit 4-8 are connected to input ports 1-81 to 1-88 of an input-side basic switch 6 of an input
10 line corresponding unit 2-8 through lines 18-1 to 18-8 constituting a feedback circuit, respectively, thereby specializing the input line corresponding unit 2-8 and the output line corresponding unit 4-8 to set bypass routes.

15 According to the fourth embodiment of the present invention, remaining input line corresponding units 2-1 to 2-7 and output line corresponding units 4-1 to 4-7 can have the basic arrangement shown in the first embodiment of the present invention. Therefore, the
20 input line corresponding units and output line corresponding units can be easily increased/decreased.

Fig. 10 explains an operation performed when traffic localization occurs in the ATM switch according to the fourth embodiment of the present invention.

25 Assume that the traffics localize between the input line corresponding unit 2-1 and the output line corresponding unit 4-1, as in the description of Fig. 6. In this

case, in addition to a route A for directly transferring cells from the input line corresponding unit 2-1 to the output line corresponding unit 4-1, a route B is set to transfer some cells to be transferred to the output line corresponding unit 4-1 to the output line corresponding unit 4-8. The cells are further transferred to the input line corresponding unit 2-8 and then transferred from the input line corresponding unit 2-8 to the output line corresponding unit 4-2. As described above, a plurality of routes can be used between the input line corresponding unit 2-1 and the output line corresponding unit 4-1.

(Fifth Embodiment)

The fifth embodiment of the present invention will be described with reference to Figs. 11 and 12. Fig. 11 shows an ATM switch according to the fifth embodiment of the present invention. In the fifth embodiment of the present invention, a block without any input-side basic switch 6 is arranged as an input line corresponding unit 2-8', and output ports 5-81 to 5-88 of an output-side basic switch 11 of an output line corresponding unit 4-8 are connected to the input terminals of electro-optic converters 7-1 to 7-8 through lines 18-1 to 18-8 constituting a feedback circuit, respectively, thereby specializing the input line corresponding unit 2-8' and the output line corresponding unit 4-8 to set bypass routes.

According to the fifth embodiment of the present invention, remaining input line corresponding units 2-1 to 2-7 and output line corresponding units 4-1 to 4-7 can have the basic arrangement shown in the first
5 embodiment of the present invention. Therefore, the input line corresponding units and output line corresponding units can be easily increased/decreased.

In addition, according to the fifth embodiment of the present invention, the input line corresponding
10 unit 2-8' can have a simpler arrangement than that of the fourth embodiment of the present invention. The input line corresponding unit 2-8' has no input-side basic switch 6. However, desired routes can be set on the side of the output-side basic switch 11 of the
15 output line corresponding unit 4-8.

Fig. 12 explains an operation performed when traffic localization occurs in the ATM switch according to the fifth embodiment of the present invention. Assume that the traffics localize between the input line
20 corresponding unit 2-1 and the output line corresponding unit 4-1, as in the description of Fig. 6. In this case, in addition to a route A for directly transferring cells from the input line corresponding unit 2-1 to the output line corresponding unit 4-1, a route B is set to
25 transfer some cells to be transferred to the output line corresponding unit 4-1 to the output line corresponding unit 4-8. The cells are further transferred to the

input line corresponding unit 2-8' and then transferred
from the input line corresponding unit 2-8' to the
output line corresponding unit 4-2. As described above,
a plurality of routes can be used between the input line
5 corresponding unit 2-1 and the output line corresponding
unit 4-1.

(Sixth Embodiment)

The sixth embodiment of the present invention
will be described with reference to Fig. 13. Fig. 13
10 shows the sixth embodiment of the present invention. In
the sixth embodiment of the present invention, the
arrangement shown in the second embodiment of the
present invention is combined with that shown in the
third embodiment of the present invention.

15 When traffic localization occurs in the ATM
switch of the sixth embodiment of the present invention,
not only the bypass route shown in Fig. 6 but also that
shown in Fig. 8 can be set. With this arrangement, the
degree of freedom in setting the bypass route can be
20 increased.

(Seventh Embodiment)

The seventh embodiment of the present
invention will be described with reference to Fig. 14.
Fig. 14 shows the seventh embodiment of the present
25 invention. In the seventh embodiment of the present
invention, the arrangement shown in the third embodiment

of the present invention is combined with that shown in the fourth embodiment of the present invention.

When traffic localization occurs in the ATM switch of the seventh embodiment of the present invention, not only the bypass route shown in Fig. 6 but also that shown in Fig. 10 can be set. With this arrangement, the degree of freedom in setting the bypass route can be increased.

The same description can apply to a combination of the arrangement shown in the third embodiment of the present invention and that shown in the fifth embodiment of the present invention.

As has been described above, the present invention can solve the complex link connection and cope with traffic localization. In addition, a large-scale ATM switch with the minimum quantity of hardware can be realized. Furthermore, an ATM switch capable of flexibly coping with an increase/decrease in number of input/output lines can be realized.

20 (Eighth Embodiment)

The eighth embodiment of the present invention will be described with reference to Fig. 15. Fig. 15 shows the arrangement according to the eighth embodiment of the present invention. In the eighth embodiment, the present invention is applied to a large-scale ATM switch.

In this embodiment, a first-stage ATM switch SW1 has the same arrangement as that shown in the block diagram of Fig. 1. In a second-stage ATM switch SW2, input-side basic switches 6 constituting input line
5 corresponding units 2-1 to 2-8 are removed from the block diagram shown in Fig. 1, and the input terminals of electro-optic converters 7-1 to 7-8 are connected to the output terminals of output-side basic switches 11
10 constituting output line corresponding units 4-1 to 4-8 of the first-stage ATM switch SW1. When the third and subsequent stages must be connected, the same arrangement as that of the second-stage ATM switch SW2 is sequentially connected. The detailed structures, functions, and operations of the respective components
15 have been described in detail in the embodiment shown in Fig. 1, and a detailed description thereof will be omitted.

This arrangement can flexibly cope with a large-scale ATM switch, and the quantity of hardware can
20 be largely reduced, as compared to the prior art. With such multiple arrangement, traffic localization can be solved without using any feedback circuit, unlike the above-described embodiments.

What is claimed is:

1. An ATM switch for distributing cells arriving
2 from a plurality of input lines to a plurality of output
3 lines, comprising:
4 a plurality of input line corresponding units
5 each connected to said plurality of input lines;
6 a plurality of output line corresponding units
7 each connected to said plurality of output lines; and
8 wavelength shifting means, arranged between
9 said input line corresponding units and said output line
10 corresponding units, for shifting optical signals having
11 different wavelengths included in a plurality of
12 wavelength-multiplexed optical signals arriving from
13 said input line corresponding units and outputting the
14 wavelength-multiplexed optical signals,
15 wherein each of said input line corresponding
16 units includes an input-side basic switch for
17 distributing N (N is a positive integer) cells which are
18 respectively input to a plurality of input ports to N
19 lines, electro-optic conversion means for converting the
20 cells distributed to the N lines into optical signals
21 having different wavelengths in units of lines, and a
22 multiplexer for multiplexing the optical signals
23 converted in units of lines into one
24 wavelength-multiplexed optical signal, and

25 each of said output line corresponding units
26 includes a demultiplexer for demultiplexing in units of
27 wavelengths the wavelength-multiplexed optical signal
28 obtained by wavelength-multiplexing the optical signals
29 having N wavelengths, opto-electric conversion means for
30 converting outputs from said demultiplexer into
31 electrical signals, respectively, and an output-side
32 basic switch for distributing the cells converted into
33 the electrical signals to a plurality of output ports.

2. A switch according to claim 1, wherein said
2 wavelength shifting means is constituted by a barrel
3 shifter which distributes an optical signal having a pth
4 ($p = 0, 1, 2, \dots, (N - 1)$) wavelength in an nth ($n = 0,$
5 $1, 2, \dots,$ (the number of input line corresponding units
6 $- 1$)) wavelength-multiplexed optical signal to an ($n +$
7 p)th output line and distributes the optical signal to
8 an output of an ordinal number obtained by subtracting
9 the number of output line corresponding units from ($n +$
10 p) when $n + p$ is not less than the number of output line
11 corresponding units.

3. A switch according to claim 1, wherein at
2 least some input terminals of said input line
3 corresponding unit are connected to a circuit to which
4 some signals processed by another input line
5 corresponding unit are supplied.

4. A switch according to claim 1, wherein at
2 least some input terminals of said input line
3 corresponding unit are connected to a feedback circuit
4 to which some signals processed by said output line
5 corresponding unit are supplied.

5. A switch according to claim 1, wherein at
2 least some of output ports constituting one output-side
3 basic switch of said output line corresponding unit are
4 connected to a feedback circuit connected to input ports
5 of said input line corresponding unit corresponding to
6 said one output-side basic switch.

6.. A switch according to claim 1, wherein at
2 least some of output ports constituting each input-side
3 basic switch of each input line corresponding unit are
4 connected to a feedback circuit connected to input ports
5 constituting an input-side basic switch of another input
6 line corresponding unit.

7. A switch according to claim 1, wherein all
2 output terminals of at least one of said output line
3 corresponding units are connected to all input terminals
4 of a corresponding one of said input line corresponding
5 units.

8. A switch according to claim 1, further
2 comprising additional electro-optic conversion means
3 converting input cells into optical signals having
4 different wavelengths in units of inputs, and an
5 additional multiplexer for multiplexing the optical
6 signals converted in units of inputs,
7 said additional multiplexer being connected to
8 an input-side of said wavelength shifting means, and
9 all output terminals of one of said output
10 line corresponding units being connected to an
11 input-side of said additional electro-optic conversion
12 means.

9.. A large-scale ATM switch comprising
2 multiple-connected ATM switches,
3 wherein an ATM switch at a first stage
4 comprises a plurality of input line corresponding units
5 each connected to a plurality of input lines, a
6 plurality of output line corresponding units each
7 connected to a plurality of output lines, and wavelength
8 shifting means, arranged between said input line
9 corresponding units and said output line corresponding
10 units, for shifting optical signals having different
11 wavelengths included in a plurality of
12 wavelength-multiplexed optical signals arriving from
13 said input line corresponding units and outputting the
14 wavelength-multiplexed optical signals,

15 each of said input line corresponding
16 units including an input-side basic switch for
17 distributing N (N is a positive integer) cells
18 which are respectively input to a plurality of
19 input ports to N lines, electro-optic
20 conversion means for converting the cells
21 distributed to the N lines into optical
22 signals having different wavelengths in units
23 of lines, and a multiplexer for multiplexing
24 the optical signals converted in units of
25 lines into one wavelength-multiplexed optical
26 signal, and

27 each of said output line corresponding
28 units including a demultiplexer for
29 demultiplexing in units of wavelengths the
30 wavelength-multiplexed optical signal obtained
31 by wavelength-multiplexing the optical signals
32 having N wavelengths, opto-electric conversion
33 means for converting outputs from said
34 demultiplexer into electrical signals,
35 respectively, and an output-side basic switch
36 for distributing the cells converted into the
37 electrical signals to a plurality of output
38 ports, and

39 each of ATM switches at subsequent stages
40 comprises a plurality of input line corresponding units
41 each connected to a plurality of input lines, a

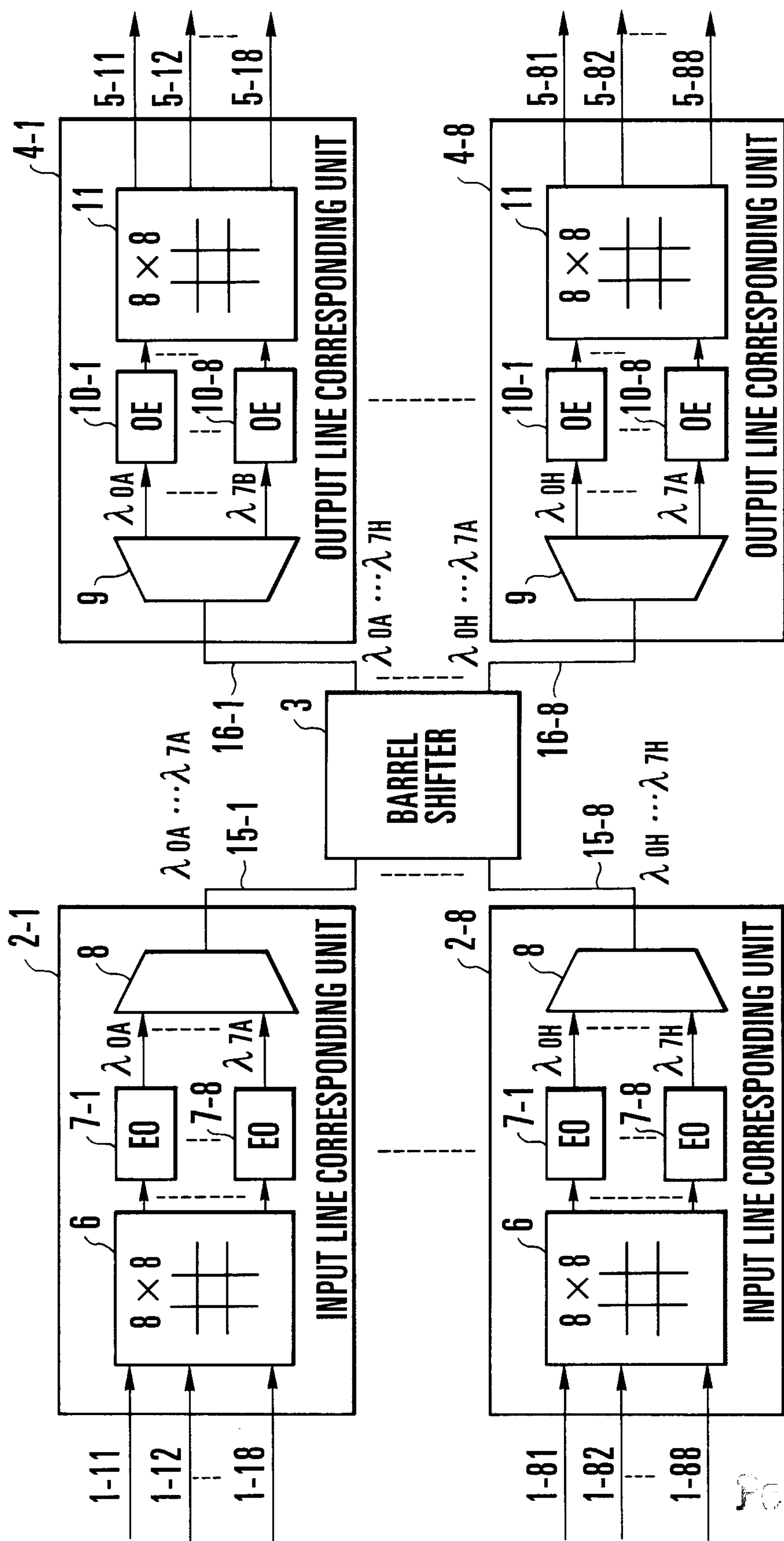
42 plurality of output line corresponding units each
43 connected to a plurality of output lines, and wavelength
44 shifting means, arranged between said input line
45 corresponding units and said output line corresponding
46 units, for shifting optical signals having different
47 wavelengths included in a plurality of
48 wavelength-multiplexed optical signals arriving from
49 said input line corresponding units and outputting the
50 wavelength-multiplexed optical signals,

51 each of said input line corresponding
52 units of each ATM switch at the subsequent
53 stages including electro-optic conversion
54 means for converting outputs from said output
55 line corresponding units of said ATM switch at
56 the previous stage into optical signals having
57 different wavelengths in units of lines, and a
58 multiplexer for multiplexing the optical
59 signals converted in units of lines into one
60 wavelength-multiplexed optical signal, and

61 each of said output line corresponding
62 units of each ATM switch at the subsequent
63 stages including a demultiplexer for
64 demultiplexing in units of wavelengths the
65 wavelength-multiplexed optical signal obtained
66 by wavelength-multiplexing the optical signals
67 having N wavelengths, opto-electric conversion
68 means for converting outputs from said

69 demultiplexer into electrical signals,
70 respectively, and an output-side basic switch
71 for distributing cells converted into the
72 electrical signals to a plurality of output
73 ports.

**Smart & Eiggar
Ottawa, Canada
Patent Agents**



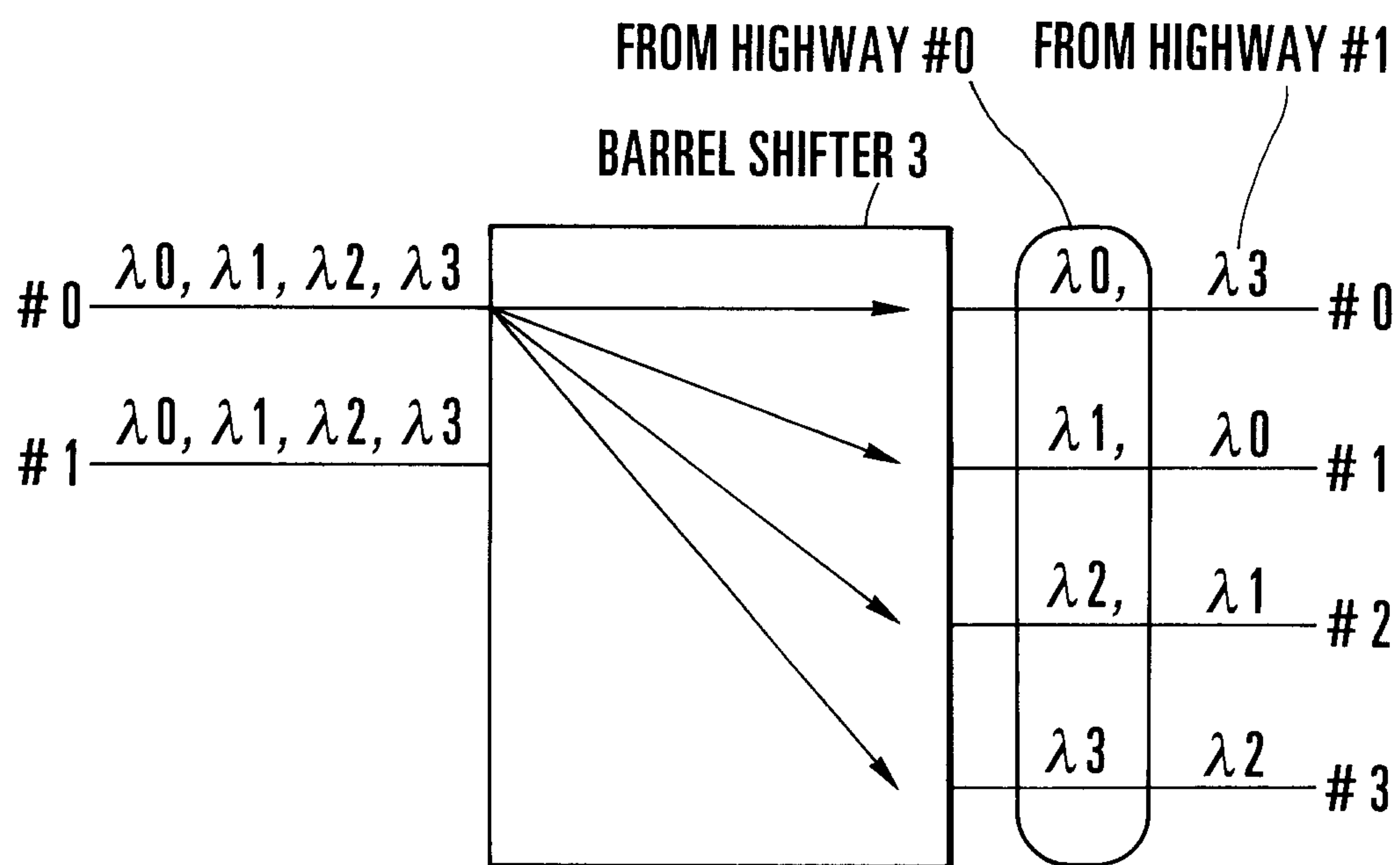


FIG. 2

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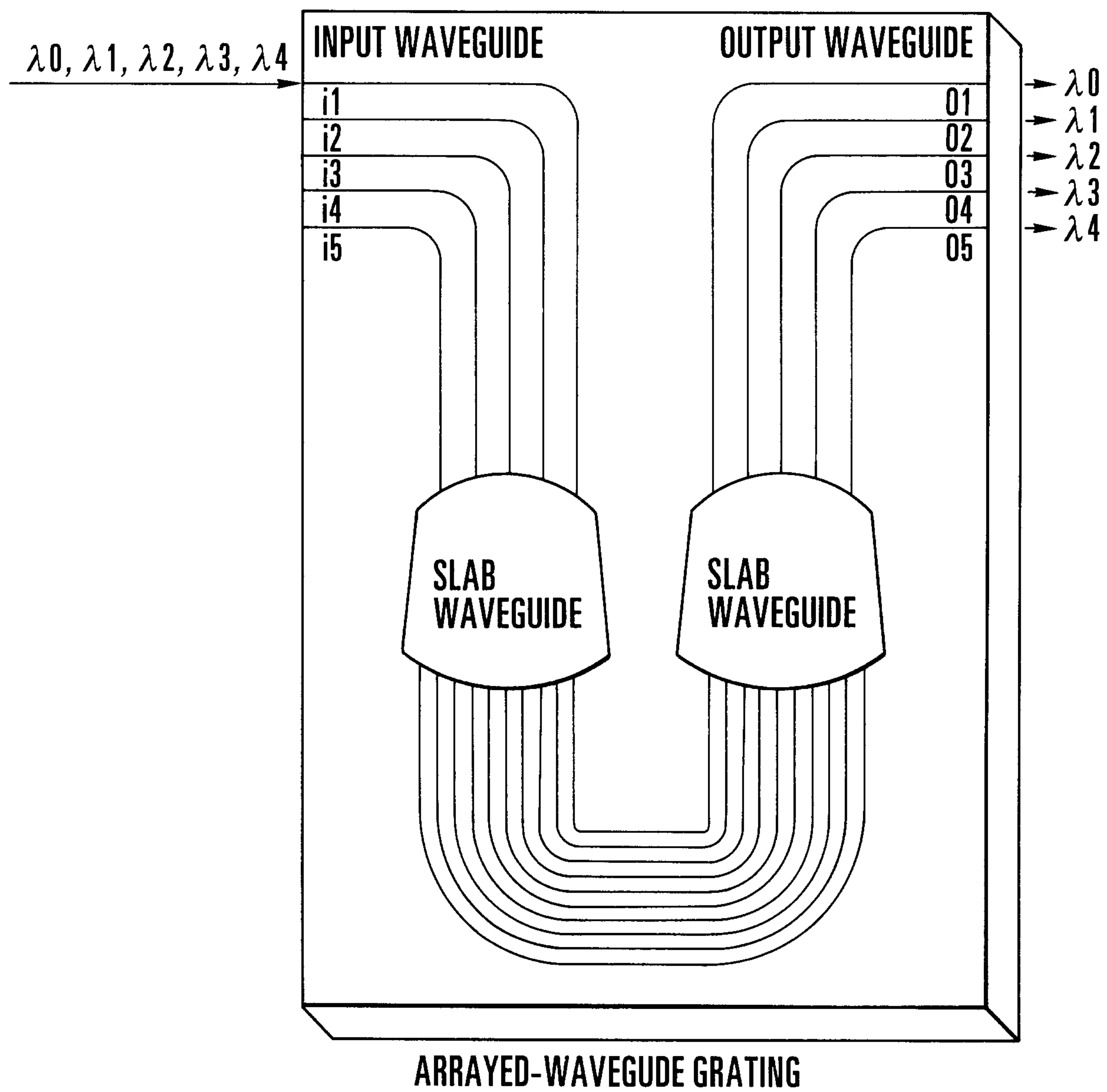


FIG. 3

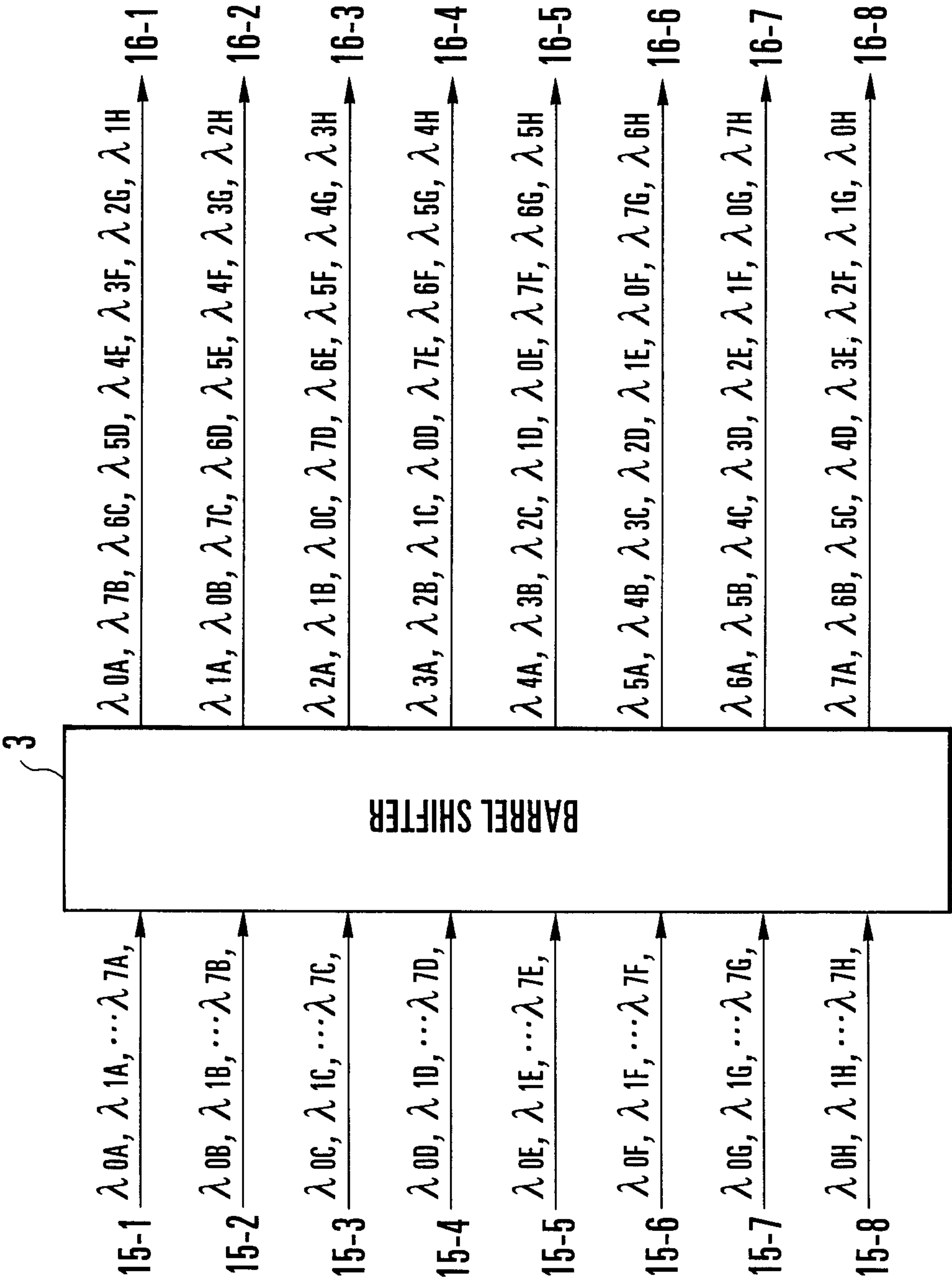


FIG. 4

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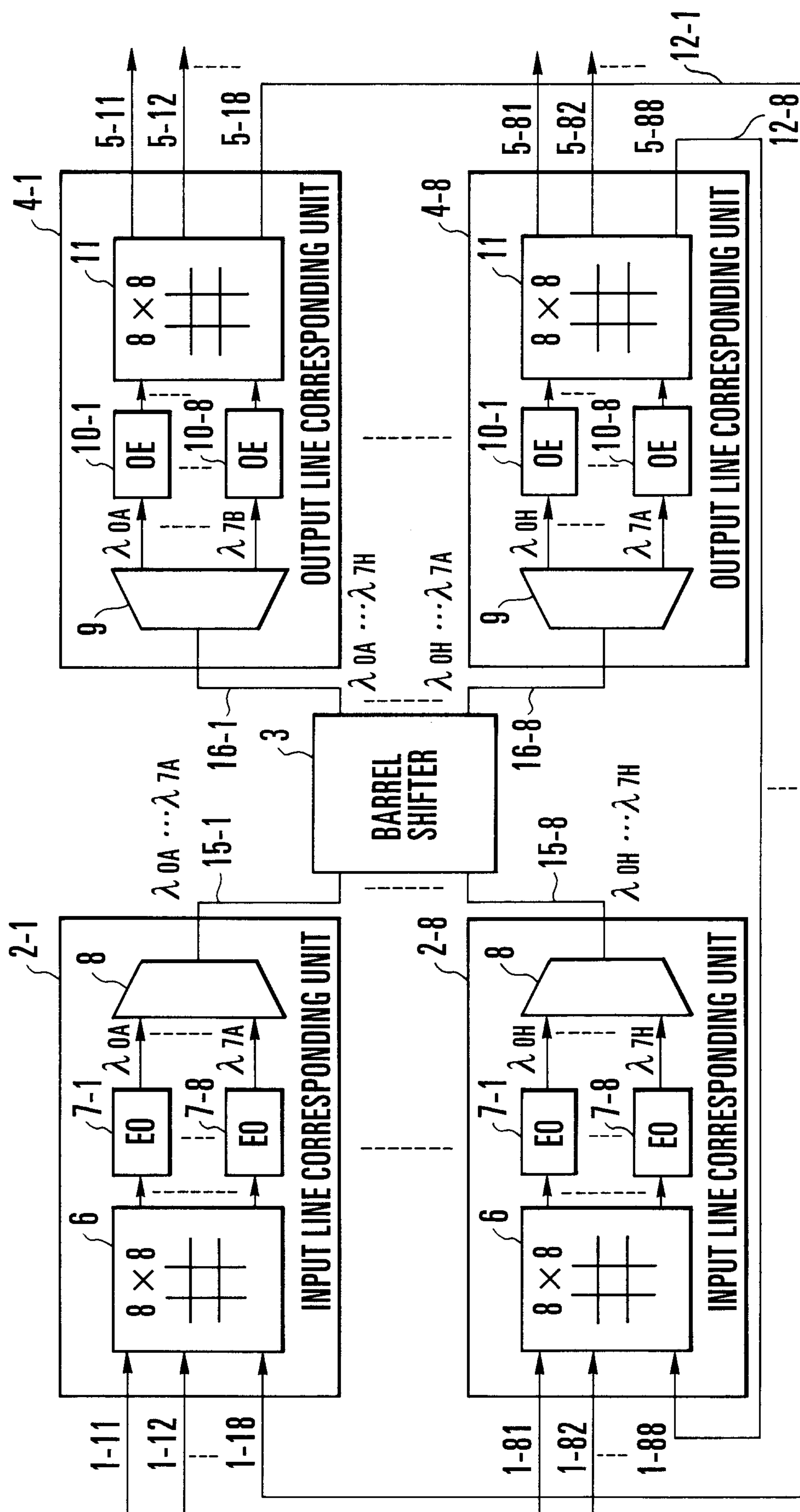


FIG. 5

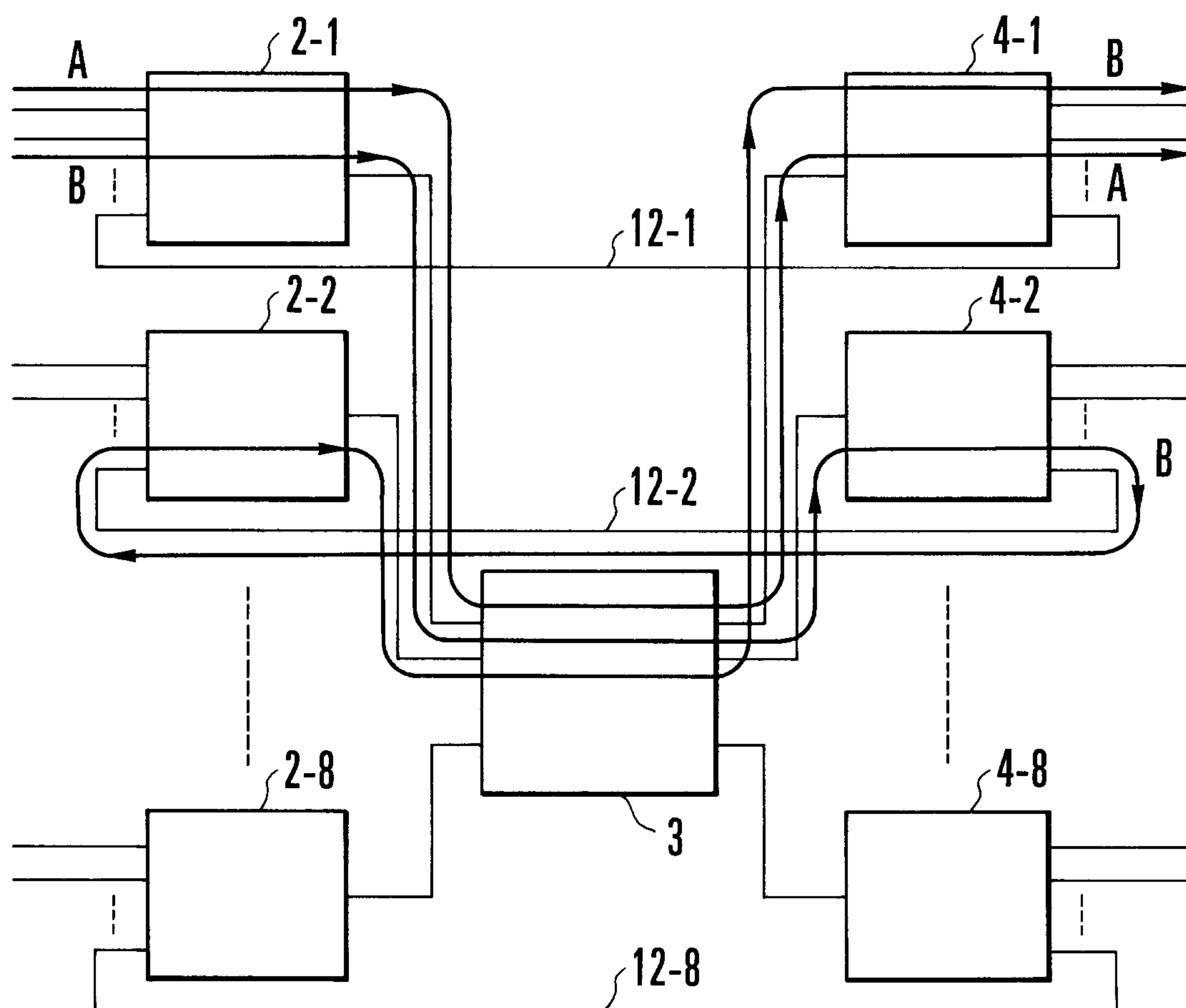


FIG. 6

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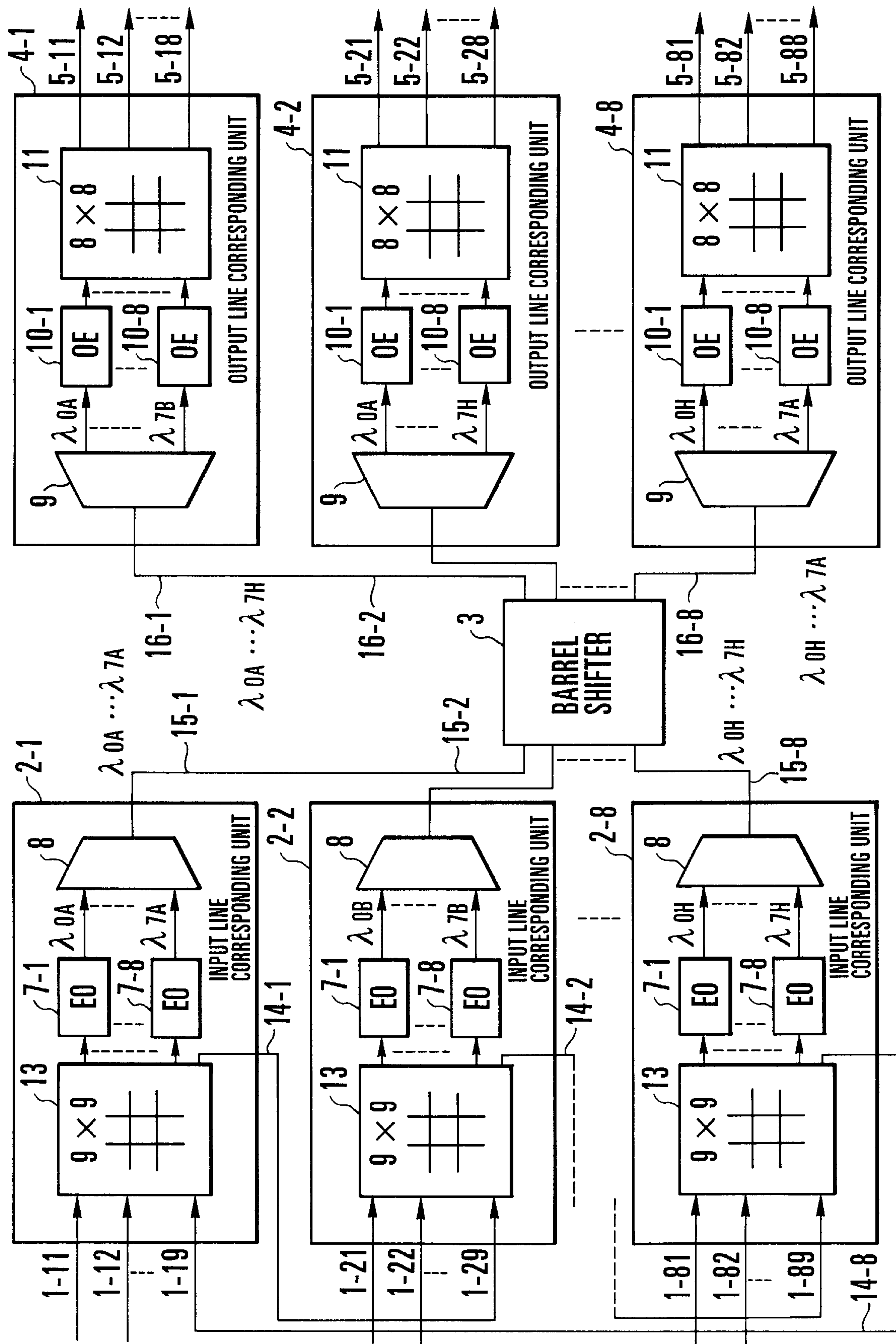


FIG. 7

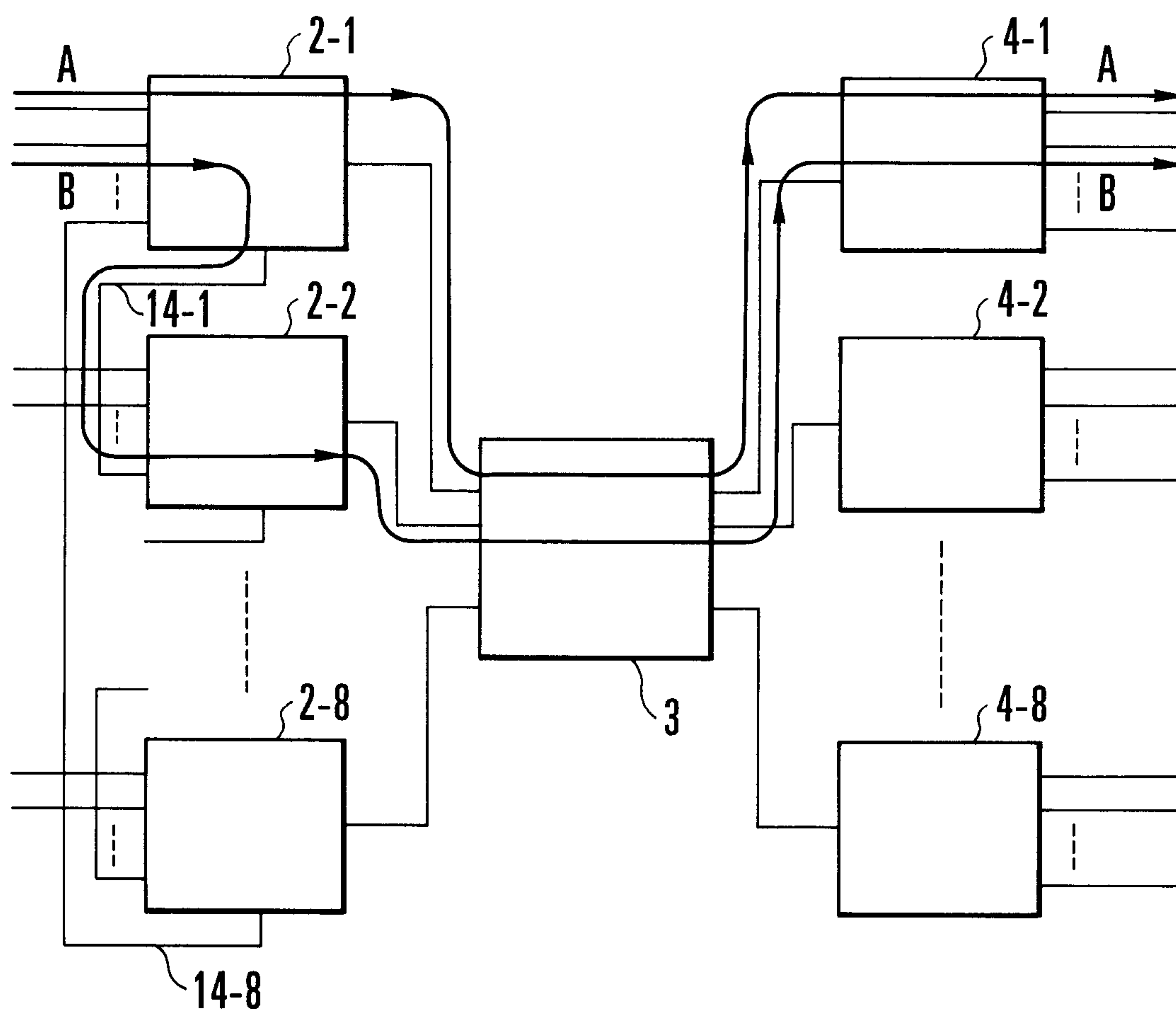


FIG. 8

2-1, 2-2, 2-8
4-1, 4-2, 4-8
14-1, 14-8

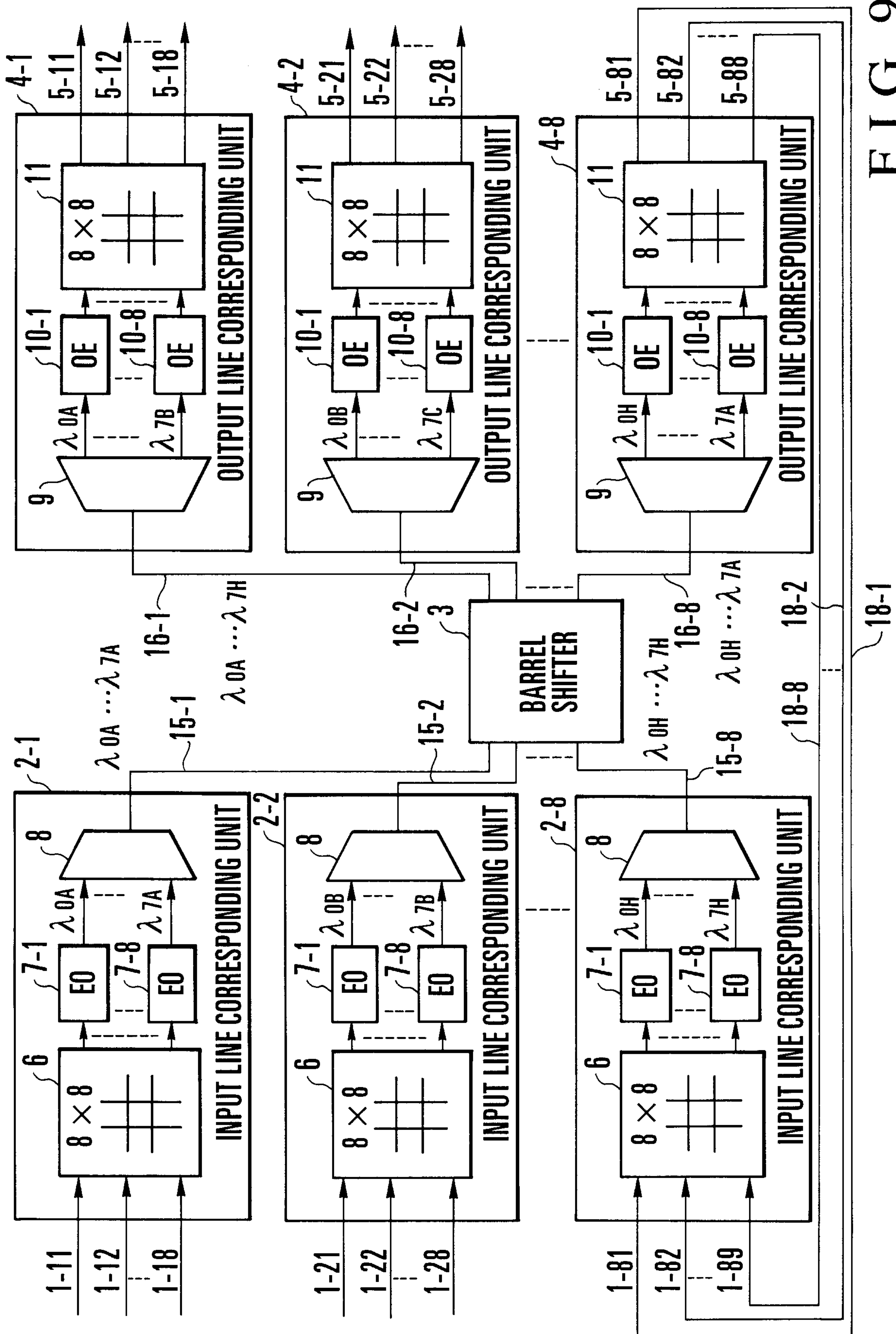


FIG. 9

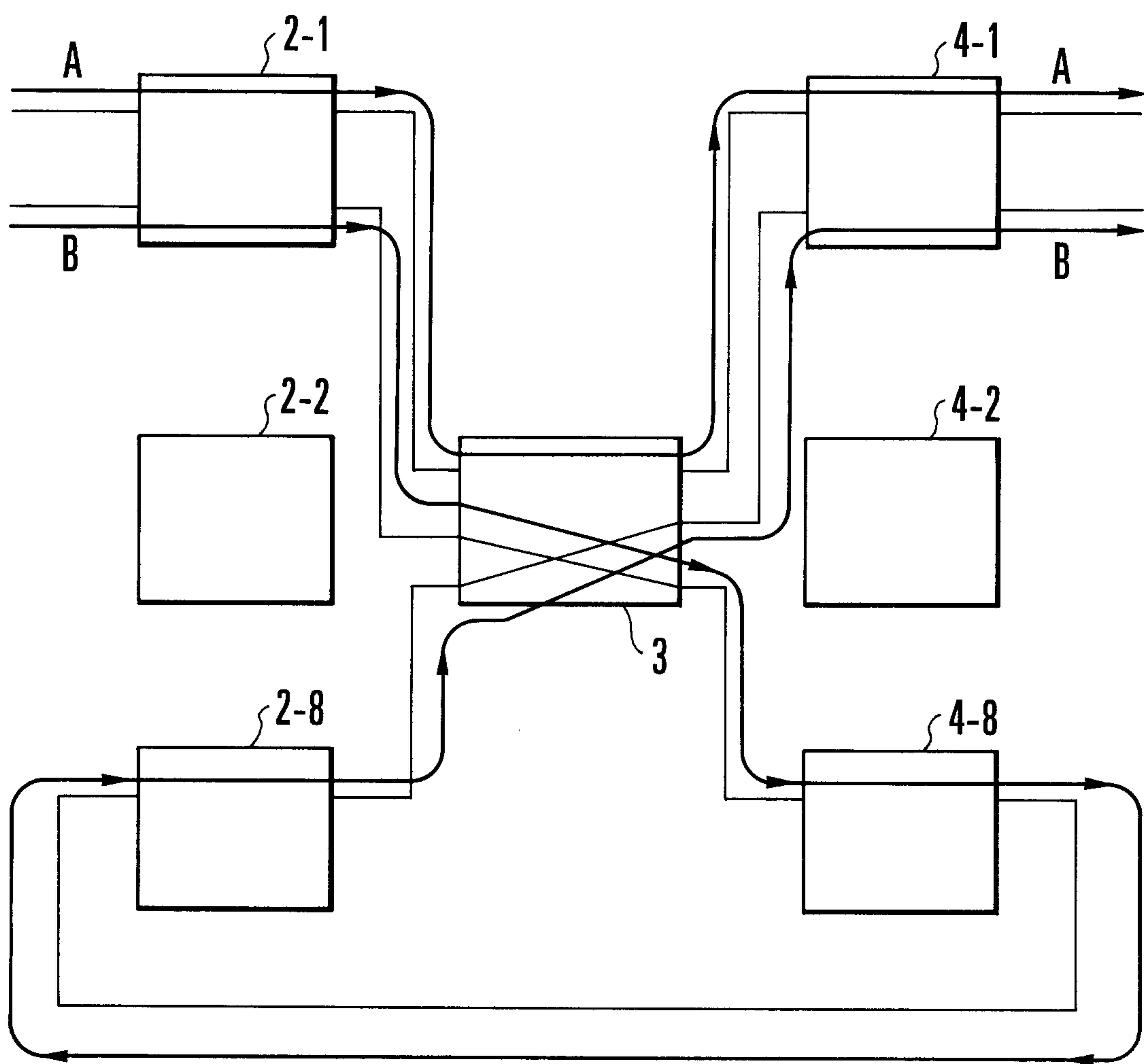


FIG. 10

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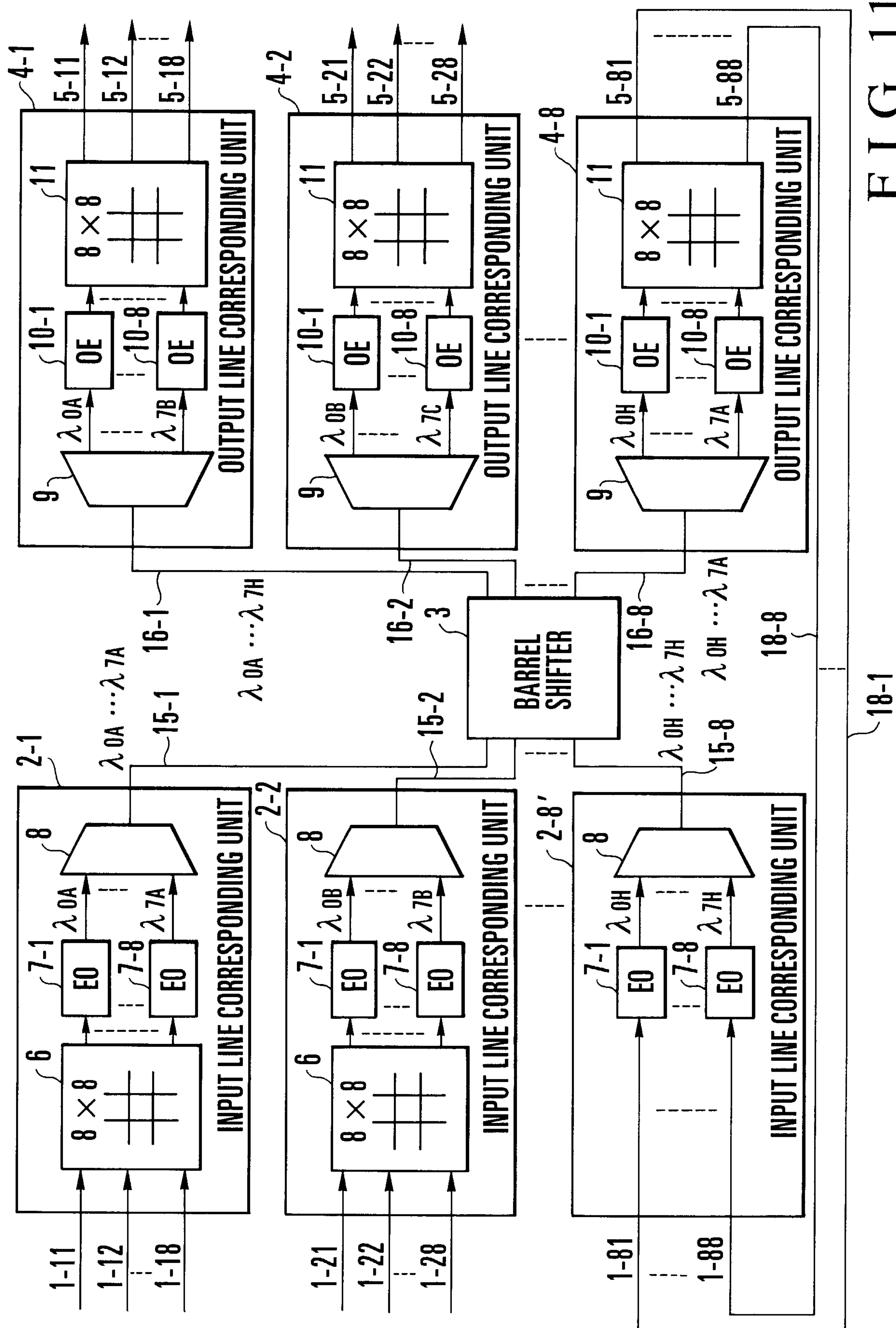


FIG. 11

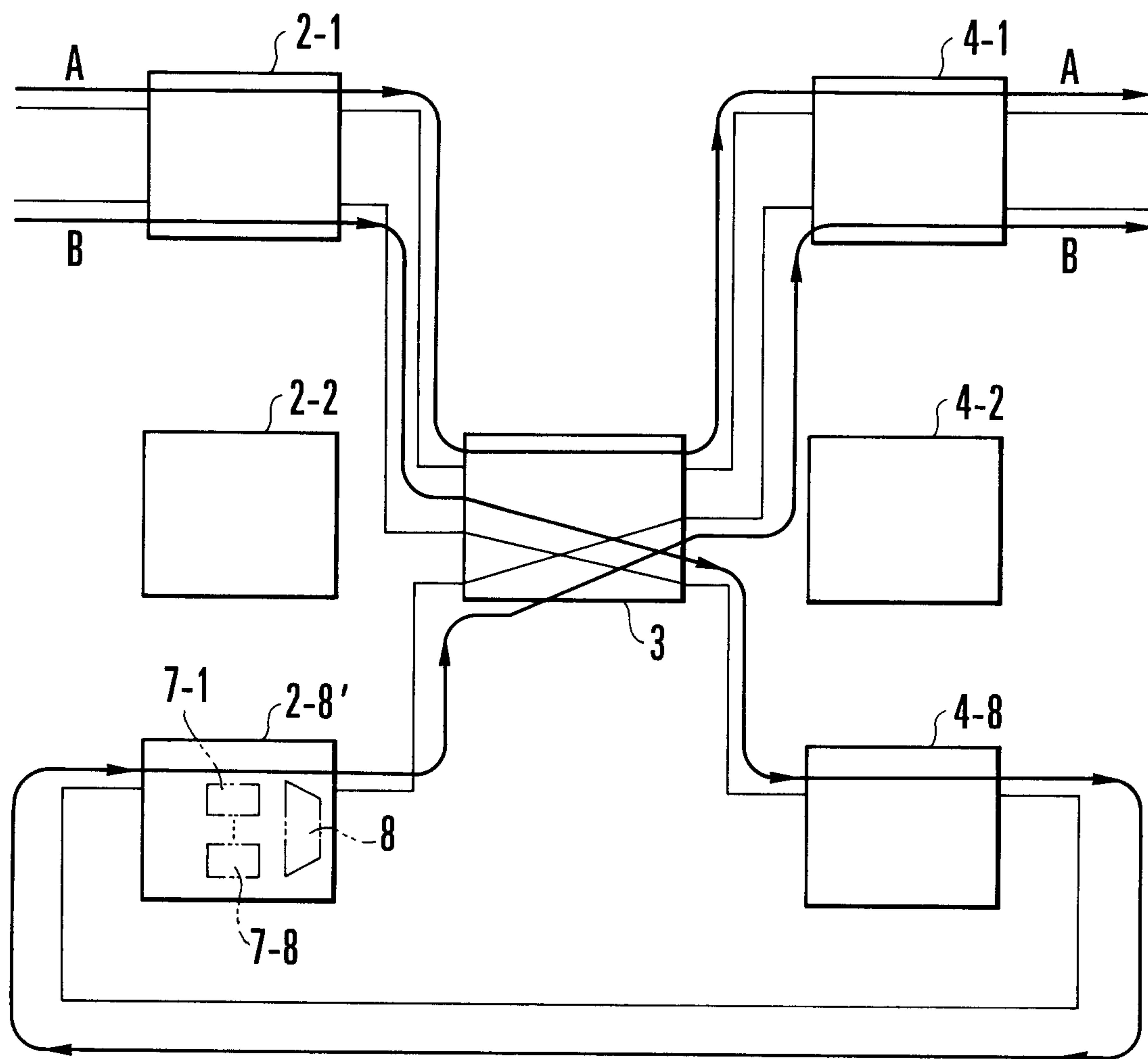


FIG. 12

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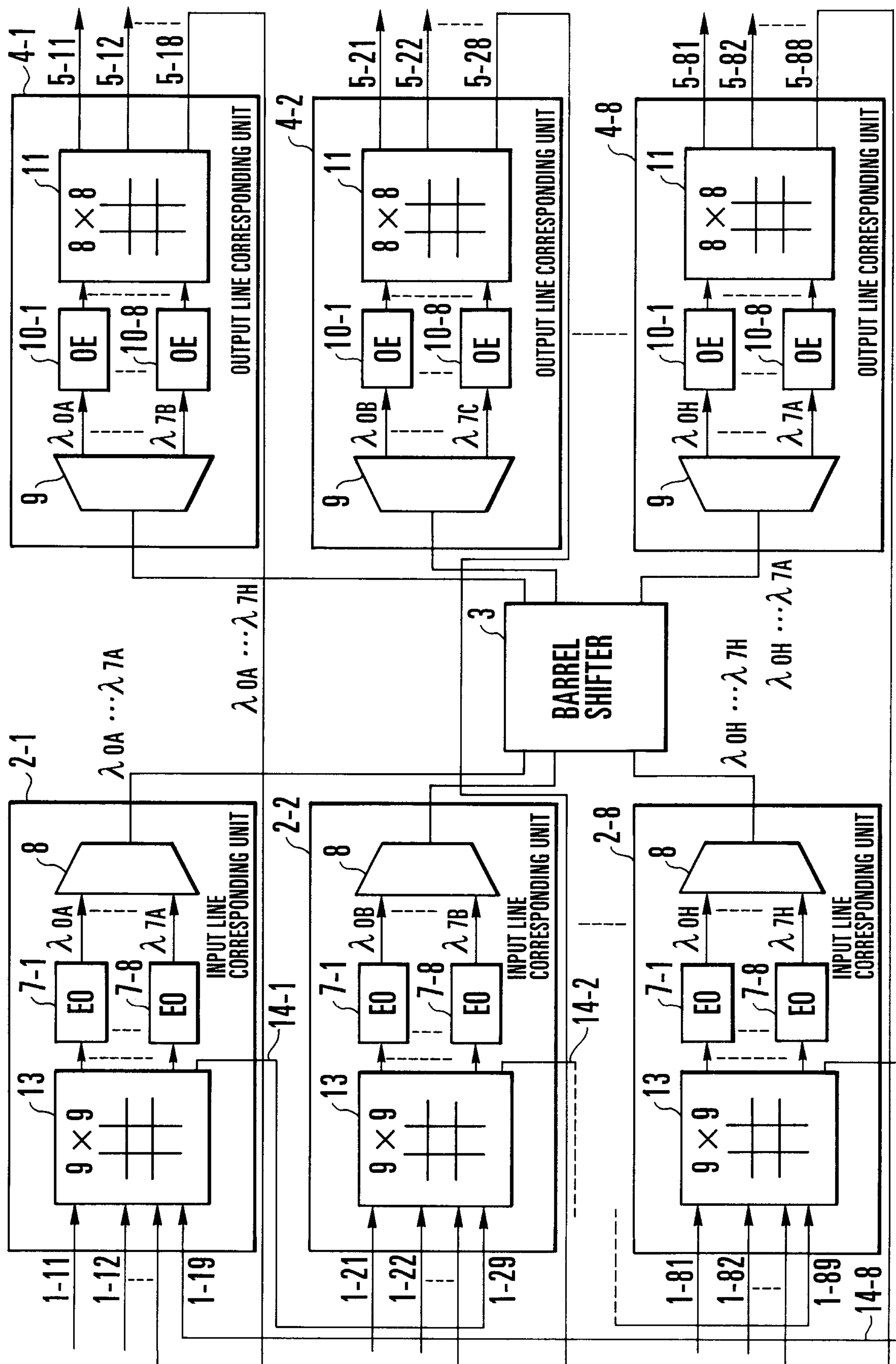


FIG. 13

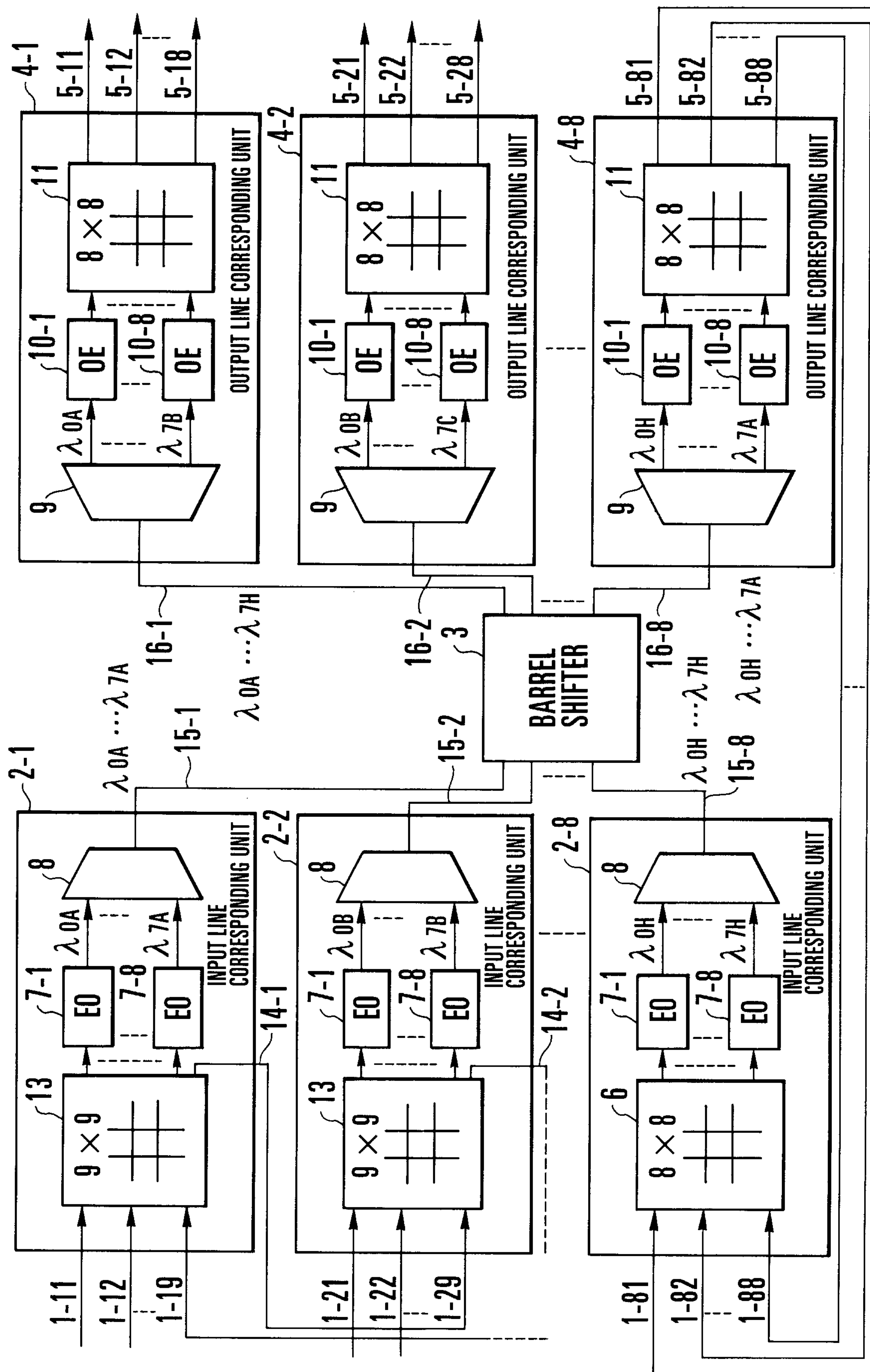


FIG. 14

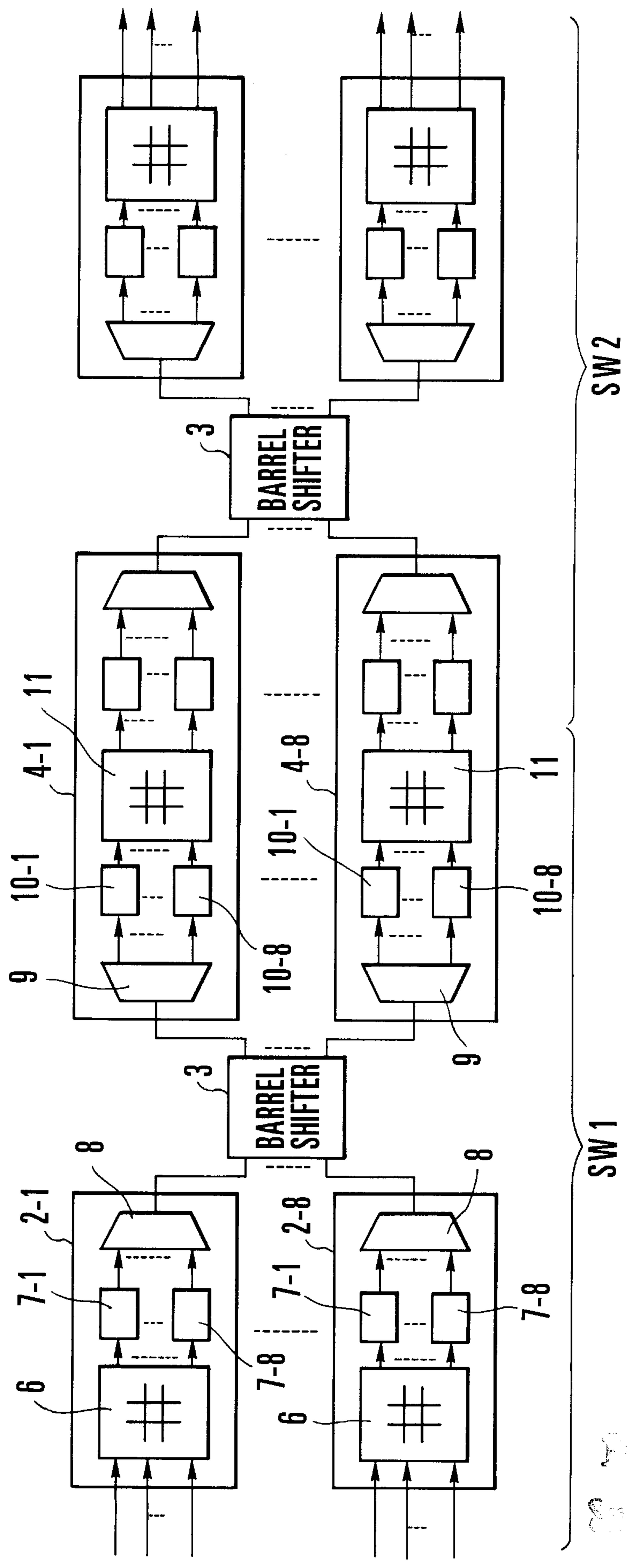


FIG. 15

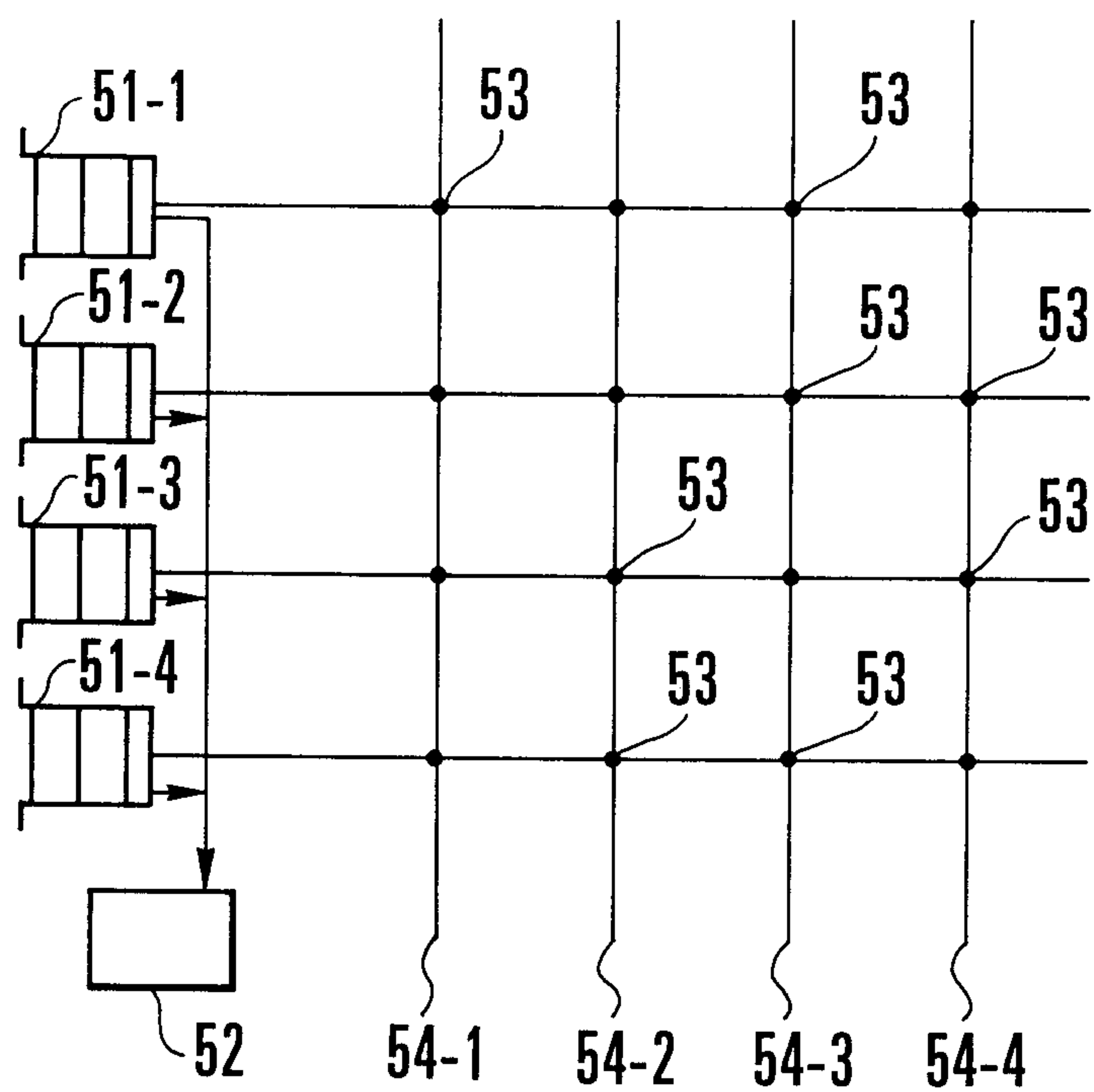


FIG. 16

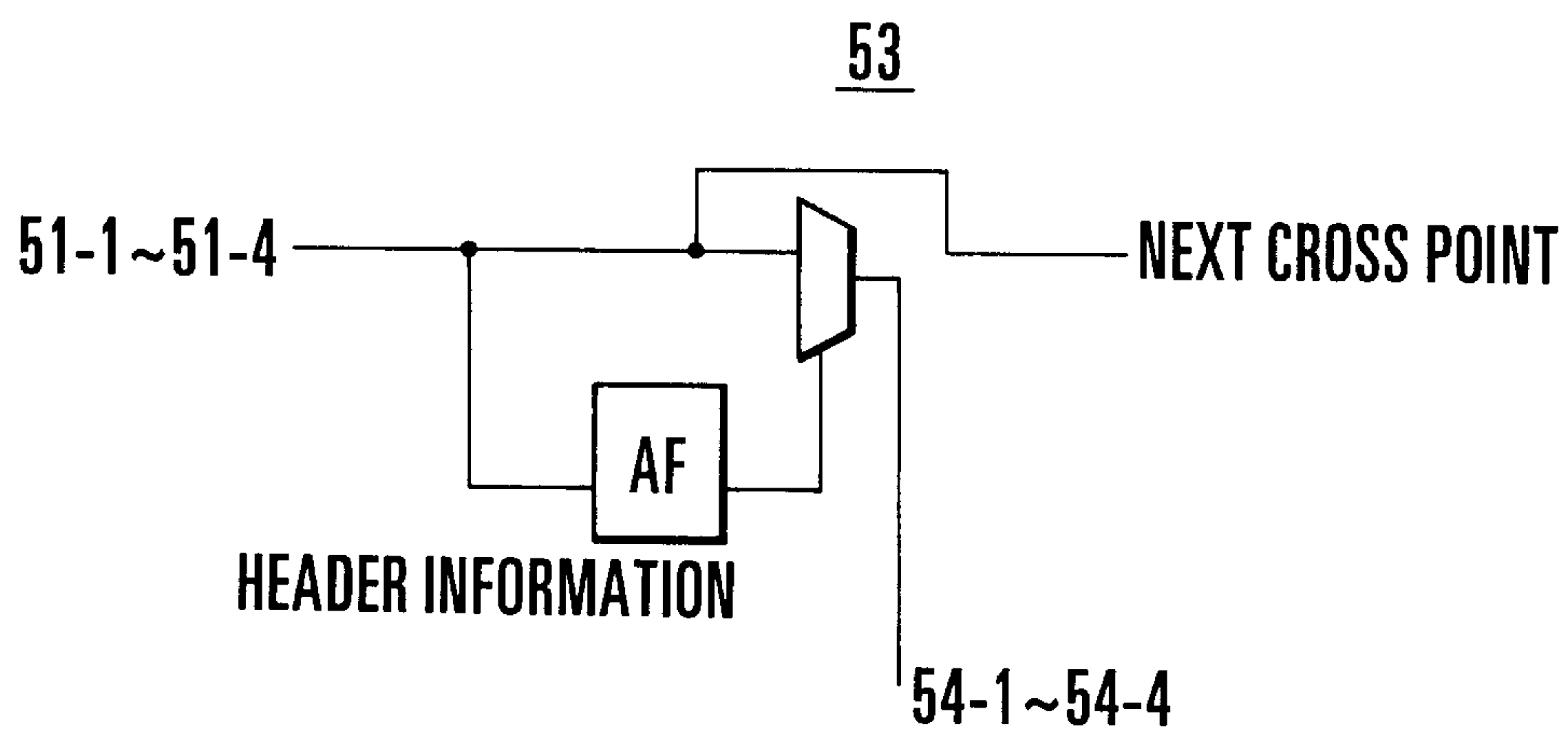


FIG. 17

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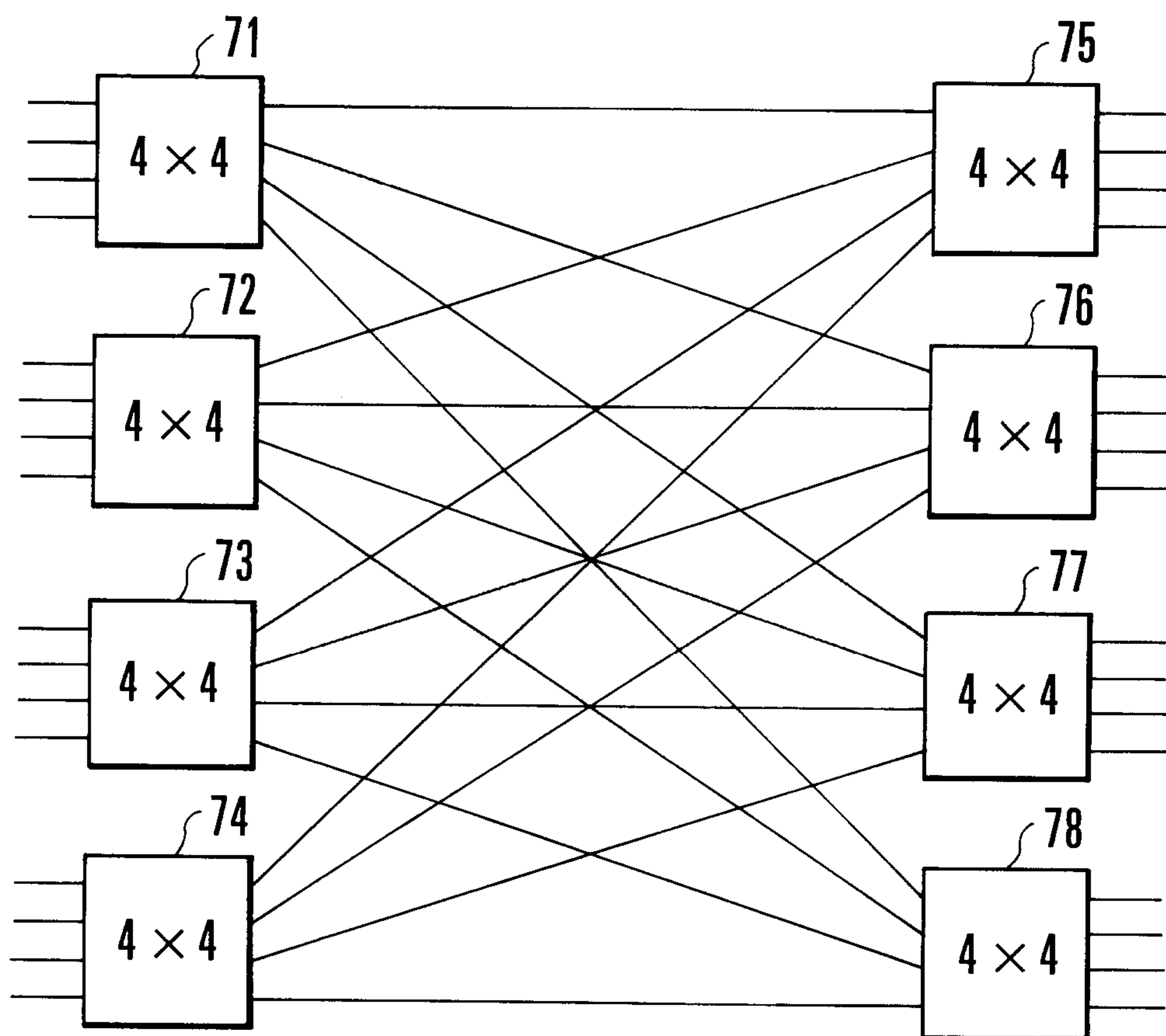


FIG. 18

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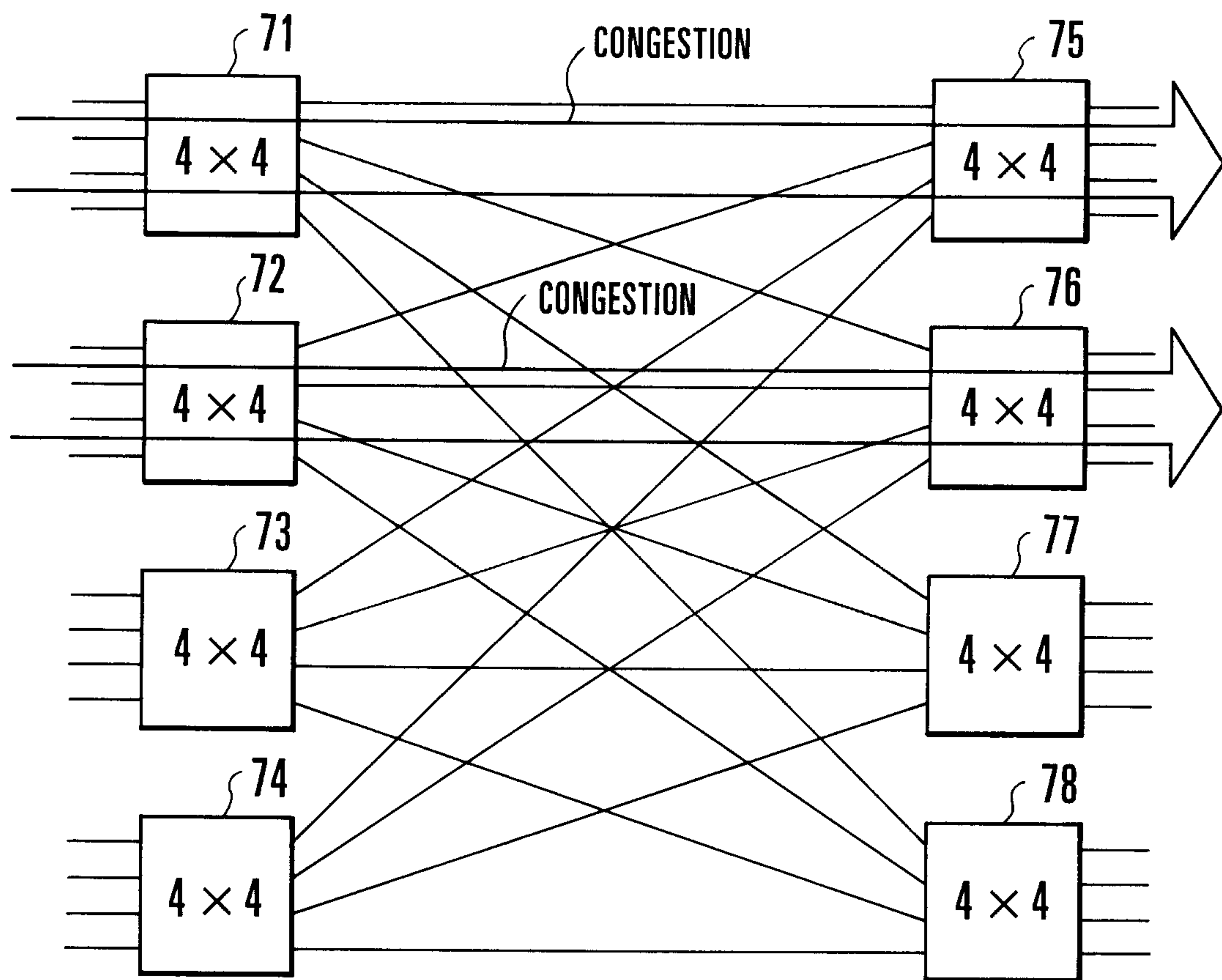


FIG. 19

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