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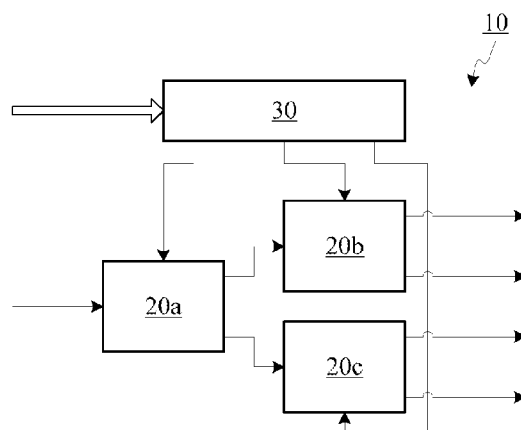


FIG. 1

(57) Abstract: The present invention relates to an optical signal distribution device. An optical distribution device (10) in an embodiment includes: a first 1×2 electro-optical switch (20a), adapted to receive a first voltage control signal; a second 1×2 electro-optical switch (20b), having an input port coupled to a first output port of the first switch, and adapted to receive a second voltage control signal; a third 1×2 electro-optical switch (20c), having an input port coupled to a second output port of the first switch, and adapted to receive a third voltage control signal; and a controller (30), configured to generate the first voltage control signal, the second voltage control signal, and the third voltage control signal according to expected outputs of the second switch and the third switch. The controller is capable of selecting any combination of the outputs of the second switch and the third switch, so as to flexibly meet service requirements of an optical access network.

OPTICAL SIGNAL DISTRIBUTION DEVICECross-reference

5 This application is based on Chinese Patent Application No. xx xxx xxx filed xx/xx/2010, the disclosure of which is hereby incorporated by reference thereto in its entirety, and the priority of which is hereby claimed;

Technical field

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The present invention generally relates to photoelectronics technologies, and more particularly to an optical signal distribution device.

Background

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Currently, the Gigabit passive optical network (GPON) and the Ethernet PON (EPON) are widely used. Due to increasing bandwidth demands of services such as viewing Internet videos on a personal computer, viewing Internet videos on a television set, IPTV, and point-to-point services, the GPON and EPON are facing serious problems. A 10 Gigabit/s PON (XG-PON) is regarded as a technology for improving the capacity and cost efficiency of a PON system. Various architectures are considered as candidate solutions for next-generation PONs, including the time division multiplexing-PON (TDM-PON), wavelength division multiplexing-PON (WDM-PON), code division multiplexing-PON (CDMA-PON), and orthogonal frequency division multiplexing-PON (OFDM-PON). The TDM-PON and WDM-PON are two competitive solutions. The WDM-PON is a promising means for updating the system capacity; however, the demand for a colorless optical network unit (ONU) increases the cost, and the management for the WDM wavelength is also complex. The TDM-PON is beneficial from the perspective of service application, and improvement is made to the conventional PON by raising the TDM downlink bit rate with no aid from the WDM technology. By using the TDM-PON that applies wavelength stacking and has a low bit rate, the capacity of the PON system can be easily improved.

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However, all the foregoing technologies are based on the concept of a passive access network, and ignore the impact of network control on an optical access system. With the upgrade of the PON capacity and increase of the number of users, the bandwidth effective utilization and security problems become critical problems to be solved for the next-

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generation PONs. However, the specific implementation highly depends on the development of a photoexcited apparatus. Some researchers propose to use an optical switch structure to replace an optical splitter in the PON. Due to the passive characteristic, the PON system lacks some basic functions of a conventional electrical access network, for example, downlink
5 unicast and multicast functions. Therefore, the optical access network needs strong support from the photoexcited apparatus.

It is proposed to use an electro-optical switch to replace the passive optical splitter so as to provide unicast TDM downlink data streams in the optical access network. Although the whole system is no longer passive, security threats can still be eliminated. With the
10 development of photoelectric elements, especially the development of photoelectric integrated circuits, the power consumption of the electro-optical switch can be significantly reduced, and the optical access network having such apparatus is also referred to as a quasi-PON.

Although the electro-optical switch is an old research theme in the field of optical components, such components are mainly used in a core optical network or a network
15 emphasizing exchanging (switching) functions due to high cost. The inventor finds out that there are a few application solutions of the optical access network. Several proposals of the electro-optical switch are demonstrated from the perspective of researches.

Lead lanthanum zirconate titanate (PLZT) can be used to construct a unicast TDM-PON, and the switching time may be several nanoseconds. However, the high cost limits the
20 application of the PLZT in the field of access networks.

Summary

The present invention is mainly directed to provide an optical signal distribution device,
25 to implement distribution of an input optical signal to more than two outputs.

An embodiment provides an optical distribution device, which includes: a first 1×2 electro-optical switch, adapted to receive a first voltage control signal; a second 1×2 electro-optical switch, having an input port coupled to a first output port of the first switch, and adapted to receive a second voltage control signal; a third 1×2 electro-optical switch, having
30 an input port coupled to a second output port of the first switch, and adapted to receive a third voltage control signal; and a controller, configured to generate the first voltage control signal, the second voltage control signal, and the third voltage control signal according to expected outputs of the second switch and the third switch.

According to an embodiment, the controller of the optical distribution device is

configured to select a combination of the outputs of the second switch and the third switch. Therefore, the optical distribution device can flexibly meet various service requirements of an optical access network, for example, unicast, broadcast and multicast. Optionally, the controller of the optical distribution device is capable of selecting partial combinations of the outputs of the second switch and the third switch, for example, a combination of unicast and broadcast. Optionally, the controller of the optical distribution device can only implement a certain combination of the outputs of the second switch and the third switch.

According to an embodiment, at least the first, second and third 1×2 electro-optical switches of the optical distribution device are formed on a single silicon substrate. The first, second, and third switches in the optical distribution device are formed on the same silicon substrate, and the controller is implemented with an independent programmable logic circuit. In another embodiment, the optical distribution device is formed on a single silicon substrate.

According to an embodiment, the first, second, and third 1×2 electro-optical switches in the optical distribution device are Mach-Zehnder (MZ) interferometer electro-optical switches.

According to an embodiment, the first, second, and third 1×2 electro-optical switches in the optical distribution device respectively include: a first coupler, including at least two output ends; three parallel electrodes, adapted to receive one of the first, second, and third voltage control signals; a first arm and a second arm, respectively coupled to two output ends of the first coupler, and located between the three electrodes; and a second coupler, coupled to the first arm and the second arm.

According to an embodiment, the first, second, and third voltage control signals in the optical distribution device are configured to be synchronous with optical signals borne from the first switch to the second switch and the third switch, so as to implement a TDM-based optical access network.

According to an embodiment, the controller in the optical distribution device is adapted to receive a control signal from an optical line terminal (OLT). The OLT receives an output from the optical distribution device, and may send an (electrical) control signal to request or cancel optical signal access. The optical distribution device may determine the expected outputs of the second switch and the third switch according to the control signal of the OLT in downlink connection thereto.

According to an embodiment, the controller in the optical distribution device includes: an input terminal and first, second, and third output terminals, the first output terminal being coupled to the input terminal; a phase shifter, having an input end coupled to the input terminal; a first inverter, having an input end coupled to an output end of the phase shifter; a

first AND gate, having a first input end coupled to the output of the first inverter and a second input end coupled to the input terminal, and having an output coupled to the second output terminal; a second inverter, having an input end coupled to the input terminal; and a second AND gate, having a first input end coupled to the output of the phase shifter and a second input end coupled to an output of the second inverter, and having an output coupled to the third output terminal.

The technical features and advantages of the present invention are summarized above, so as to make the following detailed descriptions of the present invention easier to understand. Other features and advantages will be described in the following, which form the subject of the claims. It should be understood by persons skilled in the art that the disclosed concepts and embodiments may be easily used as a basis for modifying or designing other structures or procedures for implementing the same objective as the present invention. It should also be understood by persons skilled in the art that the equivalent construction does not depart from the spirit and scope of the appended claims.

Brief description of the drawings

With reference to the accompanying drawings, the following detailed descriptions about the exemplary embodiments of the present invention are easier to understand. The present invention is illustrated through the examples and is not limited to the accompanying drawings. Similar symbols in the accompanying drawings indicate similar components.

FIG. 1 is a structural block diagram of an optical distribution device 10 according to an embodiment;

FIG. 2 is a structural diagram of 1×2 electro-optical switches in the optical distribution device according to an embodiment; and

FIG. 3 is a partial schematic structural diagram of a controller in the optical distribution device according to an embodiment.

Detailed Description

The detailed descriptions of the accompanying drawings are intended to illustrate current exemplary embodiments, rather than to represent the only implementation forms. It should be understood that the same or equivalent function may be completed by different embodiments that are intended to be included within the spirit and scope of the present invention.

FIG. 1 is a structural block diagram of an optical distribution device 10 according to an embodiment. Referring to FIG. 1, the optical distribution device 10 includes: a first 1×2 electro-optical switch 20a, a second 1×2 electro-optical switch 20b, a third 1×2 electro-optical switch 20c, and a controller 30. Input ports of the second switch 20b and the third switch 20c are respectively coupled to an output port of the first switch 20a. The first, second, and third switches 20a, 20b, 20c are respectively adapted to receive first, second, and third voltage control signals. The controller 30 is configured to generate the first voltage control signal, the second voltage control signal, and the third voltage control signal according to expected outputs of the second switch 20b and the third switch 20c, so as to control the generation of the expected outputs, thereby implementing distribution from one input to four outputs of the optical distribution device 10. The first, second, and third voltage control signals are respectively used for controlling a 1×2 electro-optical switch, the implementation is not limited to a voltage signal, and multiple voltage signals may be applied to multiple terminals of the 1×2 electro-optical switch at the same time.

When the size of a component increases, the optical path is extended, the random phase shift and delay jitter are more difficult to predict and control, and the control signal synchronization and TDM are more difficult to implement. In the case that a discrete component with a size of 10 cm or even larger is used or that the coupling optical path between the switches exceeds 10 cm, due to randomness of phase difference drift and delay jitter, the synchronization of the control signals is hard to achieve, and thus the TDM cannot be actually implemented.

Preferably, the optical distribution device 10 is formed on a single silicon substrate, or at least the first, second, and third switches 20a, 20b, 20c of the optical distribution device 10 are formed on a single silicon substrate. When the first, second, and third switches 20a, 20b, 20c are formed on a single silicon substrate, the size of each switch can be controlled within several millimeters or even several micrometers, the jitter of the optical path can be ignored, and the optical path difference between the switches is consistent as for the optical distribution devices of the same specification. Therefore, the control signals can be synchronized, and the TDM can be actually implemented. The components of the optical distribution devices of the same specification have consistent performance, and the random performance difference can be reduced to an acceptable range, so that the optical distribution device can be applied on a large scale. The promotion of the optical distribution device in an optical access network is also facilitated due to its relatively low cost.

Optionally, the controller 30 of the optical distribution device 10 is capable of selecting

any combination of the outputs of the second switch 20b and the third switch 20c. Therefore, the optical distribution device can flexibly meet various service requirements of the optical access network, for example, unicast, broadcast and multicast. Optionally, the controller 30 of the optical distribution device 10 is capable of selecting partial combinations of the outputs of the second switch 20b and the third switch 20c, for example, a combination of unicast and broadcast. Optionally, the controller 30 of the optical distribution device 10 can only implement a certain combination of the outputs of the second switch 20b and the third switch 20c. The controller 30 and the first, second, and third switches 20a, 20b, 20c may be integrated on the same silicon substrate, or the controller 30 may be implemented with an independent programmable logic circuit.

The first, second, and third voltage control signals in the optical distribution device 10 are configured to be synchronous with optical signals borne from the first switch 20a to the second switch 20b and the third switch 20c. Specifically, the timing offset between the first voltage control signal and the second voltage control signal is multiplied with the velocity of light to obtain the optical path between the first switch 20a and the second switch 20b; and the timing offset between the first voltage control signal and the third voltage control signal is multiplied with the velocity of light to obtain the optical path between the first switch 20a and the third switch 20c. In this manner, the application of the voltage control signals is synchronous with the transmission of the optical signals, so that TDM can be implemented between the four outputs of the second switch 20b and the third switch 20c.

According to an embodiment of the present invention, the first, second, and third 1×2 electro-optical switches in the optical distribution device 10 are MZ interferometer electro-optical switches. FIG. 2 shows a specific structure of the MZ interferometer electro-optical switch. The MZ interferometer switch 20 (20a, 20b, 20c) includes: a first coupler 21, first, second, and third electrodes 23a, 23b, 23c, a first arm 25a and a second arm 25b respectively coupled to two output ends of the first coupler 21, and a second coupler 27 respectively coupled to the first arm 25a and the second arm 25b.

The first coupler 21 and the second coupler 27 are both 3 dB, and the first coupler 21 is Y-shaped. The optical signals entering from the input end are divided into two beams according to a light intensity proportion of 1:1, and respectively enter the first arm 25a and the second arm 25b for phase modulation. The second electrode 23b is grounded, the first electrode 23a and the third electrode 23c are respectively applied with $+V_0$, $-V_0$ direct-current voltages, and by changing V_0 , the refraction indexes of the first arm 25a and the second arm 25b in the electric field change accordingly, which may cause change of the phase

difference between the output optical signals of the first arm 25a and the second arm 25b, and eventually cause change of the light intensities of the two outputs. The $+V_0$, $-V_0$ direct-current voltages are corresponding to one of the first, second, and third voltage control signals. By ignoring the transmission loss, the normalized light intensities of the two outputs are

5 respectively $\sin^2\left(\frac{\Delta V_0}{2V_\square}\right)$, $\cos^2\left(\frac{\Delta V_0}{2V_\square}\right)$, where $V_\square$ is a half-wave voltage, which means that the phase difference between the output optical signals of the first arm 25a and the second arm 25b reaches a voltage required to be applied by π .

If the structures of the first, second, and third switches are the same, the half-wave voltages are all $V_\square$, and the first, second, and third voltage control signals are respectively
10 represented as V_A , V_B , V_C , the normalized light intensities of the four outputs of the second switch and the third switch may be respectively represented as:

$$T_1 = \sin^2\left(\frac{\Delta V_A}{2V_\square}\right) \sin^2\left(\frac{\Delta V_B}{2V_\square}\right);$$

$$T_2 = \sin^2\left(\frac{\Delta V_A}{2V_\square}\right) \cos^2\left(\frac{\Delta V_B}{2V_\square}\right);$$

$$T_3 = \cos^2\left(\frac{\Delta V_A}{2V_\square}\right) \sin^2\left(\frac{\Delta V_C}{2V_\square}\right); \text{ and}$$

$$15 \quad T_4 = \cos^2\left(\frac{\Delta V_A}{2V_\square}\right) \cos^2\left(\frac{\Delta V_C}{2V_\square}\right).$$

When $V_A=V_B=V_C=V_\square/2$, $T_1=T_2=T_3=T_4=1/4$, thereby implementing the broadcast function.

The voltage control signals having the unicast function are configured as follows:

When $V_A=V_B=V_\square$, $T_1=1$, $T_2=T_3=T_4=0$, thereby implementing the unicast of the first
20 output end;

When $V_A=V_\square$, $V_B=0$, $T_2=1$, $T_1=T_3=T_4=0$, thereby implementing the unicast of the second output end;

When $V_A=0$, $V_C=V_\square$, $T_3=1$, $T_1=T_2=T_4=0$, thereby implementing the unicast of the third output end; and

25 When $V_A=V_C=0$, $T_4=1$, $T_1=T_2=T_3=0$, thereby implementing the unicast of the fourth output end.

The configuration of the voltage control signals in a multicast service is shown in Table 1 and Table 2 in the following.

Table 1 Configuration of the voltage control signals with two of the four outputs being gated

V_A	V_B	V_C	T_1	T_2	T_3	T_4
V_π	$V_\pi/2$	—	ON	ON	OFF	OFF
$V_\pi/2$	V_π	V_π	ON	OFF	ON	OFF
$V_\pi/2$	V_π	0	ON	OFF	OFF	ON
$V_\pi/2$	0	V_π	OFF	ON	ON	OFF
$V_\pi/2$	0	0	OFF	ON	OFF	ON
0	—	$V_\pi/2$	OFF	OFF	ON	ON

Table 2 Configuration of the voltage control signals with three of the four outputs being gated

V_A	V_B	V_C	T_1	T_2	T_3	T_4
$V_\pi/2$	$V_\pi/2$	V_π	ON	ON	ON	OFF
$V_\pi/2$	V_π	$V_\pi/2$	ON	OFF	ON	ON
$V_\pi/2$	$V_\pi/2$	0	ON	ON	OFF	ON
$V_\pi/2$	0	$V_\pi/2$	OFF	ON	ON	ON

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The output ends of the optical distribution device 10 are respectively coupled to downlink OLTs. These OLTs respectively receive an output from the optical distribution device 10 and may send an (electrical) control signal to request or cancel optical signal access. The controller 30 of the optical distribution device 10 is adapted to receive control signals sent by the OLTs in downlink connection thereto, and accordingly determine the expected outputs of the second switch 20b and the third switch 20c. The expected outputs of the second switch 20b and the third switch 20c may be corresponding to any combination of the unicast, broadcast and multicast.

When the controller 30 is implemented with an erasable programmable logic circuit, the control logic of the controller 30 can be changed according to service requirements, so as to implement addition, deletion and modification of an optical access service. Optionally, the controller 30 of the optical distribution device 10 is capable of selecting any combination of the outputs of the second switch 20b and the third switch 20c. Therefore, the optical distribution device can flexibly meet various service requirements of the optical access network, for example, unicast, broadcast and multicast. Optionally, the controller 30 of the optical distribution device 10 is capable of selecting partial combinations of the outputs of the second switch 20b and the third switch 20c, for example, a combination of unicast and broadcast. Optionally, the controller 30 of the optical distribution device 10 can only implement a certain combination of the outputs of the second switch 20b and the third

switch 20c.

FIG. 3 is a partial schematic structural diagram of a controller in the optical distribution device according to an embodiment. Referring to FIG. 3, the controller 30 in this embodiment includes: an input terminal 31, first, second, and third output terminals 32a, 32b, 32c, a phase shifter 33, a first inverter 34, a second inverter 35, a first AND gate 36, and a second AND gate 37.

The first output terminal 32a is coupled to the input terminal 31, to output the first voltage control signal. An input end of the phase shifter 33 is coupled to the input terminal 31, and the phase shifter applies a phase shift of $\pi/2$ on an input signal. An input end of the first inverter 34 is coupled to an output end of the phase shifter 33. Two input ends of the first AND gate 36 are respectively coupled to an output of the first inverter 34 and the input terminal 31, and an output of the first AND gate 36 is coupled to the second output terminal 32b, to output the first voltage control signal. An input end of the second inverter 35 is coupled to the input terminal 31. Two input ends of the second AND gate 37 are respectively coupled to the output of the phase shifter 33 and an output of the second inverter 35, and an output of the second AND gate 37 is coupled to the third output terminal 32c, to output the third voltage control signal. The control circuit in this embodiment can implement a unicast service, and when the input signal of the input terminal 31 is a square-wave signal with a duty ratio of 50%, the specific output signals of the optical distribution device 10 are four output ends being periodically and sequentially gated for a time slot.

The above embodiment describes a specific implementation manner of cascading and controlling two 1×2 electro-optical switches to obtain a 1×4 optical signal distribution function. Under this principle, through selection of the control logic, persons skilled in the art can easily think of specific implementation manners of cascading and controlling more 1×2 electro-optical switches to obtain optical signal distribution functions of 1×8, 1×16, 1×32 and other grades.

Although different embodiments are illustrated and described above, the present invention is not limited to these embodiments. The ordinal numerals such as "first" and "second" in the claims are only used for distinguishing, instead of defining any special sequence or connection relation between corresponding parts. Besides, the technical features that merely appear in some items of the appended claims or some embodiments may also be combined with the features in the other items of the appended claims or other embodiments to implement new beneficial technical solutions. Many modifications, alterations, variations,

replacements and equivalences are obvious to persons skilled in the art without departing from the spirit and scope of the present invention described in the appended claims.

We Claim:

1. An optical distribution device, comprising:
 - a first 1×2 electro-optical switch adapted to receive a first voltage control signal;
 - 5 a second 1×2 electro-optical switch having an input port coupled to a first output port of the first switch, and adapted to receive a second voltage control signal;
 - a third 1×2 electro-optical switch having an input port coupled to a second output port of the first switch, and adapted to receive a third voltage control signal; and
 - a controller configured to generate the first voltage control signal, the second
 - 10 voltage control signal, and the third voltage control signal according to expected outputs of the second switch and the third switch.
2. The device according to claim 1, wherein the controller is configured to select a combination of the outputs of the second switch and the third switch.
3. The device according to claim 1, wherein at least the first, second and third 1×2
- 15 electro-optical switches are formed on a single silicon substrate.
4. The device according to claim 1, wherein the first, second, and third 1×2 electro-optical switches are Mach-Zehnder (MZ) interferometer electro-optical switches.
5. The device according to claim 1, wherein each of the first, second, and third 1×2 electro-optical switches comprises:
 - 20 a first coupler comprising at least two output ends;
 - three parallel electrodes adapted to receive one of the first, second, and third voltage control signals;
 - a first arm and a second arm, respectively coupled to two output ends of the first coupler, and located between the three electrodes; and
 - 25 a second coupler coupled to the first arm and the second arm.
6. The device according to claim 1, wherein the first, second, and third voltage control signals are configured to be synchronous with optical signals borne from the first switch to the second switch and the third switch.
7. The device according to claim 1, wherein the controller is adapted to receive a
- 30 control signal from an optical line terminal (OLT).

8. The device according to claim 1, wherein the controller comprises:

an input terminal (31) and first, second, and third output terminals (32a, 32b, 32c), the first output terminal (32a) being coupled to the input terminal (31);

a phase shifter (33) having an input end coupled to the input terminal (31);

5 a first inverter (34) having an input end coupled to an output end of the phase shifter (33);

a first AND gate (36) having a first input end coupled to the output of the first inverter (34) and a second input end coupled to the input terminal (31), and having an output coupled to the second output terminal (32b);

10 a second inverter (35) having an input end coupled to the input terminal (31); and
a second AND gate (37) having a first input end coupled to the output of the phase shifter (33) and a second input end coupled to an output of the second inverter (35), and having an output coupled to the third output terminal (32c).

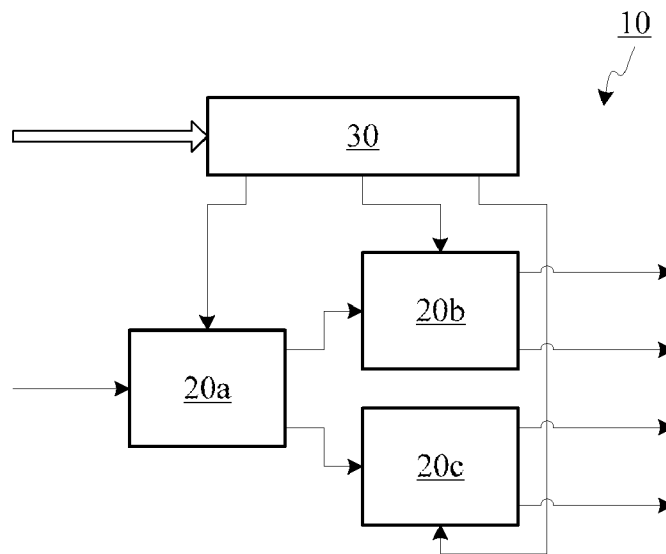


FIG. 1

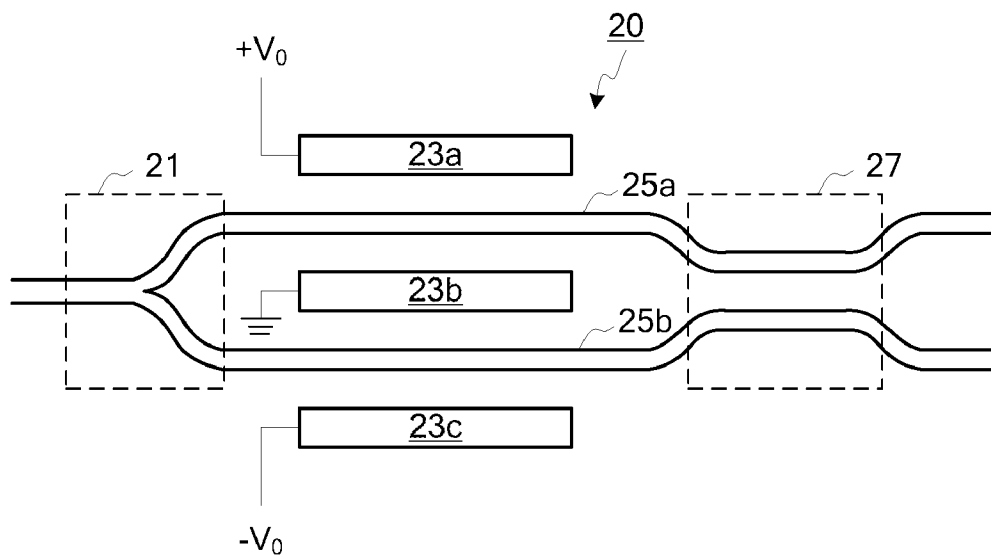


FIG. 2

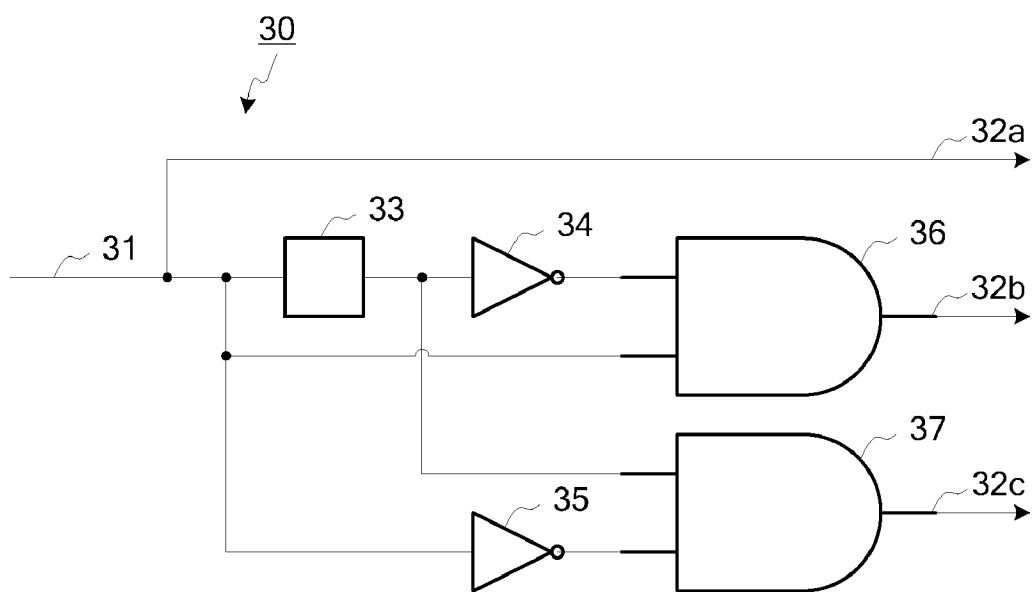


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2013/002215

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04Q11/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KUNITAKA ASHIZAWA ET AL: "Efficient singlecast / multicast method For active optical access network using PLZT high-speed optical switches", HIGH PERFORMANCE SWITCHING AND ROUTING (HPSR), 2010 INTERNATIONAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 13 June 2010 (2010-06-13), pages 14-19, XP031759367, ISBN: 978-1-4244-6969-7 the whole document ----- -/--	1-8

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents :

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	UEDA H ET AL: "NEW OPTICAL ACCESS NETWORK ARCHITECTURE USING OPTICAL PACKET SWITCHES", IEICE TRANSACTIONS ON COMMUNICATIONS, COMMUNICATIONS SOCIETY, TOKYO, JP, vol. E89B, no. 3, 1 March 2006 (2006-03-01), pages 724-730, XP001240939, ISSN: 0916-8516 the whole document -----	1-8