A switcher for connecting one of a plurality of input terminals to a subset of output terminals comprises first and second circuit boards (102) each comprising a substrate (102) and at least one switch module (90-96). Each switch module has a plurality of signal in terminals (48), a plurality of signal out terminals (50), and a plurality of input expansion terminals (52), and is operative to connect any selected signal in terminal to any selected subset of signal out terminals and to connect any input expansion terminal selectively to a corresponding signal out terminal. The signal in terminals of the modules of the first and second circuit boards are coupled to respective input terminals of the switcher. The signal out terminals of the switch module of the first circuit board are coupled to the input expansion terminals of the switch module of the second circuit board, and the signal out terminals of the switch module of the second circuit board are coupled to respective output terminals of the switcher.
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+ Any designation of “SU” has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.
SWITCH COMPOSED OF IDENTICAL SWITCH MODULES

Background of the Invention

This invention relates to a switch composed of identical switch modules.

Crosspoint switches, i.e., switches having multiple inputs and outputs arranged so that any input can be connected to any output, are widely used in, for example, communication networks. A simple 2 x 2 crosspoint switch (a switch having two inputs and two outputs) may be constructed of two parallel input conductors, two parallel output conductors crossing the input conductors, and four crosspoint elements at the crossing points of the input and output conductors. The crosspoint elements are operable to select any one or more output conductors for connection to a selected input conductor. In principle, a switch of this nature may have an arbitrarily large number of inputs and an arbitrarily large number of outputs. However, a crosspoint switch of this kind with a large number of inputs, the length of the input conductors depending on the number of outputs and the length of the output conductors depending on the number of inputs, is not well suited for use with very high frequency signals because the portion of the selected output conductor on the opposite side of a selected crosspoint element from the output constitutes a stub, whose length depends on the input conductor that is selected, and if the stub is long the signal propagated to the output is degraded. Moreover, this technique for building a large crosspoint switch does not lend itself well to use of modular construction techniques, except at the level of a single crosspoint element.
Consequently, most crosspoint switches are constructed in two or more stages, each stage being formed of multiple identical modules. FIG. 1 of the accompanying drawings shows a 4 x 4 crosspoint switch composed of four 2 x 2 primary modules 2 and four 2 x 1 secondary modules 8. As shown, each input to the 4 x 4 crosspoint switch must be provided with a fanout amplifier 12 that is able to drive the input conductors of two primary modules. Further, eight fanout conductors 14 are needed to connect the fanout amplifiers to the primary modules and eight secondary conductors 16 are needed to connect the primary modules to the secondary modules.

At the level of the 4 x 4 crosspoint switch, the need to drive multiple primary modules and provide transmission lines to connect the primary modules and the secondary modules does not give rise to major problems. However, with a large crosspoint switch, for example a 512 x 512 switch based on (256) 64 x 16 primary modules and (512) 8 x 1 secondary modules, each input must be provided with a fanout amplifier able to drive the input conductors of 32 primary modules, and there must be 16,384 cables connecting the fanout amplifiers to the primary modules and 4,096 cables connecting the primary modules to the secondary modules. It is self-evident that a switch of this complexity is very expensive to build and is very large.

A routing switcher having, for example, 1,024 input terminals and 1,024 output terminals can be implemented using a crosspoint switch having fewer than 1,024 inputs and 1,024 outputs by use of time division multiplexing techniques. The input
signals, which may, for example, be audio, video or data, are converted to digital form and applied to a multiplexer, which allocates time slots to its terminals. The multiplexer has output terminals that are connected to respective input terminals of a crosspoint switch, whose output terminals are connected to a demultiplexer that is synchronized with the multiplexer and has output terminals connected to respective digital to analog converters. If the operator wishes a particular input terminal of the switcher to be connected to a particular set of output terminals of the switcher (which set may have only one element) a controller issues a crosspoint select signal that causes particular crosspoint elements of the crosspoint switch to become conductive during the time slot that is allocated to the desired input terminal and the demultiplexer receives the input signal and applies it to the appropriate set of output terminals. The DAC converts the digital signal provided by the demultiplexer to analog form. In such a switcher, the bandwidth of the crosspoint switch depends not only on the bandwidth of the input signals, but also on the relationship between the number of input signals and the number of input terminals to the crosspoint switch and the number of bits to which the input signals are digitized. It will therefore be seen that signals of much higher bandwidth than the input signals are propagated through the crosspoint switch.

Summary of the Invention
In accordance with a first aspect of the invention, a crosspoint switch having M input
terminals and N output terminals comprises \((M/m)\) times \((N/n)\) crosspoint switch modules each having \(m\) input conductors and \(n\) output conductors. \((M/m)\) of the modules have their input conductors connected to the \(M\) input terminals respectively of the crosspoint switch and \((N/n)\) of the modules have their output conductors connected to the \(N\) output terminals respectively of the crosspoint switch. The input conductors of the first module are connected to respective input conductors of a second module and the output conductors of the first module are connected to respective output conductors of a third module.

In accordance with a second aspect of the invention, a crosspoint switch module comprises \(m\) input conductors, \(n\) output conductors, \(m \times n\) crosspoint elements operable selectively for connecting any selected input conductor to at least one selected output conductor, \(n\) input expansion conductors, and \(n\) input expansion crosspoint elements for connecting the input expansion conductors to the output conductors respectively.

**Brief Description of the Drawings**

For a better understanding of the invention, and to show how the same may be carried into effect, further reference will be made, by way of example, to the accompanying drawings in which,

FIG. 1 illustrates in simplified form a \(4 \times 4\) crosspoint switch of known construction,

FIG. 2 illustrates schematically a \(2 \times 2\) crosspoint module embodying the present invention,

FIG. 3 illustrates in somewhat simplified form a \(4 \times 4\) crosspoint switch based on the module shown in FIG. 2,
FIG. 4 is a plan view of a circuit board comprising a substrate and an 8 x 8 crosspoint switch based on 4 x 4 crosspoint modules,

FIG. 5 is a front elevation of a distribution switcher including multiple circuit boards of the kind shown in FIG. 4,

FIG. 6 is a block diagram of one channel of an input transducer module of the switcher,

FIGS. 7 and 8 illustrate details of the manner in which the circuit boards are mounted in the switcher,

FIG. 9 illustrates schematically the arrangement of three of the circuit boards of the switcher,

FIG. 10 is a block diagram of an output data channel of the switcher,

FIG. 11 is a block diagram of a control channel of the switcher,

FIG. 12 is a block diagram of a switch based on multiplexers, and

FIG. 13 is a schematic perspective view of an enlarged switch based on multiplexers.

In the several figures, like reference numerals designate identical or corresponding components.

Detailed Description

The 2 x 2 switch module shown in FIG. 2 comprises two input conductors 20, having input buffers 24 at one end and output expansion buffers 28 at the opposite end, and two output conductors 30. Each output conductor 30 traverses the two input conductors, and two primary crosspoint elements 40 are provided for connecting the output conductor selectively to one or the other of the input conductors. Each output conductor has an
output buffer 32 at one end and is connectable at its opposite end by an input expansion crosspoint element 36 to an input expansion buffer 34. Each crosspoint element has a control terminal 42 for receiving a control signal that places the crosspoint element either in the conductive state or the non-conductive state. Control terminals 42 are connected to respective outputs of a crosspoint selector 44.

The switch module illustrated in FIG. 2 has two signal in terminals 48 connected to the inputs of buffers 24, two signal out terminals 50 connected to the outputs of buffers 32, two input expansion terminals 52 connected to the inputs of buffers 34, two output expansion terminals 54 connected to the outputs of buffers 28, a crosspoint control input terminal 56 connected to the input of crosspoint selector 44 and a crosspoint control output terminal 46 connected to the output of crosspoint selector 44. Destination termination resistors 58 are connected between the inputs of buffers 24, 34 and ground, and source termination resistors 60 are connected between the outputs of buffers 28, 32 and terminals 54, 50, respectively. Buffers 24, 28, 32 and 34 have sufficient gain to compensate for loss in the termination resistors.

The module shown in FIG. 2 may be implemented in a single monolithic integrated circuit chip by use of conventional photolithographic techniques. The chip has power and ground terminals (not shown), for supplying operating current for the buffers 24, 28, 32 and 34, in addition to the terminals discussed above. A 2 x 2 module has been described by way of example only, and in order to make full use of current technology a module based
on the principles described with reference to FIG. 2 would normally have more than two inputs and more than two outputs. For example, a module having sixteen signal in terminals and sixteen signal out terminals could be fabricated on a single monolithic integrated circuit chip using photolithographic technology that is currently available.

FIG. 3 shows a 4 x 4 switch that comprises four 2 x 2 switch modules 60-66 and a crosspoint controller 68. The signal out terminals 50 of modules 60 and 64 are connected to the input expansion terminals 52 of modules 62 and 66 by respective transmission lines that are terminated at source and destination, and the output expansion terminals 54 of modules 60 and 62 are connected to the signal in terminals 48 of modules 64 and 66 by respective transmission lines that are terminated at source and destination. The input expansion terminals 52 of modules 60 and 64 are unused, as are the output expansion terminals 54 of modules 64 and 66. By use of transmission lines to connect the various modules and the source and destination terminations that are included in the modules, a favorable environment for transmission of high frequency signals is provided.

Crosspoint controller 68 has outputs connected to the crosspoint control input terminals 56 of modules 62 and 66, the crosspoint control output terminals 46 of these modules being connected to the crosspoint control input terminals of modules 60 and 64 respectively.

Crosspoint controller 68 receives a command indicating that a particular signal in terminal, for example terminal 72 shown in FIG. 3, is to be
connected to a subset of signal out terminals, for example the subset composed of terminals 74 and 76. The command might ultimately originate from a user interface 70, at which a user operates controls indicating that an input signal provided by a source connected to terminal 72 should be distributed to devices that are connected to terminals 74 and 76. Crosspoint controller 68 generates two serial control words, which it applies to the crosspoint control input terminals 56 of modules 62 and 66 respectively. As shown in FIG. 2, the crosspoint selector 44 connected to each terminal 56 may be composed of a shift register 78 and a decoder 80. Each control word is composed of six data bits and appropriate control bits. The first group of three data bits of the control word applied to the terminal 56 of module 62 is transmitted through shift register 78 of module 62 and is loaded into shift register 78 of module 60, and the second group of three data bits is loaded into shift register 78 of module 62. Alternatively, each crosspoint selector might accept all data bits of the control word and decode only those that relate to the crosspoint elements of that module. Yet again, the command might include, associated with each control word, an address word that identifies a unique module so that a particular control word is loaded only into the crosspoint selector identified by the corresponding address word. In either case, a three-bit data word is used to control the states of the crosspoint elements 36 and 40 of module 62.

The crosspoint selector 44 of module 62 decodes the three-bit data word into two three-component vectors, associated respectively with the
two output conductors of module 62. The vector associated with the output conductor connected to terminal 74 has the components \{0,1,0\}, indicating that crosspoint element 40A should be conductive and crosspoint elements 36A and 40C should be non-conductive, and the vector associated with the signal out terminal of module 62 has the components \{X,0,X\} (where X designates don't care), indicating that crosspoint element 40B of module 62 should be non-conductive.

The crosspoint selector of module 66 generates the vectors \{X,0,X\} and \{0,1,0\} so that crosspoint elements 36B, 40A and 40D are non-conductive and crosspoint element 40B is conductive. In this fashion, the input signal applied to the input 72 is isolated from modules 60 and 64. If, on the other hand, crosspoint controller 68 received a command that the signal in terminal 82 should be connected to the signal out terminal 84, the crosspoint selector of module 60 would generate the vectors \{X,X,0\} and \{X,X,0\}, so that crosspoint elements 40C and 40D were non-conductive, the crosspoint selector of module 62 would generate the vectors \{X,X,X\} and \{X,X,X\}, while the crosspoint selector of module 64 would generate the vectors \{0,0,1\} and \{X,X,0\}, which render only the primary crosspoint element 40D of that module conductive and the crosspoint elements 36A, 40A and 40C non-conductive, and the crosspoint selector of module 66 would generate the vectors \{1,0,0\} and \{X,X,X\}, which render the input expansion crosspoint element 36A conductive and the primary crosspoint elements 40A and 40D non-conductive. In this fashion, a signal provided at a signal in terminal of module 60 can be propagated to any set of signal out
terminals, including a single output terminal, through module 62 or 66, but a signal at one of the signal in terminals of module 62 is isolated from modules 60 and 64 by virtue of the input expansion crosspoint elements 36 of modules 62 and 66 being non-conductive. In either case, the maximum length of a stub portion of an output conductor is sufficiently small that it does not degrade the signal being propagated through the switch.

A crosspoint switch module based on the principles described with reference to FIG. 2 allows a crosspoint switch to be constructed with an arbitrarily large number of inputs and an arbitrarily large number of outputs without the complication of the two stage design described with reference to FIG. 1. The modules are functionally arranged in a simple rectangular array, and the buffers of a module each need drive no more than one input or output conductor of one adjacent module. Each module is connected only to the module(s) that is(are) adjacent it in the array. The number of interconnect conductors is therefore much less than in the case of the switch described with reference to FIG. 1. The number of crosspoint elements in an M x N switch composed of m x n modules, where m and n are integer submultiples of M and N respectively, is \((M \times N) \times (m + 1)/m\).

FIG. 4 shows schematically an 8 x 8 switch that comprises four 4 x 4 switch modules 90-96 arranged in a 2 x 2 array. The signal out terminals 50 of modules 90 and 92 are connected to the input expansion terminals 52 of modules 94 and 96. The signal in terminals 48 of modules 92 and 96 are connected to the output expansion terminals 54 of modules 90 and 94 respectively.
The output expansion terminals of modules 92 and 96 are unused. The crosspoint controller of the FIG. 4 switch is not shown.

The switch modules 90-96 are mounted on a circuit board 100 comprising a substrate 102 and conductor runs 104 connected to the terminals of the modules. The signal in terminals 48 of modules 90 and 94 are connected through respective conductor runs to optical repeaters 114, which are aligned with openings 116 in the substrate. Each optical repeater comprises an infrared optical receiver, such as a photodiode, and an optical emitter, such as an LED or laser diode. When optical radiation is incident on the optical receiver, the repeater applies an electrical signal to its associated conductor run and also energizes the optical emitter so that it emits an optical signal. The signal out terminals 50 of modules 94 and 96 are connected through conductor runs to respective infrared optical emitters 118.

The input expansion terminals of modules 90 and 92 are connected to respective infrared optical receivers 120. The crosspoint control input terminals 56 of modules 94 and 96 are connected to respective infrared optical receivers 124, and the crosspoint control output terminals 46 of modules 90 and 92 are connected to respective infrared optical emitters 128.

FIG. 5 illustrates an audio signal distribution switcher comprising a frame 130 that is divided into four compartments 132-138. The upper three compartments 132-136 each contain an input transducer module 142 and sixteen circuit boards 100_i (i = 0...15) of the form shown in FIG. 4.
The input transducer module 142 has eight channels each with an input terminal 144 (FIG. 6) for receiving an analog electrical signal at audio frequencies. The analog audio input signal is digitized and encoded into serial data words by an analog-to-digital converter (ADC) 146 and the serial data words are applied to an LED driver 148 for driving an infrared emitter 150, such as an LED or laser diode. Each emitter 150 emits an optical signal in serial digital form representative of the analog audio signal received at the corresponding input terminal.

As shown in FIGS. 7 and 8, the circuit boards 100_1 are received in slots defined between pressed-out formations 152 of top and bottom plates 154, 156 that bound the compartment 132, for example, and engage a back plate 158. The emitters 118 and receivers 124 of each board in compartments 132-136 are disposed vertically above respective receivers and emitters in the compartment immediately below. The plates that separate compartments 132-138 from each other are formed with holes 160 that are positioned relative to the back plate 158 so that an optical signal from an emitter 118 of a board 100_1 in compartment 132, for example, is received by the corresponding receiver 120 of the corresponding board in compartment 134.

Each repeater 114 on each board in compartment 132 lies in a linear array containing one repeater of each other board in that compartment. Each emitter 150 of the input transducer module 142 is aligned with one of the rows of sixteen repeaters 114. Therefore, the optical signal received by a repeater 114 of the board 100_0 from an emitter 150 of the input module generates an electrical signal.
that is applied to the corresponding conductor run of the board 100₀ and also is repeated to provide an optical signal that is applied to the corresponding optical repeater of the board 100₁. In this fashion, each input terminal of the transducer module 142 is coupled to a signal input terminal of each of the sixteen circuit boards.

The bottom compartment 138 of frame 130 contains a transducer module 170 and a crosspoint controller 172. The transducer module 170 has 128 data channels, each of which comprises an infrared receiver 174 (FIG. 10). The 128 receivers are arranged in a rectangular array for receiving light emitted by the emitters 118 of the circuit boards in compartment 136. Each receiver provides an encoded electrical signal to a digital-to-analog converter (DAC) 176. DAC 176 generates an analog electrical output signal representative of the digital optical signal received by the receiver. The outputs of the DACs are connected to respective output terminals 178 of the switcher.

Considering, for example, the circuit boards 100₀ of compartments 132-136, it can be seen, as shown in FIG. 9, that the crosspoint switch modules are arranged in two columns each containing six crosspoint switch modules. Since there are sixteen circuit boards in each compartment, there are 32 columns of crosspoint switch modules. The transducer module 170 has 32 control channels, associated respectively with the columns of crosspoint switch modules. Each control channel has an input terminal 180 connected to the crosspoint controller for receiving a data word from the crosspoint controller 172, an LED driver 182 and an infrared optical emitter 184, such as an LED or laser diode.
A user interface (not shown) generates a command that identifies an input terminal of the switcher and a set of output terminals. In response to this command, crosspoint controller 172 generates up to 32 serial data words. The 32 data words define the states of the crosspoint elements in the 32 columns of crosspoint modules that should be established in order to connect the selected set of output terminals to the specified input terminal of the switcher. The serial data words are encoded into electrical signals, which are applied to optical emitters 184 respectively. The optical emitters convert the electrical signals to optical form. Each optical emitter 184 of the transducer module 170 is aligned with a receiver 124 of a board in compartment 136. Thus, the crosspoint control signal emitted by an emitter 184 of the transducer module 170 is applied to a selected optical receiver 124 of a unique board in compartment 136.

It will therefore be seen that the circuit boards of the FIG. 5 switcher communicate with one another and with the transducer modules by use of free space optics, i.e. by propagation of light in free space rather than in a guided medium, such as an optical fiber.

Each crosspoint switch module has twenty crosspoint elements, and therefore a five-bit data word is needed in order to generate a vector for controlling all crosspoint elements independently of each other. Each column of crosspoint switch modules contains six modules, and so each of the 32 crosspoint control words may be composed of 30 data bits. The appropriate data bits are loaded into the respective crosspoint selectors and control the

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states of the primary crosspoints and input expansion crosspoints of the module. The number of bits actually required may be reduced below 30 by use of a decoding scheme that takes account of the fact that if the input expansion crosspoint element associated with a particular output conductor of a crosspoint switch module is conductive, none of the primary crosspoint elements on that conductor should be conductive.

It can readily be seen that the switcher described with reference to FIGS. 5-11 can be expanded to accommodate additional inputs simply by adding one or more compartments similar to compartments 132-136. The input transducer module of each additional compartment is independent of the other input transducer modules, and the circuit boards of the additional compartment(s) are coupled to the circuit boards of the existing compartments without any need for wiring, other than for power supplies for operating the devices mounted on the circuit boards. A switcher able to accommodate additional outputs can be constructed by including additional circuit boards in each compartment. Increasing the number of outputs necessitates modification of transducer module 170 and crosspoint controller 172.

FIG. 12 illustrates a 12 x 1 switch 188 based on 2 x 1 multiplexers. The switch is composed of three 4 x 1 switch modules 190, 192 and 194. Module 192, for example, comprises two first stage multiplexers 202 and 204, which receive the four inputs of the module, a second stage multiplexer 208, whose inputs are connected to the outputs of the multiplexers 202 and 204 respectively, and an input expansion multiplexer 212, which receives at
a first input the output of second stage multiplexer 208 and at a second input the output of the input expansion signal multiplexer of module 190. The output of multiplexer 212 of module 192 constitutes the output of the module and is connected to the second input of the input expansion multiplexer 212 of module 194, the output 214 of which is the output of the switch. Each multiplexer selects one of its two inputs in dependence upon the state of a control bit. Multiplexer 212 of module 190 always selects the first input, since its second input is not connected to another module. Accordingly, the module shown in FIG. 12 is able to connect its four signal inputs selectively to its signal output.

The module also comprises a configuration selector 216, which provides a four-bit configuration control word to a configuration controller 218. The controller 218 decodes the control word into three four-bit vectors, the components of which constitute the control bits for multiplexers 202—212.

The modules shown in FIG. 12 implement a 12 x 1 switch. Output expansion is provided by identical modules having corresponding input terminals connected together, as described with reference to FIGS. 4-10 and as shown in FIG. 13.

It will be appreciated that the invention is not restricted to the particular embodiments that have been described, and that variations may be made therein without departing from the scope of the invention as defined in the appended claims and equivalents thereof. For example, the invention is not limited to the switch module operating with electrical signals, since by use of
integrated optic techniques a module for routing optical signals may be fabricated by employing an optical directional coupler for each switch element, in which case a switcher similar to that shown in FIGS. 5-10 may be constructed in which it is not necessary to convert the optical signals provided by the input transducer module 142 to electrical form before reaching the transducer module 170. Of course, in the case in which optical directional couplers are used as the switch elements, electrical signals are nevertheless required for control purposes. Use of free space optics for board-to-board communication does not exclude the possibility of employing lenses or light guides to limit diffusion of light. For example, as shown in FIGS. 7 and 8, a lens 220 or light guide 222 may be mounted in the hole 116 or 160, and communication between repeaters 114 or from emitter 118 to receiver 120 would still employ free space optics. Although it is preferred that free space optics be used for board-to-board communication in a switcher having the architecture described with reference to FIG. 9, it would also be possible to use electrical connectors, such as zero insertion force (ZIF) connectors, for interconnecting the boards. The invention is not limited to a switch in which the number of inputs or outputs is equal to an integer multiple of the number of inputs or outputs of a module, since a 15 x 15 switch, for example, may be constructed either using a 4 x 4 array of 4 x 4 modules leaving one input and one output unused or using a 3 x 3 array of 4 x 4 modules plus three 4 x 3 modules, three 3 x 4 modules and one 3 x 3 module. Such a switch may be conceived of as a 12 x 12 switch plus an 8 x 3 switch, a 3 x 8 switch and a 3 x 3 switch.
In the case of the module described with reference to FIG. 11, each multiplexer would normally have more than two inputs. Multiplexers having four inputs are commercially available and would allow construction of a 16 x 1 switch module with four first stage multiplexers and two second stage multiplexers. The input expansion multiplexer only needs to be a 2 x 1 multiplexer.
Claims

1. (FIGS. 4-11) A switcher for connecting one of a plurality of input terminals to a subset of output terminals, said switcher comprising:

at least first and second circuit boards (100) each comprising a substrate (102) and at least one switch module (90-96) having a plurality of signal in terminals (48), a plurality of signal out terminals (50), and a plurality of input expansion terminals (52), the switch module being operative to connect any selected signal in terminal to any selected subset of signal out terminals and being operative to connect any input expansion terminal selectively to a corresponding signal out terminal,

means (146, 148, 150) coupling the signal in terminals of the modules of the first and second circuit boards to respective input terminals of the switcher,

means (104, 118, 120) coupling the signal out terminals of the switch module of the first circuit board to the input expansion terminals of the switch module of the second circuit board, and

means (104, 118, 174, 176) coupling the signal out terminals of the switch module of the second circuit board to respective output terminals of the switcher.

2. (FIG. 2) A switcher according to claim 1, wherein at least one circuit board comprises at least first, second and third switch modules each comprising m input conductors (20), n output conductors (30), m x n crosspoint elements (40) operable selectively for connecting any selected
input conductor to at least one selected output conductor, n input expansion conductors, and n
input expansion crosspoint elements (36) for connecting the input expansion conductors to
the output conductors respectively, the input conductors of the first module (60) being connected
to respective input conductors of the second module (64) and the output conductors of the first module
being connected to respective input expansion conductors of the third module (62).

3. A switcher according to claim 2, wherein each of the input conductors (20) of each of the
first, second and third modules has first and second opposite ends and the module comprises m
input buffers (24) connected to the input conductors respectively at the first end thereof
and m output expansion buffers (28) connected to the input conductors respectively at the second
end thereof.

4. A switcher according to claim 2, wherein each of the output conductors (30) of each of the
first, second and third modules has first and second opposite ends and the module comprises n
output buffers (32) connected to the output conductors respectively at the first end thereof
and n input expansion buffers (34) connected to the expansion conductors respectively, the n input
expansion crosspoint elements (36) connecting the input expansion conductors to the output conductors
respectively at the second end thereof.
5. (FIG. 3) A switcher according to claim 1, wherein each circuit board has \( M \) signal in terminals (72, 82) and \( N \) signal out terminals (74, 76, 84) and comprises \((M/m)\) times \((N/n)\) switch modules (60-66) each having \( m \) input conductors (20) and \( n \) output conductors (30), \((M/m)\) of the modules having their input conductors connected to the \( M \) signal in terminals respectively of the circuit board, \((N/n)\) of the modules having their output conductors connected to the \( N \) signal out terminals respectively of the circuit board, the input conductors of the first module (60) being connected to respective input conductors of a second module (64) and the output conductors of the first module being connected to respective output conductors of a third module (62).

6. A switcher according to claim 5, wherein the third module (62) comprises \( m \times n \) crosspoint elements (40) operable selectively for interconnecting any combination composed of one input conductor and a set of output conductors, \( n \) input expansion terminals (52) connected to respective output conductors of the first module (60) and \( n \) input expansion crosspoint elements (36) operable selectively for connecting the input expansion terminals to respective output conductors of the third module.

7. A switcher according to claim 6, wherein the third module (62) comprises \( n \) output buffers (32) connected to its output conductors (30) respectively at a first end thereof and \( n \) input expansion buffers (34) connectable to its output conductors respectively at a second end thereof by
the input expansion crosspoint elements (36), the input expansion buffers having input terminals connected to respective output conductors of the first module.

8. A switcher according to claim 5, wherein each of the first and second modules (60, 64) includes m input buffers (24) connected to its input conductors respectively at a first end thereof, and m output expansion buffers (28) connected to its input conductors respectively at a second end thereof, the output expansion buffers of the first module (60) having respective outputs connected to respective inputs of the input buffers of the second module (64).

9. A switcher according to claim 5, wherein each module comprises n output buffers (32) connected to its output conductors (30) respectively at a first end thereof and n input expansion buffers (34) connectable to its output conductors respectively at a second end thereof, the output buffers of the first module (60) having output terminals connected to the input terminals of the respective input expansion buffers of the third module (62).

10. A switcher according to claim 5, comprising a fourth switch module (66) having its input conductors (20) connected to respective input conductors of the third module (62) and its output conductors (30) connected to respective output conductors of the second module (64).
11. (FIGS. 4, 7, 8) A switcher according to claim 1, wherein the first circuit board comprises a plurality of optical emitters (118) having respective electrical input terminals each connected to one signal out terminal of the switch module of the first circuit board and being operative to emit into free space an optical signal in response to an electrical signal received thereby, the second circuit board comprises a plurality of optical receivers (120) having respective electrical output terminals each connected to one signal in terminal of the switch module of the second circuit board and being operative to generate an electrical signal at its electrical output terminal in response to an optical signal received thereby, and wherein the switcher comprises means (152, 154, 156, 158) supporting the first and second circuit boards in relative positions such that an optical signal emitted into free space by an emitter of the first circuit board is received by a receiver of the second circuit board.

12. A switcher according to claim 11, wherein the second circuit board further comprises at least one optical emitter (128) having an electrical input terminal connected to an output terminal of the switch module of the second circuit board and operative to emit into free space an optical signal in response to an electrical signal received thereby, the first circuit board comprises at least one optical receiver (124) having an electrical output terminal connected an input terminal of the switch module of the first circuit board and operative to generate an electrical signal at its
electrical output terminal in response to an optical signal received thereby, and wherein the first and second circuit boards are supported in relative positions such that an optical signal emitted into free space by the emitter of the second circuit board is received by the receiver of the first circuit board.

13. A switcher according to claim 11, comprising a light guide or lens (222) disposed between an emitter of one of the circuit boards and a receiver of the other circuit board for limiting diffusion of light emitted by the emitter and guiding light toward the receiver.

14. (FIGS. 4, 6, 7, 8) A switcher according to claim 1, wherein one of the first and second circuit boards (100) further comprises an optical repeater (114) mounted on the substrate and having an output terminal connected to a signal input terminal of the switch module, the repeater being responsive to an optical signal to generate an electrical signal at its output terminal and also to emit an optical output signal into free space, and wherein the switcher further comprises a third circuit board comprising a substrate (102), at least one integrated circuit module (90-96) mounted on the substrate and having an input terminal (48), and an optical receiver (114) mounted on the substrate and having an output terminal connected to the input terminal of the integrated circuit module, the receiver being responsive to an optical signal to generate an electrical signal at its output terminal, and wherein the switcher comprises means (152, 154, 156, 158) supporting said one...
circuit board and said third circuit board in relative positions such that an optical signal emitted into free space by the optical repeater of said one circuit board is received by the optical receiver of said third circuit board.

15. (FIG. 3) A crosspoint switch having \( M \) input terminals (72, 82) and \( N \) output terminals (74, 76, 84) and comprising \( (M/m) \times (N/n) \) crosspoint switch modules (60-66) each having \( m \) input conductors (20) and \( n \) output conductors (30), \( (M/m) \times (N/n) \) of the modules having their input conductors connected to the \( M \) input terminals respectively of the crosspoint switch, \( (N/n) \) of the modules having their output conductors connected to the \( N \) output terminals respectively of the crosspoint switch, the input conductors of the first module (60) being connected to respective input conductors of a second module (64) and the output conductors of the first module being connected to respective output conductors of a third module (62).

16. (FIG. 2) A crosspoint switch module comprising:

- \( m \) input conductors (20),
- \( n \) output conductors (30),
- \( m \times n \) crosspoint elements (40) operable selectivelly for connecting any selected input conductor to at least one selected output conductor,
- \( n \) input expansion conductors, and
- \( n \) input expansion crosspoint elements (36) for connecting the input expansion conductors to the output conductors respectively.
17. (FIGS. 4, 7, 8) Electrical apparatus comprising:
    first and second circuit boards (100) each comprising a substrate (102), at least one integrated circuit module (90-96) mounted on the substrate and having at least one input terminal (52, 56) and at least one output terminal (46, 50), an optical receiver (120, 124) having an electrical output terminal connected to the input terminal of the integrated circuit module and being operative to generate an electrical signal at its electrical output terminal in response to an optical signal received thereby, and an optical emitter (118, 128) having an electrical input terminal connected to the output terminal of the integrated circuit module and being operative to emit into free space an optical signal in response to an electrical signal received thereby, and the first and second circuit boards in relative positions such that an optical signal emitted into free space by the emitter of the first circuit board is received by the receiver of the second circuit board and an optical signal emitted into free space by the emitter of the second circuit board is received by the receiver of the first circuit board.

18. (FIGS. 4, 6, 7, 8) Electrical apparatus comprising:
    first and second circuit boards (100) each comprising a substrate (102), at least one integrated circuit module (90-96) mounted on the substrate and having an input terminal (48), and an optical repeater (114) mounted on the substrate
and having an output terminal connected to the input terminal of the integrated circuit module, the repeater being responsive to an optical signal to generate an electrical signal at the output terminal and also to emit an optical output signal into free space, and

means (152, 154, 156, 158) supporting the first and second circuit boards in relative positions such that an optical signal emitted into free space by the optical repeater of the first circuit board is received by the optical repeater of the second circuit board.

19. (FIG. 12) A switch having M input terminals and one output terminal and comprising P switch modules (190-194) each comprising:

an input selector (202-208) having (M/P) signal input terminals and one output terminal, the input terminals of the input selectors being connected to the M input terminals respectively of the switch,

an output selector (212) having a signal input terminal connected to the output terminal of the input selector, an input expansion terminal, and an output terminal,

the output terminals of the output selector of the ith (i = 1...(P-1)) switch module being connected to the input expansion terminal of the output selector of the (i + 1)th switch module, and the output terminal of the output selector of the Pth switch module being connected to the output terminal of the switch.
20. (FIG. 12) A switch according to claim 19, wherein $M$ is equal to $(q^r)$ and each input selector comprises a first stage composed of $q$ multiplexers (208) each having $r$ inputs and one output, and a second stage composed of one multiplexer having $q$ inputs and one output, the outputs of the first stage being connected to the inputs of the second stage.

21. (FIG. 13) A switch having $M$ input terminals and $N$ output terminals and comprising $N$ switch circuits each having $M$ input terminals and one output terminal, the $i$th ($i = 1...M$) input terminal of each switch circuit being connected to the $i$th input terminal of each other switch circuit, and each of the $N$ switch circuits comprising:

P switch modules (192, 194) each having $(M/P)$ input terminals and one output terminal, the input terminals of the modules being connected to the $M$ input terminals respectively of the switch, and

an output selector (212) having $P$ input terminals connected to the output terminals respectively of the switch modules, the output selector being operative to connect any one of its input terminals to its output terminal.
AMENDED CLAIMS
[received by the International Bureau on 28 April 1992 (28.04.92);
original claims 1-21 replaced by amended claims 1-20 (10 pages )]

1. (FIGS. 4-11) A switcher for connecting one of a plurality of input terminals to a subset of output terminals, said switcher comprising:

5 at least first and second circuit boards (100) each comprising a substrate (102) and at least one switch module (90-96) having a plurality of signal in terminals (48), a plurality of signal out terminals (50), and a plurality of input expansion terminals (52), the switch module comprising m input conductors (20) connected to respective signal in terminals, n output conductors (30) connected to respective signal out terminals, m x n matrix crosspoint elements (40) operable selectively for connecting any selected input conductor to at least one selected output conductor, whereby any selected signal in terminal can be connected to any selected subset of signal out terminals, n input expansion conductors connected to respective input expansion terminals, and n input expansion crosspoint elements (36) operable selectively for connecting the input expansion conductors to the output conductors respectively, whereby any input expansion terminal can be connected to a corresponding signal out terminal,

10 means (146, 148, 150) coupling the signal in terminals of the modules of the first and second circuit boards to respective input terminals of the switcher,

15 means (104, 118, 120) coupling the signal out terminals of the switch module of the first circuit board to the input expansion terminals of the switch module of the second circuit board, and
means (104, 118, 174, 176) coupling the signal out terminals of the switch module of the second circuit board to respective output terminals of the switcher.

2. (FIG. 2) A switcher according to claim 1, wherein at least one circuit board comprises at least first, second and third such switch modules each comprising m input conductors (20), n output conductors (30), m x n matrix crosspoint elements (40) operable selectively for connecting any selected input conductor to at least one selected output conductor, n input expansion conductors, and n input expansion crosspoint elements (36) for connecting the input expansion conductors to the output conductors respectively, the input conductors of the first module (60) being connected to respective input conductors of the second module (64) and the output conductors of the first module being connected to respective input expansion conductors of the third module (62).

3. A switcher according to claim 2, wherein each switch module has m output expansion terminals (54), and each of the input conductors (20) of each of the first, second and third modules has first and second opposite ends and the module comprises m input buffers (24) connected between the signal in terminals (48) of the module and the input conductors respectively at the first end thereof, m output expansion buffers (28) connected between the output expansion terminals and the input conductors respectively at the second end thereof, a source termination resistor (58) connected between each signal in terminal and a
reference potential level, and a destination
termination resistor (60) connected between each
output expansion buffer and the corresponding
output expansion terminal.

4. A switcher according to claim 2, wherein
each of the output conductors (30) of each of the
first, second and third modules has first and
second opposite ends and the module comprises n
output buffers (32) connected between the signal
out terminals (50) and the output conductors
respectively at the first end thereof and n input
expansion buffers (34) connected between the input
expansion terminals (52) and the input expansion
collectors respectively, the n input expansion
crosspoint elements (36) connecting the input
expansion conductors to the output conductors
respectively at the second end thereof.

5. (FIG. 3) A switcher according to claim 1,
wherein each circuit board has M signal in
terminals (72, 82) and N signal out terminals (74,
76, 84) and comprises (M/m) times (N/n) such switch
modules (60-66), (M/m) of the modules having their
input conductors connected to the M signal in
terminals respectively of the circuit board, (N/n)
of the modules having their output conductors
connected to the N signal out terminals
respectively of the circuit board, the input
collectors of the first module (60) being connected
to respective input conductors of a second
module (64) and the output conductors of the first
module being connected to respective input
expansion terminals of a third module (62).
6. A switcher according to claim 5, wherein the third module (62) comprises n output buffers (32) connected to its output conductors (30) respectively at a first end thereof and n input expansion buffers (34) connectable to its output conductors respectively at a second end thereof by the input expansion crosspoint elements (36), the input expansion buffers having input terminals connected to respective signal output terminals of the first module.

7. A switcher according to claim 5, wherein each of the first and second modules (60, 64) includes m input buffers (24) connected to its input conductors respectively at a first end thereof, and m output expansion buffers (28) connected to its input conductors respectively at a second end thereof, the output expansion buffers of the first module (60) having respective outputs connected to respective inputs of the input buffers of the second module (64).

8. A switcher according to claim 5, wherein each module comprises n output buffers (32) connected to its output conductors (30) respectively at a first end thereof and n input expansion buffers (34) connectable to its output conductors respectively at a second end thereof, the output buffers of the first module (60) having output terminals connected to the input terminals of the respective input expansion buffers of the third module (62).
9. A switcher according to claim 5, comprising a fourth switch module (66) having its signal in terminals (48) connected to respective output expansion terminals (54) of the third module (62) and its input expansion terminals (52) connected to respective signal out terminals of the second module (64).

10. (FIGS. 4, 7, 8) A switcher according to claim 1, wherein the first circuit board comprises a plurality of optical emitters (118) having respective electrical input terminals each connected to one signal out terminal of the switch module of the first circuit board and being operative to emit into free space an optical signal in response to an electrical signal received thereby, the second circuit board comprises a plurality of optical receivers (120) having respective electrical output terminals each connected to one input expansion terminal of the switch module of the second circuit board and being operative to generate an electrical signal at its electrical output terminal in response to an optical signal received thereby, and wherein the switcher comprises means (152, 154, 156, 158) supporting the first and second circuit boards in relative positions such that an optical signal emitted into free space by an emitter of the first circuit board is received by a receiver of the second circuit board.

11. A switcher according to claim 10, wherein the second circuit board further comprises at least one optical emitter (128) having an electrical input terminal connected to an output terminal of
the switch module of the second circuit board and operative to emit into free space an optical signal in response to an electrical signal received thereby, the first circuit board comprises at least one optical receiver (124) having an electrical output terminal connected an input terminal of the switch module of the first circuit board and operative to generate an electrical signal at its electrical output terminal in response to an optical signal received thereby, and wherein the first and second circuit boards are supported in relative positions such that an optical signal emitted into free space by the emitter of the second circuit board is received by the receiver of the first circuit board.

12. A switcher according to claim 10, comprising a light guide or lens (222) disposed between an emitter of one of the circuit boards and a receiver of the other circuit board for limiting diffusion of light emitted by the emitter and guiding light toward the receiver.

13. (FIGS. 4, 6, 7, 8) A switcher according to claim 1, wherein one of the first and second circuit boards (100) further comprises an optical repeater (114) mounted on the substrate and having an output terminal connected to a signal in terminal of the switch module, the repeater being responsive to an optical signal to generate an electrical signal at its output terminal and also to emit an optical output signal into free space, and wherein the switcher further comprises a third circuit board comprising a substrate (102), at least one integrated circuit module (90-96) mounted
on the substrate and having an input terminal (48), and an optical receiver (114) mounted on the substrate and having an output terminal connected to the input terminal of the integrated circuit module, the receiver being responsive to an optical signal to generate an electrical signal at its output terminal, and wherein the switcher comprises means (152, 154, 156, 158) supporting said one circuit board and said third circuit board in relative positions such that an optical signal emitted into free space by the optical repeater of said one circuit board is received by the optical receiver of said third circuit board.

14. (FIG. 2) A crosspoint switch module comprising:
   
   m input conductors (20),
   n output conductors (30),
   m x n matrix crosspoint elements (40) operable selectively for connecting any selected input conductor to at least one selected output conductor,

   n input expansion conductors, and
   n input expansion crosspoint elements (36) operable selectively for connecting the input expansion conductors to the output conductors respectively.

15. A crosspoint switcher according to claim 14, wherein each input conductor (20) has first and second opposite ends and the module further comprises m input buffers (24) connected to the input conductors respectively at the input ends thereof, m output expansion buffers (28) connected to the respective input conductors at the second
end thereof, a source termination resistor (58) connected between the input of each input buffer and a reference potential level, and a destination termination resistor (60) connected between the output of each output expansion buffer and an output expansion terminal (54) of the module.

16. (FIGS. 4, 7, 8) Electrical apparatus comprising:

first and second circuit boards (100) each comprising a substrate (102), at least one integrated circuit module (90-96) mounted on the substrate and having at least one input terminal (52, 56) and at least one output terminal (46, 50), an optical receiver (120, 124) having an electrical output terminal connected to the input terminal of the integrated circuit module and being operative to generate an electrical signal at its electrical output terminal in response to an optical signal received thereby, and an optical emitter (118, 128) having an electrical input terminal connected to the output terminal of the integrated circuit module and being operative to emit into free space an optical signal in response to an electrical signal received thereby, and

means (152, 154, 156, 158) supporting the first and second circuit boards in relative positions such that an optical signal emitted into free space by the emitter of the first circuit board is received by the receiver of the second circuit board and an optical signal emitted into free space by the emitter of the second circuit board is received by the receiver of the first circuit board.
17. (FIGS. 4, 6, 7, 8) Electrical apparatus comprising:
   first and second circuit boards (100)
each comprising a substrate (102), at least one
integrated circuit module (90-96) mounted on the
substrate and having an input terminal (48), and
an optical repeater (114) mounted on the substrate
and having an output terminal connected to the
input terminal of the integrated circuit module,
the repeater being responsive to an optical signal
to generate an electrical signal at the output
terminal and also to emit an optical output signal
into free space, and
   means (152, 154, 156, 158) supporting
the first and second circuit boards in relative
positions such that an optical signal emitted
into free space by the optical repeater of the
first circuit board is received by the optical
repeater of the second circuit board.

18. (FIG. 12) A switch having M input
terminals and one output terminal and comprising P
switch modules (190-194) each comprising:
an input selector (202-208) having (M/P)
signal input terminals and one output terminal,
the input terminals of the input selectors being
connected to the M input terminals respectively of
the switch,
an output selector (212) having a signal
input terminal connected to the output terminal of
the input selector, an input expansion terminal,
and an output terminal,
the output terminals of the output
selector of the ith (i = 1... (P-1)) switch module
being connected to the input expansion terminal of
the output selector of the \((i + 1)\)th switch module, and the output terminal of the output selector of the \(\text{Pth}\) switch module being connected to the output terminal of the switch.

19. (FIG. 12) A switch according to claim 18, wherein \(M\) is equal to \((q^*r)\) and each input selector comprises a first stage composed of \(q\) multiplexers (208) each having \(r\) inputs and one output, and a second stage composed of one multiplexer having \(q\) inputs and one output, the outputs of the first stage being connected to the inputs of the second stage.

20. (FIG. 13) A switch having \(M\) input terminals and \(N\) output terminals and comprising \(N\) switch circuits each having \(M\) input terminals and one output terminal, the \(i\)th \((i = 1...M)\) input terminal of each switch circuit being connected to the \(i\)th input terminal of each other switch circuit, and each of the \(N\) switch circuits comprising:

\(P\) switch modules (192, 194) each having \((M/P)\) input terminals and one output terminal, the input terminals of the modules being connected to the \(M\) input terminals respectively of the switch, and

an output selector (212) having \(P\) input terminals connected to the output terminals respectively of the switch modules, the output selector being operative to connect any one of its input terminals to its output terminal.
FIG. 1
PRIOR ART
# INTERNATIONAL SEARCH REPORT

**International Application No.** PCT/US91/08084

## I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC

- **IPC(5)**: H04Q 1/00
- **U.S. CL.**: 340/825.86, 825.79

## II. FIELDS SEARCHED

<table>
<thead>
<tr>
<th>Classification System</th>
<th>Classification Symbols</th>
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<tr>
<td>U. S.</td>
<td>340/825.86, 825.79, 825.8, 825.02, 825.03, 826</td>
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<td>370/65.5, 359/117;</td>
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<td>361/393, 394, 395, 396, 415</td>
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

## III. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of Document</th>
<th>Relevant to Claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>US, A, 4,635,250 (GEORGIOU) 06 JANUARY 1987</td>
<td>15</td>
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<tr>
<td>Y</td>
<td>See Abstract, Fig. 1,8,9, Cols. 1-2.</td>
<td>1-10,16</td>
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<tr>
<td>X</td>
<td>US, A, 4,929,940 (FRANASZEK) 29 MAY 1990</td>
<td>15</td>
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<td>Y</td>
<td>See Abstract, Fig. 5, Cols. 5-6.</td>
<td>1,2,5,10,16</td>
</tr>
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<td>X</td>
<td>&quot;Branch exchange still relies on space-division switch&quot;. Electronics, 11 MAY 1978, pages 39-41</td>
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<td>Y</td>
<td>US, A, 4,075,608 (KONIG) 21 FEBRUARY 1978</td>
<td>1,2,5,10,16</td>
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<td></td>
<td>See Abstract, Fig. 1-2; Col. 3, lines 4-21.</td>
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<td>Y</td>
<td>US, A, 4,885,569 (LELOUCHE) 05 DECEMBER 1989</td>
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<td></td>
<td>See Abstract, Figs 1-3; Col. 3-4.</td>
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<td>Y</td>
<td>US, A, 4,929,939 (VARMA) 29 MAY 1990. See Abstract Fig. 3, Col. 5.</td>
<td>11-14,17-18</td>
</tr>
<tr>
<td>Y</td>
<td>EP, A, 0,387,788 (COOPERMAN) 19 SEPTEMBER 1990</td>
<td>19-21</td>
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<tr>
<td>A</td>
<td>See Abstract, Figs 2-3, Col. 2.</td>
<td></td>
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<tr>
<td>A</td>
<td>US, A, 4,677,436 (BURLINGAME) 30 JUNE 1987</td>
<td>1</td>
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</table>

* Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier document but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

**IV. CERTIFICATION**

- Date of the Actual Completion of the International Search: 24 JANUARY 1992
- Date of Mailing of the International Search Report: 28 FEB 1992
- International Searching Authority: ISA/US
- Signature of Authorized Officer: [Signature]

Form PCT/ISA/210 (second sheet) (Rev.11-97)
FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claim numbers because they relate to subject matter not required to be searched by this Authority, namely:

2. Claim numbers because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claim numbers because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(b).

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This International Searching Authority found multiple inventions in this international application as follows:

I. Claims 1-18 drawn to crosspoint matrix switches and modules, classified in 340/825.79+.

II. Claims 19-21 drawn to tree selectors and selector modules, classified in 340/825.02.

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remarks on Protest:

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.