A data storage system (10) is provided wherein each one of a plurality of disk interfaces (32) is coupled to a corresponding storage disk drive (40). The disk interfaces (32) in one portion are coupled through a first unidirectional channel (34) to a first disk controller (20₁) and the disk interfaces (32) in another portion of the disk interfaces are coupled through a second unidirectional channel (28) to a second disk controller (20₂). Each disk interface includes (32) a switch (42) adapted to allow data to pass to another disk drive (40) in the channel (42) thereof; and, when the other channel becomes inoperative, coupling the disk drive (40) in the inoperative channel to the operative fiber channel. With such arrangement, a disk drive may be removed without requiring a shut-down of the storage system (i.e., the disk drive may be "hot swapped"). In one embodiment, a pair of the switches is disposed on the common printed circuit board (43) with the disk interface for enabling depopulation, or removal of, disk drives from the storage system.
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DATA STORAGE SYSTEM

Background of the Invention

This invention relates generally to data storage systems and more particularly to data storage systems having a plurality of magnetic storage disk drives in a redundancy arrangement whereby the disk drives are controllable by primary disk controllers and secondary disk controllers. Still more particularly, the invention also relates to systems of such type wherein the disk drives are coupled to the disk controllers through a series, unidirectional, "ring" or, fiber channel protocol, communication system.

As is known in the art, in one type of data storage system, data is stored in a bank of magnetic storage disk drives. Each one of the disk drives is coupled to a corresponding disk interface. The disk interface is a printed circuit board having a programmable array logic (PAL) circuit for decoding address signals fed to it by a disk controller. When the PAL detects its address, it produces a signal to activate a relay and thereby turn its disk drive "on". The PAL is also used to turn its LED "on" when the disk drive needs to be replaced.

The disk drives, and their coupled interfaces, are arranged in sets, each set being controlled by a primary disk controller and a secondary disk controller. More particularly, in order to enable the set of disk drives to operate in the event that there is a failure of the primary disk controller, each set is also coupled to a secondary, or redundant disk controller. Therefore, if either the primary or secondary disk controller fails, the set can be accessed by the other one of the disk controllers.
While today, most disk storage systems of this type use a Small Computer System Interconnection (SCSI) protocol, in order to operate with higher data rates, other protocols are being introduced. One higher data rate protocol is sometimes referred to as a fiber channel (FC) protocol. Such FC channel protocol uses a series, unidirectional, "ring" communication system. In order to provide for redundancy, that is, to enable use of the set of disk drives in the event that the primary disk controller fails, as discussed above, the set is coupled to the second, or redundant disk controller, using a separate, independent, "ring", or fiber channel communication protocol. Thus, two fiber channels are provided for each set of disk drives and their disk interfaces; a primary fiber channel and a secondary fiber channel.

As is also known, when using the fiber channel communication protocol, if any element in the channel becomes inoperative, the entire channel becomes inoperative. That is, if the primary disk controller becomes inoperative, or if any one of the disk drives in the set coupled to the primary channel becomes inoperative (i.e., as where the disk interface fails, the disk interface is inoperative, or removed with its coupled disk drive, or where the disk drive coupled thereto fails, or is removed), the primary fiber channel, is "broken", or open, and becomes inoperative. The data stored in the entire portion of the set of disk drives coupled to the primary disk channel is therefore unavailable until the inoperative primary disk controller or inoperative disk drive is replaced. This is true with either the primary channel or the secondary channel. One technique suggested to solve this problem is through the use of a switch, sometimes referred to as an LRC (i.e., a
loop resiliency circuit) switch. Such LRC switch is used to remove an inoperative disk drive from its channel.

In one suggested arrangement, a printed circuit board is provided for each disk drive. The printed circuit board has a pair of LRCs, one for the primary channel and one for the secondary channel. Thus, the open channel may be "closed" in the event of an inoperative disk drive by placing the LRC thereof in a by-pass condition. While such suggested technique solves the inoperative disk drive, or open channel problem, if one of the pair of LRCs fails, the entire printed circuit board having the pair of LRCs must be replaced thereby disrupting both the primary and secondary channels; and, hence, disrupting the operation of the entire data storage system.

One technique suggested to solve this disruption problem requires n LRC switches (where n is the number of disk drives in the set) in the primary channel, i.e., one LRC for each one the n disk drives in the set and another n LRC switches in the secondary channel for each one of the n disk drives in the secondary channel. The primary channel set of n LRCs is mounted on one printed circuit board and the secondary channel set of n LRCs is mounted on a different printed circuit board. A backplane is used to interconnect the two LRC printed circuit boards, the associated multiplexers, and the disk drives. In order to provide the requisite serial, or sequential, fiber channel connections, an elaborate, complex, fan-out wiring arrangement has been suggested for the backplane.

Further, the slots provided for the two LRC boards eliminates two disk drives, and the disk interfaces which would otherwise be plugged into these two slots of the backplane.
Summary of the Invention

In accordance with the present invention, a data storage system is provided wherein each one of a plurality of disk interfaces is coupled to a corresponding storage disk drive. A first portion of the disk interfaces is coupled to a first disk controller through a first unidirectional channel and a second portion of the disk interfaces is coupled to a second disk controller through a second unidirectional channel.

Each disk interface in the first portion includes a switch adapted to allow address control and data (hereinafter referred to, collectively, as data) to pass though the first channel; and, when the second channel becomes inoperative, couple an operative disk drives in the inoperative second channel to the first channel.

With such arrangement, redundancy is provided because if the second disk controller becomes inoperative, the first disk controller is able to store data in and/or retrieve data from the disk drives in the second channel.

Further, if one of the disk drives in the second channel is inoperative, all of the other, operative disk drives in the second channel are switched to the first channel, thereby enabling the disk drive to be replaced without having to shut down the operative disk drives in the second channel, i.e., the inoperative disk drive may be "hot swapped".

In accordance with another feature of the invention, the switch is disposed on a common printed circuit board with the disk interface. Thus, the interface and its disk drive are packaged as a module to facilitate maintenance and providing system modularity. With such arrangement a simpler, local (i.e., the disk interface and the switch are located on a common printed circuit board) connecting arrangement is used to interconnect the disk drives and their associated
switches as compared with the complex, fan-out connection arrangement discussed above. Still further, with this arrangement, there is no loss of slots on the backplane.

In accordance with still another feature of the invention, each disk interface includes a pair of the switches. The additional switch enables termination of a channel at a point where additional disk drives are no longer needed. Thus, the second switch enables "depopulation" or removal of a portion of the disk drives in the channel when a such portion is no longer needed by the storage system.

Brief Description of the Drawing

FIG. 1 is a block diagram of a computer system having a data storage system according to the invention; FIG. 2 is sketch showing how FIGS. 2A and 2B are arranged to make up a block diagram of a set of storage disk drives and their disk interfaces according to the invention, such set being used in the computer system of FIG. 1; and,

FIG. 3 is a block diagram of an exemplary addressable interface used in the disk interfaces of FIG. 2; and

FIG. 4 is a block diagram of a pair of disk drives and their interfaces in accordance with an alternative embodiment of the invention.

Description of the Preferred Embodiments

Referring now to FIG. 1, a computer system 10 is shown. The computer system 10 includes a main frame computer section 12 for processing data. Portions of the processed data are stored in, and retrieved data from, a bank 16 of magnetic storage disk drives through an conventional system interface 18. The system interface 18 includes disk controllers 201-20m, central processor unit (CPU) controllers 22 and cache memories 24 electrically interconnected, in a conventional manner, as
shown, through a pair of buses 26, 28 provided for redundancy in a backplane printed circuit board 30.
Thus, disk controllers 20_1, ... 20_m-1 are coupled to bus 26, and disk controllers 20_2 ... 20_m are coupled to bus 28, as shown. Each one of the disk controllers 20_1-20_m is coupled to a corresponding one of sets 32_1-32_m of the disk drives 40_1-40_n and associated disk interfaces 42_1-42_n, respectively, as shown, through primary fiber channel protocol channels 34_1-34_m, respectively, as shown. Each one of the sets 32_1 - 32_m of disk drives and associated disk interfaces is identical in construction, an exemplary one thereof, here set 32_1 being shown, and discussed in detail, in connection with FIG. 2. Further, each one of the disk controllers 20_1-20_m is coupled to another one of the sets 32_1-32_m of disk drives 40_1-40_n and associated disk interfaces 42_1-42_n through secondary fiber protocol channels 38_1-38_m, as shown, here indicated by dotted lines. Thus, for example, disk controller 20_1 is coupled to set 32_1 through primary fiber channel 34_1 and is also coupled to set 32_2 through secondary fiber channel 38_1. Likewise, disk controller 20_2 is coupled to set 32_2 through primary fiber channel 34_2 and is also coupled to set 32_1 through secondary fiber channel 38_2, as shown. Thus, while set 32_1 is, during normal mode of operation, coupled through disk controller 20_1 to bus 26, in the event that disk controller 20_1 becomes inoperative, set 32_1 is coupled to bus 28 through disk controller 20_2. Finally, it should be noted that the cache memories 24 are coupled to both buses 26 and 28, in a conventional manner.

Referring now also to FIG. 2, an exemplary one of the plurality of sets 32_1-32_m, here set 32_1 of disk drives 40_1-40_n and associated disk interfaces 42_1-42_n, is shown. Each one of the disk interfaces 42_1-42_n is adapted to control a corresponding one of the magnetic storage disk
drives $40_1$-$40_n$ coupled thereto, respectively, as shown. In normal mode of operation, data passes from the disk controller $20_1$ (FIG. 1) sequentially through the disk interfaces $42_1$, $42_3$, ... $42_{n-3}$, $42_{n-1}$ (and hence through the disk drives $40_1$, $40_3$, ... $40_{n-3}$, $40_{n-1}$ coupled thereto), via the primary fiber channel $34_1$; and, data passes from the disk controller $20_2$ sequentially through the disk interfaces $42_2$, $42_4$, ... $42_{n-2}$, $42_n$ (and hence through the disk drives $40_2$, $40_4$, ... $40_{n-2}$, $40_n$ coupled thereto), via the secondary fiber channel $38_1$, as indicated by the dotted lines.

More particularly, the disk interfaces $42_1$-$42_n$ are arranged in groups, or cells, $43_1$-$43_p$; here groups of two (i.e., pairs) of successive disk interfaces; thus, here $p=n/2$. Thus, pairs of disk interfaces $42_1$, $42_2$; $42_3$, $42_4$; ... $42_{n-1}$, $42_n$, and their associated disk drives $40_1$, $40_2$; $40_3$, $40_4$; ... $40_{n-1}$, $40_n$, are grouped together to form cells $43_1$-$43_n/2$, respectively as shown. Each one of the cells $43_1$-$43_n/2$ is identical in construction, an exemplary one thereof, here cell $43_1$ is shown to include disk interfaces $42_1$, $42_2$, and their coupled disk drives $40_1$, $40_2$, respectively, as indicated. Each one of the cells $43_1$-$43_n/2$ has a primary input port $PI_1$-$PI_{n/2}$, respectively, as shown, and a primary output port $PO_1$-$PO_{n/2}$, respectively, as shown. Each one of the cells $43_1$-$43_n/2$ has a secondary input port $SI_1$-$SI_{n/2}$, respectively, as shown, and a secondary output port $SO_1$-$SO_{n/2}$, respectively, as shown. The cells $43_1$-$43_n/2$ are sequentially (i.e. serially) coupled to the controllers $20_1$, $20_2$ through the fiber channels $34_1$, $38_1$, respectively, from primary output port $PO$ to primary input port $PI$, for the primary fiber channel $34_1$ and from secondary input port $SI$ to secondary output port $SO$, for the secondary channel $38_1$. 

Each one of the disk interfaces 42₁⁻⁴₂n includes a corresponding one of a plurality of switches 44₁⁻⁴₄n, as shown. Each one of the switches 44₁⁻⁴₄n is identical in construction and, here, switches 44₁⁻⁴₄n are conventional LRC switches. Thus, each one of the switches 44₁⁻⁴₄n includes a pair of input ports I₁, I₂ and a pair of output ports O₁, O₂, as shown. When one of the switches 44₁⁻⁴₄n is in the feed-through condition (as indicated by curved arrow B) the data fed to first input port I₁ thereof passes to the first output port O₁ thereof and, likewise, data fed to the second input port I₂ thereof passes to the second output port O₂ thereof; however, when of the switches 44₁⁻⁴₄n is in the by-pass condition (as indicated by the arrows A), data fed to input port I₁ thereof is diverted from the first output port O₁ thereof and is coupled directly to the second output port O₂ thereof. Each one of the switches 44₁⁻⁴₄n is placed in either the feed-through condition or the by-pass condition by a control signal fed thereto via control line 46₁⁻⁴₆n, respectively, as shown.

In the normal mode of operation, primary disk controller 20₁ is coupled, as noted above, to disk drives 40₁, 40₃, ... 40ₙ₋₃, 40ₙ₋₁, by primary fiber channel 34₁. Likewise, secondary disk controller 20₂ is coupled to disk drives 40₂, 40₄, ... 40ₙ₋₂, 40ₙ through secondary fiber channel 38₁. (It should be noted that while the data is depicted as passing from the disk drives 40 and then to the switches 44, it is preferable that the data passes from the switches 44 and then to the disk drives, i.e., it is preferable that the direction indicated by the arrow in primary channel 34₁ be reversed in direction). Thus, in the normal mode of operation, switch 44₁ is in the by-pass condition, as indicate by the curved arrow A. Thus, data from disk controller 20₁ is fed, via twisted pair 47, to primary input port PI₁ of
cell 43₁ to disk interface 42₁, to disk drive 40₁, then to the first input port I₁ of switch 44₁. Because switch 44₁ is in the by-pass condition by the control signal on control line 46₁, data from disk drive 40₁ passes directly to second output port 0₂ and then to primary output port P₀₁. From there, the data passes, in like manner, to disk interface 42₃ of the next successive cell 43₂, where the process repeats for disk drive 40₃; and then, in like manner, sequentially through the other cells and to cells 43(n/2)-1-43ₙ and then back to the primary controller 2₀₁ (FIG. 1).

Likewise, in the normal mode of operation, switch 44₂ is in the by-pass condition by a control signal on line 46₂, as indicated by the arrow A and data from disk controller 2₀₂ (FIG. 1) passes to secondary input port S₁₁ of cell 43₁, then from first input port I₁ of switch 44₂ directly to second output port 0₂ of switch 44₂. The data then passes from disk drive 40₂ to secondary output port S₀₂. From there, the data passes, in like manner, to disk interface 42₄ of the next successive cell 43₂, where the process repeats for disk drive 40₄; and then, in like manner, sequentially through the other cells and to cells 43(n/2-1)-4ₙ/2 and then back to the secondary controller 2₀₂ (FIG. 1).

If disk controller 2₀₂ becomes inoperative, for example, an effect which "breaks" the secondary channel "ring", the switches 4₄₁, 4₄₃..., 4₄ₙ₋₁, 4₄ₙ₋₁ are placed in the feed-through condition by the control signal on line 4₆₁, 4₆₃..., 4₆ₙ₋₁, 4₆ₙ₋₁ and therefore, primary disk controller 2₀₁ is coupled, via primary fiber channel 3₁₁, to disk drives 4₀₁, 4₀₂, 4₀₃, 4₀₄..., 4₀ₙ₋₁, 4₀ₙ₋₁, 4₀ₙ. More particularly, in such feed-through condition, indicated by the arrows B, data at the first input ports I₁ of switches 4₄₁, 4₄₃..., 4₄ₙ₋₁, 4₄ₙ₋₁ pass directly to first output ports 0₁ thereof, and passes to disk drives
$40_2$, $40_4$ ... $40_{n-2}$, $40_n$, then directly from second input ports $I_2$ to second output ports $O_2$ of switches $44_1$, $44_3$ ... $44_{n-3}$, $44_{n-1}$ to primary channel output ports $P_{O2}$ thereby coupling disk interfaces $42_2$, $42_4$, ... $42_{n-2}$, $42_n$ and their coupled disk drives $40_2$, $40_4$, ... $40_{n-2}$, $40_n$ to the primary fiber channel $34_1$.

On the other hand, if the primary disk controller $20_1$ becomes inoperative, for example, an effect which "breaks" the primary channel "ring". the switches $44_2$, $44_4$ ... $44_{n-2}$, $44_n$ are placed in the feed-through condition and therefore, secondary disk controller $20_2$ is coupled, via secondary fiber channel $38_1$, to disk drives $40_1$, $40_2$, $40_3$, $40_4$ ... $40_{n-3}$, $40_{n-2}$, $40_{n-1}$, $40_n$. More particularly, in such feed through condition, disk interfaces $42_1$, $42_3$, ... $42_{n-3}$, $42_{n-1}$ and their coupled disk drives $40_1$, $40_3$, ... $40_{n-1}$, $40_{n-1}$ are coupled to the secondary fiber channel $38_1$.

If any one of the disk drives $40_2$, $40_4$, ... $40_{n-2}$, $40_n$, in the secondary channel $38_1$ becomes inoperative thereby breaking the secondary channel $38_1$, all other operative disk drives in the secondary channel $38_1$ become coupled to the primary channel $34_1$. For example, if disk drive $40_2$ becomes inoperative, an effect which "breaks" the secondary channel $38_1$, switches $44_3$ - $44_{n-1}$ are switched from the by-pass condition to the feed through condition; switch $44_1$ remaining in the by-pass condition. Therefore, the primary disk controller $20_1$ becomes coupled to disk drives $40_1$, $40_3$, $40_4$, ... $40_{n-3}$, $40_{n-2}$, $40_{n-1}$, and $40_n$.

On the other hand, if any one of the disk drives $40_1$, $40_3$, ... $40_{n-3}$, $40_{n-1}$ in the primary channel $34_1$ becomes inoperative, thereby breaking the primary channel $34_1$, all other operative disk drives in the primary channel $34_1$ become coupled to the secondary channel $38_1$.

For example, if disk drive $40_3$ becomes inoperative, an
effect which "breaks" the primary channel 34₁, switches 44₂, 44₅ (not shown), ..., 44ₙ₋₂, and 4ₙ are switched from the by-pass condition to the feed through condition; switch 4ₙ₄ remaining in the by-pass condition.

Therefore, the secondary disk controller 2₀₂ becomes coupled to disk drives 4₀₁, 4₀₂, 4₀₃, 4₀₅ (not shown), ..., 4₀ₙ₋₃, 4₀ₙ₋₂, 4₀ₙ₋₁, and 4₀ₙ.

The control signal on line 4₆₁ is produced by an addressable control section 5₁₁, shown in FIG. 3 to include a PAL and an OR gate. The addressable control section 5₁₁ is included in disk interface 4₂₁. The addressable control section 5₁₁ is addressable by controller 2₀₁ (FIG. 1) via a separate control line bus 5₃₁. More particularly, the bus 5₃₁ is fed to address the PAL. The addressable control section 5₁₁ is also fed by a signal on line 5₇₁ generated by disk interface 4₂₂ indicating that disk drive 4₀₂ is inoperative. In response to the signals fed to the addressable control section 5₁₁ from either disk controller 2₀₁ on bus 5₃₁ or the disk interface 4₂₂ on line 5₇₁, the addressable control section 5₁₁ places switch 4₄₁ in either the feed-through, or alternatively, by-pass condition. More particularly, addressable control section 5₁₁ places switch 4₄₁ in the by-pass condition if the disk drive 4₀₂ is inoperative, as described above (i.e., via the signal on line 5₇₁, or when disk controller 2₀₂ becomes inoperative, as described above, via the signals on bus 5₃₁. In like manner, the control signal on line 4₆₂ is produced by an addressable control section 5₁₂ included in disk interface 4₂₂. The addressable control section 5₁₂ is addressable by the primary controller 2₀₂ (FIG. 1) via a separate control bus 5₃₂ from controller 2₀₂. The addressable control section 5₁₂ is also fed by a signal on line 5₇₂ generated by disk interface 4₂₂ indicating that disk drive 4₀₁ is inoperative. In response to the
signals fed thereto from either controller 20₁ on bus 53₂ or the disk interface 42₁ on line 57₂, the addressable control section 51₂ places switch 44₂ in either the feed-through, or alternatively, by-pass condition. More particularly, addressable control section 51₂ places switch 44₂ in the by-pass condition if disk controller 20₁ is inoperative, or if the disk drive 40₁ becomes inoperative, as described above. Addressable control sections 5₁₃-₅₁ₙ, are included in the other disk interfaces 4₂₃-₄₂ₙ, in a similar manner.

Each one of the switches 4₄₁-₄₄ₙ is disposed on a common printed circuit board with a corresponding one of the disk interface, 4₂₁-₄₂ₙ, respectively.

Referring now to FIG. 4, an exemplary pair of cells 4₃’ₘ/₂-₁, ₄₃’ₘ/₂ is shown, where m is an integer between 1 and n. Cells 4₃’ₘ/₂-₁, ₄₃’ₘ/₂ differ from cells 4₃₁-₄₃ₙ/₂ described above in connection with FIG. 2 in that each disk interface 4₂₁, ₄₂ₙ includes a second LRC switch 4₄’. Thus, for the exemplary interfaces 4₂₃, ₄₂ₙ-₂, ₄₂ₙ-₁, such interfaces include switches 4₄₃ₐₐₚₙ₃, ₄₄ₘ-₂, ₄₄ₘ-₁ and ₄₄ₘ, respectively, and switches 4₄’ₘₐₚₙ₃, ₄₄’ₘ-₂, ₄₄’ₘ-₁ and ₄₄’ₘ, respectively, as shown.

Switches 4₄₃ₐₐₚₙ₃, ₄₄ₘ-₂, ₄₄ₘ-₁ and ₄₄ₘ are normally in the by-pass condition as indicated and as described above in connection with FIGs. 1 and 2, while switches 4₄’ₘₐₚₙ₃, ₄₄’ₘ-₂, ₄₄’ₘ-₁ and ₄₄’ₘ are normally in the feed-through condition as indicated. Here again the primary fiber channel ₃₄₁ is indicated by the solid line and the secondary fiber channel ₃₈₁ is indicated by the dotted line, as in FIG. 1 and 2. A control signal is fed to switch 4₄’ₘₐₚₙ₃ via control line ₅₇’₁ from disk interface ₄₂’ₘ-₁, as shown. A control signal is fed to switch 4₄’ₘₐₚₙ₂ via control line ₅₇’₂ from disk interface ₄₂’ₘ, as shown. Switches 4₄’ₘₐₚₙ₃, ₄₄’ₘ-₂, ₄₄’ₘ-₁, and ₄₄’ₘ are provided to enable "depopulation" of disk drives. For
example, if disk drive $40_{m-1}$ is no longer required by the storage system 10, a control signal is produced on control line $57'_1$ to place switch $44'_{m-3}$ in the by-pass condition thereby making disk drive $40_{m-3}$ the last disk drive in the primary fiber channel 34. Likewise, if disk drive $40_m$ is removed, a control signal is produced on control line $57'_2$ to place switch $44'_{m-2}$ in the by-pass condition thereby making disk drive $40_{m-2}$ the last disk drive in the secondary fiber channel 34. Further, a fiber channel may be terminated at any point by the switches $44'$.

Other embodiments are within the spirit and scope of the appended claims.
1. A data storage system, comprising:
a plurality of disk interfaces, each one being
adapted to control a storage disk drive coupled thereto,
a first portion of the disk interfaces being adapted to
receive signals from a first controller through a first
channel and a second portion of the disk interfaces being
adapted to receive data from a second controller through
a second channel, each one of the disk interfaces in the
first portion having:
a switch adapted to allow data to pass through the
first channel; and, when the second channel becomes
inoperative, couple an operative disk drive in the
inoperative second channel to the first channel.

2. The data storage system recited in claim 1
each one of the disk interfaces in the second portion
has:
a switch adapted to allow data to pass through the
second channel; and, when the first channel becomes
inoperative, couple an operative disk drive in
inoperative first channel to the second channel.

3. A data storage system wherein each one of a
plurality of disk interfaces is coupled to a
Corresponding storage disk drive, a first portion of the
disk interfaces being connected sequentially in a first
unidirectional channel, to a first disk controller and a
second portion of the disk interfaces being coupled to a
second controller through a second unidirectional
channel:
each one of the first portions of the disk
interfaces including a first switch, disposed in the
first channel, adapted to allow data to pass to the next
sequential disk drive in the first channel; and, when the
second channel becomes inoperative, couple an operative
disk drive in second channel to the first channel; and,
each one of the disk interfaces in the second
portion including a switch, disposed in the second
channel, adapted to allow data to pass to the next
sequential disk drive in the second channel; and, when
the first channel becomes inoperative, couple an
operative disk drives in first channel to the second
channel.

4. A method for changing a disk drive in a data
storage system, each one of a first portion of disk
drives being coupled through a first fiber channel, each
one of a second portion of the disk drives being coupled
through a secondary fiber channel, each of the disk
drives being coupled to a switch, comprising the step of:
operating the switch to remove the disk drive
being changed from the first fiber channel and coupling
the other disk drives in first fiber channel to the
second fiber channel.

5. A disk interface adapted for coupling a disk
drive to a fiber channel to control the disk drive, such
interface having:
an interface input port;
an interface output port;
a switch having a pair of input ports and a
pair of output ports, a first one of the pair of switch
input ports being serially coupled to the interface
through the disk drive, and one of the pair of output
ports being coupled to the interface output port, the
other one of the pair of input ports and the other one of
the pair of output ports being adapted for coupling to
another disk interface, such switch, in response to one
state of a control signal coupling a first one of the
pair of input ports to a first one of the pair of output ports and a second one of the pair of input ports to a second one of the pair of output ports, and in response to a second state, coupling the first one of the pair of input ports to the second one of the pair of output ports.

6. A disk interface adapted for coupling a disk drive to a fiber channel to control the disk drive, such interface having:

   an interface input port;
   an interface output port;
   a first switch having a pair of input ports and a pair of output ports, such first switch, in response to one state of a control signal coupling a first one of the pair of input ports to a first one of the pair of output ports; 
   a second switch having a pair of input ports and a pair of output ports, such second switch, in response to one state of a control signal coupling a first one of the pair of input ports to a first one of the pair of output ports and a second one of the pair of input ports to a second one of the pair of output ports, and in response to a second state, coupling the first one of the pair of input ports to the second one of the pair of output ports;
   a first one of the pair of first switch input ports being serially coupled to the interface through the disk drive;
   one of the pair of first switch output ports being coupled to a first one of the pair of second switch input ports;
a first one of the second switch output ports
being coupled to the interface output port;
the other one of the pair of first switch
input ports and the other one of the pair of first switch
output ports being adapted for coupling to another disk
interface; and,
the other one of the pair of second switch
input ports and the other one of the pair of second
switch output ports being adapted for coupling to the
fiber channel.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :G06F 11/10
US CL :395/180, 181, 182, 441, 858; 371/10.1
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)
U.S. : 395/180, 181, 182, 441, 858; 371/10.1
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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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</table>

Further documents are listed in the continuation of Box C.  See patent family annex.

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