After a decade of development and waiting in the wings, Fibre Channel appears poised for deployment—delivering 100-Mbyte/sec data rates in storage and networking subsystems. Vendors now offer designers a plethora of building-block products, starting with ICs, and including connectors, cables, modules, boards, and disk drives.

Fibre Channel finally fills the gap in I/O subsystems

MAURY WRIGHT, TECHNICAL EDITOR

After a tempestuous marketing battle and a lengthy development process, Fibre Channel is finally ready to prosper. The technology offers compelling features that start with 100-Mbyte/sec data rates and include a unique flexibility that can serve storage and networking applications and even replace a computer bus in some cases. Moreover, vendors now offer a variety of products that be-comes more affordable every day. To understand how you can deploy Fibre Channel in general-purpose computers or embedded systems, you should examine the basics of the technology, speculate about what might be a killer application, and identify the key products that enable high-speed subsystem designs.

Hubs such as Vixel's Rapport family introduce reliability into FC-AL via a star topology, just as Ethernet hubs augment 10BaseT LAN reliability.

The concept of Fibre Channel emerged more than a decade ago and, in retrospect, posed a daunting challenge to semiconductor vendors. After all, typical SCSI implementations then attained 1.5-Mbyte/sec rates, with a few vendors offering 4-Mbyte/sec synchronous products. Ethernet and other LANs operated even slower. Yet, Fibre Channel's founders envisioned that a serial interface could ramp to 100-Mbyte/sec rates. When you realize that no interface enjoys wide success until vendors ship single-chip implementations, it's unsurprising that Fibre Channel took more than a decade to mature.

The ANSI committee working on Fibre Channel, however, didn't just concentrate on unheard-of data rates; it also conceived a switched architecture that could provide dedicated, full-duplex connections between two devices connected via a fabric (**Figure 1**). The standard leverages separate transmitting and receiving circuits to enable concurrent 100-Mbyte/sec communications in each direction (**Figure 2**). Theoretically, a Fibre Channel fabric can support a virtually unlimited number of nodes. The addressing scheme allocates 16 million individual

@a glance

- The marketing battles are over, and Fibre Channel is clearly the future in high-end storage.
- The transition to Fibre Channel will start at the subsystem level, thereby coexisting with SCSI for some time.
- Storage-area networks will drive volumes, enabling low-cost components for other applications, including embedded systems.
- Fibre Channel ICs have reached the single-chip integration level that typically spurs a market.

addresses. The ports on the fabric are "F_ports," and the ports in each device, or node, are "N_ports." The physical distance any point-to-point link can span varies based on the type of cable, and the standard provides for multiple copper and optic cable choices (**Table 1**).

FC-AL storage evolves

As the Fibre Channel standard progressed, it became clear that dedicating a switch port to every device might be neither economically feasible nor necessary in many applications. For example, a single host might need to connect with a number of disk drives, and that scenario cannot justify a switch. The committee developed the Fibre Channel Arbitrated Loop (FC-AL) for just such applications. FC-AL connects the transmitting port from one node into the receiving node of the next port (**Figure 2**). Data transfers proceed in one direction around the loop. At any time, one node on an FC-AL loop can arbitrate for the media, receive access, and use the loop as a dedicated link to another node on the loop. Fabric ports that connect to a loop are "FL_ports," and loop ports on devices such as disk drive are "NL_ports."

An FC-AL configuration can connect as many as 126 devices, although a typical loop connecting disk drives might comprise only 10 to 20 nodes. In cases requiring greater bandwidth or reliability, you can deploy dual counter-rotating loops in which each node is dual-ported. Disk-drive vendors plan to ship dual ports as a standard feature. Similar to the Fiber Distributed Data Interface (FDDI), a dual-FC-AL implementation doubles aggregate bandwidth when all nodes are working. Moreover, the second loop provides a way for the loop to heal automatically and form a single loop when any node fails. Fibre Channel implementations can mix and match looped and switched connections.

As you can see, the Fibre Channel committee developed a capable physical interface but also sought to make that interface protocol-independent. This Fibre Channel feature differentiates it from other interfaces, allowing network protocols, such as TCP/IP, to operate over Fibre Channel just as readily as do SCSI disk protocols, which are called Fibre Channel Protocols (FCP) when you map them to the serial interface. (See **boxes** "Data storage meets network layers" and "Fibre Channel standards and organizations" and **References 1** through **3**. For more information, check the Web sites of the Fibre Channel Loop Community (FCLC) and the Fibre Channel Association (FCA).)

Fibre Channel application path

Given a basic understanding of Fibre Channel capabilities, you can envision an application-migration path in which the new technology slowly supplants other storage interfaces and networks. Fibre Channel proponents fought a lengthy marketing battle with another serial interface, the Serial Storage Architecture (SSA), which IBM championed. Today, it's clear that SSA isn't a roadblock and will disappear over time, despite the fact that IBM has shipped SSA in much greater volume than total Fibre Channel shipments to date. In data storage, Fibre Channel must replace the venerable SCSI, although you can expect the two to coexist throughout the next decade. Fibre Channel is also unlikely to replace Ethernet but will carry network traffic in some cases.

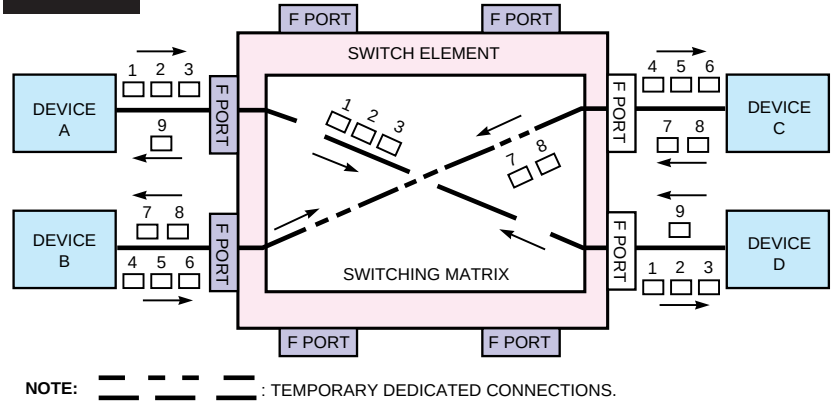
Early on, the opportunity for Fibre Channel lies in solving problems that SCSI can't address. For example, Fibre Channel can span far greater distances, both between nodes and in total. The long cables make Fibre Channel a natural for box-to-box links. For example, such companies as Sun (www.sun.com), Silicon Graphics (www.sgi.com), and even Compaq (www.compaq.com) have widely deployed Fibre Channel as a link between computers and disk subsystems and arrays.

Within a Fibre Channel disk subsystem—either a RAID (redundant array of inexpensive disks) or JBOD (just a bunch of drives)—the actual disk dri-

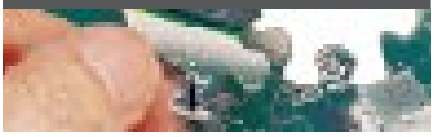
TABLE 1—COPPER AND OPTIC CABLE CHOICES

Media type	Node-to-node distance
9-mm single-mode fiber	10 km
50-mm multimode fiber	500m
62.5-mm multimode fiber	175m
Video coax	25m
Miniature coax	10m
Twisted pair	50m (25 Mbytes/sec)

FIGURE 1



Fibre Channel includes several potential topologies, such as full-duplex links that are switched through fabrics.



ves can use the SCSI or FC-AL interface. Bridging an FCP stream to a SCSI channel within a subsystem is a relatively trivial task.

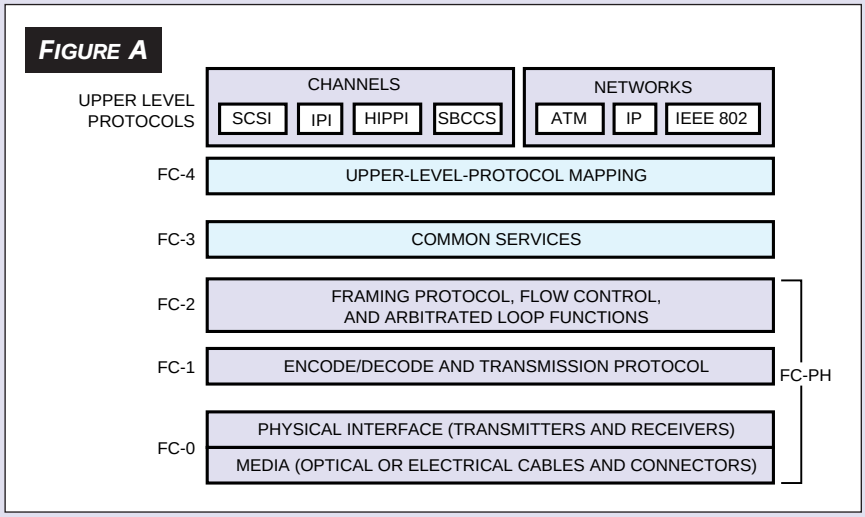
Inside the box, SCSI remains attractive because vendors have pushed data rates to 80 Mbytes/sec in wide Ultra 2 drives that use low-voltage-differential signaling (LVDS). SCSI drives also have a significant sales volume advantage that translates to lower cost, ensuring that the drives will be around for a long time in most applications. Even at the high end, SCSI drives will remain inside Fibre Channel subsystems as long as SCSI drives keep pace with the raw data rate from the disk media and maintain a cost advantage over FC-AL drives. Today, only Seagate ships FC-AL drives in volume, and it proclaims that SCSI and FC-AL drives have reached price parity. Realistically, FC-AL drives still cost 20% more. This premium will drop as Seagate ships products in higher volumes and as Hitachi, Fujitsu, and Quantum ship drives in volume.

Fibre Channel proponents, especially those such as Hewlett-Packard that offer no SCSI products, proclaim a number of advantages—that may offset a price premium—resulting from using FC-AL drives. Some of these proclamations hold water, and some don't. For example, the small-diameter serial cable and small connector attributed to serial Fibre Channel presumably offer cost and convenience advantages over parallel SCSI cable and connectors. However, in the space that FC-AL and SCSI compete, either interface runs along backplanes rather than cables. The SCSI backplane may be marginally more complex, but the effect on cost is negligible, especially considering SCSI volumes. The two also use similar backplane connectors, as Revision 2 of the Single Connector Attachment (SCA) spec defines.

DATA STORAGE MEETS NETWORK LAYERS

Although your first thought about Fibre Channel probably centers on data-storage applications, the layered architecture actually resembles a network. Fibre Channel's developers conceived it as a way to address high-bandwidth needs in networking and storage applications. It offers a unique ability to host a variety of high-level protocols on a layered stack that resembles but does not directly map to the open-systems-interconnection seven-layer network model. Figure A depicts the layers of the standard and demonstrates how the interface can equally well carry TCP/IP network traffic and SCSI commands and data packets.

FIGURE A



Unlike most storage interfaces, Fibre Channel relies on a layered networklike model and can carry storage or networking protocols.

The FC-0 Physical Interface and Media Layer specifies the lowest level of the physical (PHY) interface, including a choice of several copper or optical media and the required transmitters and receivers.

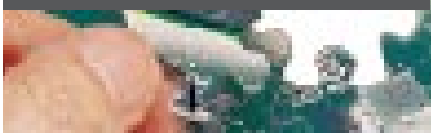
The FC-1 Transmission Protocol Layer adds the 8B/10B data-encoding method that Fibre Channel shares with other communication standards, such as Gigabit Ethernet and the Fiber Distributed Data Interface. Fibre Channel uses 10 bits to represent 8 bits of actual data—dedicating the overhead to error control. Taking the overhead into account, a 1-GHz signal yields 100-Mbyte/sec data rates. Note that Gigabit Ethernet uses basically the same PHY but boosts the raw signaling rate by 20% to realize an even 1-Gbps rate.

The FC-2 Framing Protocol Layer defines the rules for framing data and the mechanisms for using circuit- and packet-switched services that the spec defines. This layer also defines the means by which a fabric or loop manages the sequence of a data transfer, including the unique identification of each frame in a sequence.

The FC-3 Common Service Layer defines services such as multicast, data striping to increase bandwidth in a disk array, and hunt groups that allow more than one port to respond to the same alias address. The ANSI X11 committee is still working on the FC-3 Layer.

The FC-4 Upper Level Protocol Mapping Layer defines application interfaces for storage and network protocols. Supported data-storage protocols include SCSI, the Intelligent Peripheral Interface (IPI), IBM's Single Byte Command Code Set (SBCCS), and the High Performance Parallel Interface (HiPPI). Supported network standards include ATM, TCP/IP, and all IEEE 802 LANs, including Ethernet and Token Ring.

FIBRE CHANNEL TECHNOLOGY



FC-AL boosts reliability

FC-AL does offer some potential advantages in reliability and fault tolerance. Designers using SCSI drives have developed backplanes and arrays that support hot-swapped drives and fault tolerance, but FC-AL supports such concepts even in a loop configuration. FC-AL vendors have also taken reliability even further. For example, a number of vendors have developed Fibre Channel hubs that work in a similar way to Ethernet hubs. A hub allows individual drives or small FC-AL configurations to connect with a large loop via the hub in a star topology. By making the hub the center of the star, vendors can add fault-tolerant features in the hub yet maintain a logical loop. In turn, the hub can bypass any failed nodes and manage maintenance and repair operations.

In the not-too-distant future, it may be possible to connect a rack of FC-AL drives via a backplane with a hub residing directly on the backplane. The local hub could greatly improve reliability and maintenance. Moreover, the hub could be modular, providing users with a choice of using a hub or a switch to connect the drives, thereby offering a trade-off of cost vs aggregate bandwidth. These ad-vancements should enable FC-AL drives to supplant SCSI drives within subsystems.

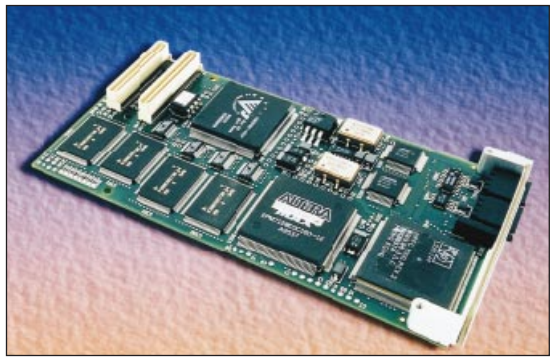
In the short term, the most promising opportunity for FC-AL drives comes in single-channel JBOD subsystems or FC-AL configurations that connect more than the 15 drives that wide SCSI supports on a channel. Applications such as video editing can require more than 15 drives and benefit from the slightly higher data rates that FC-AL drives afford.

You may think that none of these scenarios applies to you, so you needn't worry about Fibre Channel. However, no one can predict all the applications that Fibre Channel will find. Suffice it to say that designers have deployed the technology as often in embedded applications as in MIS departments. For example, DY 4 offers the $2500 PMC-640 Fibre Channel module for its VMEbus single-board computers and targets the product as a replacement for Mil-Std-1553 links. Moreover, you would be well-advised to consider Fibre Channel whenever you need a low-latency, high-speed interface for point-to-point, bus, or network topologies.

The killer application

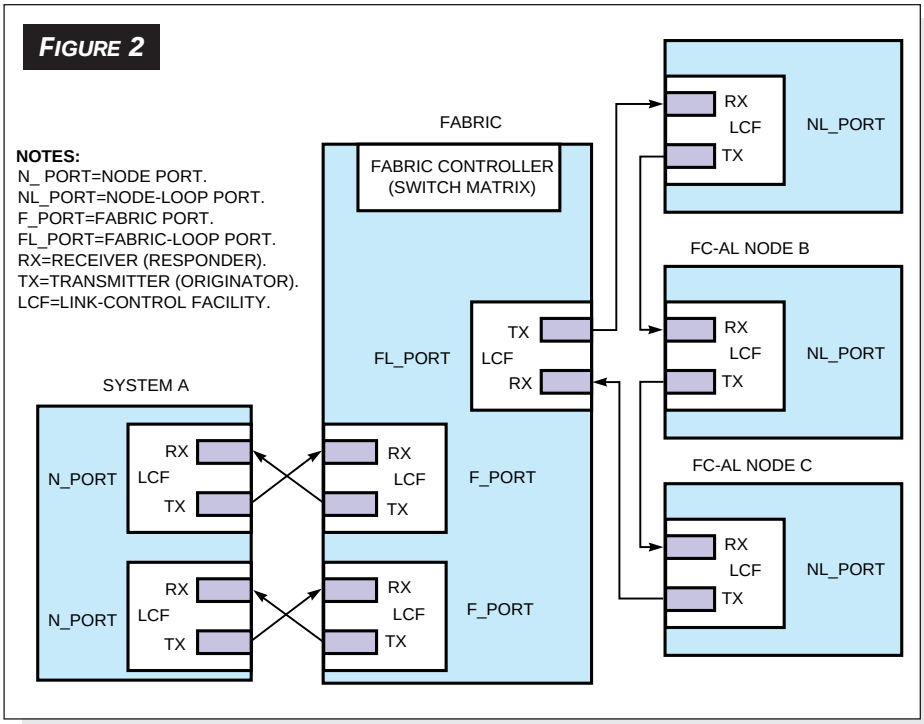
An imminent killer application—storage-area networking—that only Fibre Channel can address will benefit all potential Fibre Channel applications by creating more products and lower prices. This emerging application links multiple servers and data-storage devices on a private backbone network that lies behind one LAN or more (**Figure 3**). On a storage-area network (SAN), the servers communicate with the storage devices using the SCSI protocol, which is generally more efficient than TCP/IP or another networking protocol.

SANs can mix and match Fibre Channel loops and fabrics using switches and hubs. The SAN might fea-



Fibre Channel technology will reach far beyond general-purpose computers into embedded systems and even military applications. For example, DY 4 has developed its PMC-640 adapter for use with VMEbus boards and targets the product as a replacement for serial interfaces, such as the Mil-Std-1553 interface.

FIGURE 2



Designers can mix and match Fibre Channel topologies using switches and hubs to connect individual nodes or Arbitrated Loops.

ture FC-AL-to-SCSI routers and bridges and, potentially, even bridges between FCP or SCSI and TCP/IP traffic. Regardless of whether FC-AL or SCSI drives prevail in SAN environments, the environment requires numerous Fibre Channel interface cards and ICs. The SAN promises to ramp volumes of these key Fibre Channel components, quickly making them more attractive for other applications.

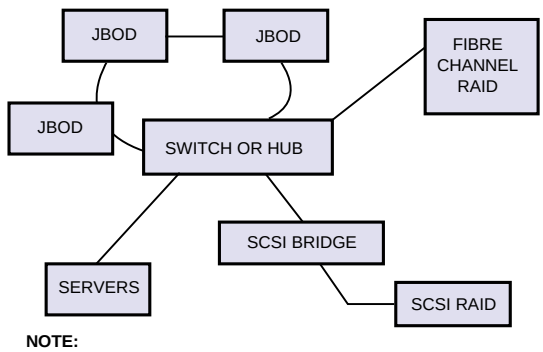
Vendors have recently been jumping on the Fibre Channel bandwagon in great numbers. More than 70 vendors have announced Fibre Channel products, and a dozen or so more vendors will emerge this year (**Table 2**). Several vendors serve every category of products with key areas, such as interface cards and ICs, enjoying the greatest support.

A single-chip implementation of an interface or network is the key for widespread acceptance, and that gate to Fibre Channel success has opened. QLogic has begun shipping its ISP2100 Fibre Channel protocol IC that integrates a 64-bit, 66-MHz PCI bus on one side and a direct interface to copper Fibre Channel media on the other. The IC costs around $150, but a PCI-interface card requires little extra other than passive components and software drivers. QLogic's ISP2100 can serve only in FC-AL—not switch or hub—applications.

Not surprisingly, competing IC vendors don't think QLogic developed the best Fibre Channel implementation, given the current state of semiconductor technology. QLogic is the first company to build a CMOS IC that integrates the mixed-signal transceiver, including the serializer/deserializer (SERDES) function that sits between the outside serial world and the internal 8B/10B encoder/decoder. Competitors such as Hewlett-Packard and Emulex feel strongly that an IC vendor could better realize the transceiver in bipolar or GaAs technology. These companies assert that QLogic's CMOS SERDES may work in some applications but may create reliability problems in noisy environments or as cables get longer. Your media choice can also affect transceiver issues (see **box** "Media choices complicate physical interface").

Both Emulex and Hewlett-Packard have developed ICs that target FC-AL interface cards, integrate a PCI interface, and provide a 10-bit parallel interface to an external SERDES. Note that QLogic's IC also offers a parallel interface for external transceivers. The company claims that the auxiliary interface will be useful to designers who need to connect optical transceivers or who want to use a more robust bipolar or GaAs transceiver in copper applications. Several companies, including Hewlett-Packard, make Fibre Channel transceivers. Perhaps Vitesse offers the most extensive set of choices, which it makes using GaAs technology. Vitesse asserts that a stand-alone SERDES IC adds reliability and that volume prices of such ICs will reach

FIGURE 3

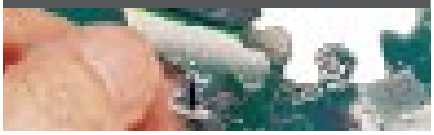


Storage-area networks link multiple servers and data-storage devices on a private backbone network that lies behind one LAN or more.

FIBRE CHANNEL STANDARDS AND ORGANIZATIONS

Designers looking for more Fibre Channel background information and copies of the pertinent specifications can turn to several organizations for help. For starters, two technical/marketing organizations have emerged as facilitators to the ANSI X11 committee that shepherds Fibre Channel and other storage specs. The Fibre Channel Loop Community (FCLC, www.fcloop.org) is the older of the two and is primarily dedicated to the FC-AL segment of the industry that targets data-storage applications. The organization's Web site offers background information, contacts at member companies, and some product information. Meanwhile, the Fibre Channel Association (FCA, www.fibrechannel.com) champions the entire Fibre Channel universe and offers some interesting background on storage-area-network applications.

For copies of the standard, you can turn to Global Engineering Documents. The company sells copies of all ANSI documents, including ANSI X11 standards. Designers who need ready access and frequent updates might prefer to turn to ENDL, which long-time X11 standards facilitator Dal Allan operates. ENDL offers a CD-ROM subscription service that keeps you up to date on Fibre Channel, SCSI, and other storage standards. ENDL distributes a new CD-ROM every two months with the latest version of the standards and notes on all ongoing standards activity. For individual use, an annual subscription costs $480 for Fibre Channel and $480 for SCSI. ENDL also facilitates the Small Form Factor (SFF) committee that shepherds the ATA and other PC storage specs. A CD-ROM subscription that covers SFF activity costs $660. Customers who subscribe to all three offerings pay $1080/year. ENDL also offers site licenses that allow companies to host the standards information on an intranet starting at $1800/year.



approximately $3 by the end of this year.

In other features, Hewlett-Packard's $150 TachLite matches QLogic's offering with a 64-bit, 66-MHz PCI implementation. Emulex's IC includes only a 32-bit PCI interface but supports simultaneous full-duplex operation, whereas the ICs from QLogic and Hewlett-Packard can only transmit or receive at any moment. Emulex plans to offer the IC not as an off-the-shelf product but integrated on the company's $600 LP3000 PCI-interface card. Emulex has, however, provided access to its ICs, so interested parties might be able to negotiate an IC deal and use the LP3000 as a reference design. Emulex's LP3000 adapter costs approximately the same as cards from QLogic and Hewlett-Packard, so the IC could have

MANUFACTURERS OF FIBRE CHANNEL PRODUCTS

For more information on Fibre Channel products such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card, or use *EDN*'s Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

Adaptec Inc
Milpitas, CA
1-408-945-8600
www.adaptec.com
Circle No. 301

AMCC
San Diego, CA
1-619-450-9333
www.amcc.com
Circle No. 302

American Megatrends Inc
Norcross, GA
1-770-246-8600
www.ami.com
Circle No. 303

Amp Inc
Harrisburg, PA
1-800-522-6752
www.amp.com
Circle No. 304

Ancor Communications Inc
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www.ancor.com
Circle No. 305

Ancot Corp
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www.ancot.com
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Artecon Inc
Carlsbad, CA
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www.artecon.com
Circle No. 307

Atto Technology Inc
Amherst, NY
1-716-691-1999
www.attotech.com
Circle No. 308

Box Hill Systems Corp
New York, NY
1-212-989-4455
www.boxhill.com
Circle No. 309

Brocade Communications Systems Inc
San Jose, CA
1-408-487-8000
www.brocade.com
Circle No. 310

Ciprico Inc
Plymouth, MN
1-612-551-4000
www.ciprico.com
Circle No. 311

Clariion
Southboro, MA
1-800-672-7729
www.clariion.com
Circle No. 312

Computer Network Technology
Minneapolis, MN
1-612-797-6000
www.cnt.com
Circle No. 313

Crossroads Systems Inc
Austin, TX
1-512-349-0300
www.crossroads.com
Circle No. 314

CS Electronics
Irvine, CA
1-714-475-9100
www.scsi-cables.com
Circle No. 315

Distributed Processing Technology
Maitland, FL
1-407-830-5522
www.dpt.com
Circle No. 316

DY 4 Systems
Kanata, ON
Canada
1-613-599-9199
www.dy4.com
Circle No. 317

Emulex Corp
Costa Mesa, CA
1-714-662-5600
www.emulex.com
Circle No. 318

ENDL
Saratoga, CA
1-408-867-6630
Circle No. 319

Eurologic
Acton, MA
1-978-266-9224
www.eurologic.com
Circle No. 320

Finisar Corp
Mountain View, CA
1-650-691-4000
www.finisar.com
Circle No. 321

Fujikura America
Marietta, GA
1-888-385-4587
Circle No. 322

Fujitsu Compound Semiconductor Inc
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1-408-232-9500
www.fcsi.fujitsu.com
Circle No. 323

Fujitsu Computer Products of America Inc
San Jose, CA
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www.fcpa.com
Circle No. 324

Gadzoox Networks Inc
San Jose, CA
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www.gadzoox.com
Circle No. 325

Genroco Inc
Slinger, WI
1-414-644-8700
www.genroco.com
Circle No. 326

Global Engineering Documents
Englewood, CO
1-800-854-7179
http://global.ihs.com
Circle No. 327

G2 Networks Inc
Los Gatos, CA
1-408-399-3800
www.g2networks.com
Circle No. 328

Hewlett-Packard Co
Santa Clara, CA
1-800-537-7715, ext 9969
www.hp.com
Circle No. 329

Hitachi America Ltd
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1-415-589-8300
www.hitachi.com
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I-Tech Corp
Edina, MN
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Circle No. 331

IBM
Somers, NY
1-800-426-2255
www.rs6000.ibm.com
Circle No. 332

Infortrend Technology Inc
Santa Rosa, CA
1-707-541-3400
www.infortrend.com
Circle No. 333

Intercon Systems Inc
Middletown, PA
1-717-540-5660
www.interconsystems.com
Circle No. 334

Interphase Corp
Dallas, TX
1-214-654-5000
www.iphase.com
Circle No. 335

Jaycor Networks Inc
San Diego, CA
1-619-535-3121
www.jni.com
Circle No. 336

a price similar to that of ICs from those companies.

Hewlett-Packard, Emulex, and QLogic have also taken different approaches to the internal IC architecture. Hewlett-Packard uses a hardwired, state-machine implementation, whereas the others include onboard processors. Emulex includes dual parallel processors that enable full-duplex support. It's tough to judge the performance merits of the IC designs because no benchmarks exist. Moreover, the maximum Fibre Channel rate exceeds the capabilities of most PCI hosts. For the short term, you may have to base your IC choice on purely theoretical performance arguments or on logistics issues, such as the SERDES or software drivers. For example, QLogic's IC uses the same processor core it uses in its SCSI ICs, and the company asserts that its FC-AL driver uses 90% of the same code as its SCSI driver. Designers familiar with the SCSI IC could quickly scale the FC-AL learning curve.

JMR Electronics Inc
Chatsworth, CA
1-818-993-4801
fax 1-818-993-9173
www.jmr.com
Circle No. 337

LSI Logic Corp
Milpitas, CA
1-408-433-8000
www.lsilogic.com
Circle No. 338

Maxstrat Corp
Milpitas, CA
1-408-383-1600
www.maxstrat.com
Circle No. 339

McData Corp
Broomfield, CO
1-303-460-9200
www.mcdata.com
Circle No. 340

Megadrive Systems Inc
Chatsworth, CA
1-818-700-7600
www.megadrive.com
Circle No. 341

Meltek Inc
Scotts Valley, CA
1-408-438-4986
www.meltek.com
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Methode Electronics Inc
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Molex Inc
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Mylex Corp
Fremont, CA
1-510-796-6100
www.mylex.com
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Myriad Logic Inc
Silver Spring, MD
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www.myriadlogic.com
Circle No. 346

nStor Corp
Lake Mary, FL
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OneofUs Company Ltd
Taipei Ta-An District 106
Taiwan
011-886-2-2702-1649
www.oneofus.com
Circle No. 348

Performance Technologies Inc
Rochester, NY
1-716-256-0200
www.pt.com
Circle No. 349

Prisa Networks
San Diego, CA
1-619-677-0030
www.prisa.com
Circle No. 350

QLogic Corp
Costa Mesa, CA
1-714-438-2200
www.qlc.com
Circle No. 351

Quantum Corp
Milpitas, CA
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Raidtec Corp
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Circle No. 353

Seagate Technology Inc
Scotts Valley, CA
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www.seagate.com
Circle No. 354

SGS-Thomson
Lincoln, MA
1-617-259-0300
www.st.com
Circle No. 355

Storage Concepts Inc
Irvine, CA
1-714-852-8511
www.storageconcepts.com
Circle No. 356

Storage Dimensions
Milpitas, CA
1-408-954-0710
www.storagedimensions.com
Circle No. 357

SWS/Storagepath
Newbury Park, CA
1-805-498-6727
www.storagepath.com
Circle No. 358

Symbios
Fort Collins, CO
1-970-223-5100
www.symbios.com
Circle No. 359

Syred Data Systems
Howell, NJ
1-908-886-1400
www.syred.com
Circle No. 360

Systran Corp
Dayton, OH
1-937-252-5601
www.systran.com
Circle No. 361

Texas Instruments
Dallas, TX
1-800-477-8924, ext 4500
www.ti.com
Circle No. 362

Transoft Technology Corp
Santa Barbara, CA
1-805-897-3350
www.transoft.net
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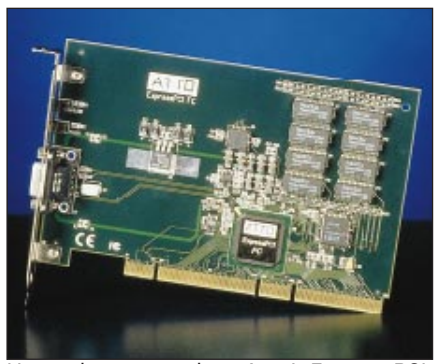
Now and in the near future, you face a plethora of other IC choices. Adaptec and Symbios have announced ICs, although Adaptec has also announced plans to buy Symbios. It's unclear which ICs will emerge as mainstream products from those companies. Also, expect ASIC houses, such as LSI Logic and VLSI Technology, to offer Fibre Channel support in their portfolios.

Should you need an IC to develop switch fabrics or hubs, you will have a more limited menu of choices. Emulex has a three-chip set that it uses on its $1495 LP7000 adapters and in its own hubs and switches. The chip set relies on a Strong ARM μP and supports Fibre Channel profiles other than FC-AL.

Hewlett-Packard offers by far the most popular choice in its Tachyon IC, which has been available for several years. The IC offers the full-duplex support that's the key differentiator between FC-AL and switched or point-to-point Fibre Channel links. Unlike the Tachlite FC-AL controller, the Tachyon has no PCI interface but rather a Hewlett-Packard-proprietary interface. Moreover, Hewlett-Packard doesn't publicly offer a companion PCI to the Tachyon IC, although you can buy one from Interphase.

Tachlite and QLogic's ISP2100 are a generation ahead of any IC that targets full-duplex links other than the Emulex ASIC that the LP3000 uses. Expect QLogic to offer a full-duplex IC soon, and expect Hewlett-Packard to announce a successor to the full-duplex Tachyon as well.

You probably should also take a brief glance at the future before you settle on an IC or a board-level product. Some Fibre Channel proponents are discussing 2-Gbyte/sec data rates, and Hewlett-Packard claims that its state-machine-based Tachyon architecture can easily move to the higher rates. Hewlett-Packard envisions a market much like the current 10/100-Mbps Ethernet market in which end users get 100-Mbps support even if they need only a 10-Mbps adapter. The company believes a number of vendors will ship 2-Gbyte/sec adapters long before most loops or switches support those speeds. Vitesse indicates that it plans to sample 2-Gbyte/sec transceivers this quarter. It remains to be seen whether Hewlett-Packard or others can essentially give away faster silicon. In many cases, dual 1-Gbyte/sec ports offer more advantages than single 2-Gbyte ports. Moreover, it's clear that 1-Gbyte/sec ports will dominate in switches and hubs for at least five years. EDN



Host adapters, such as Atto's Express-PCI, demonstrate that IC and board manufactures have finally achieved the high levels of integration necessary for Fibre Channel to drop in price and achieve widespread acceptance.

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You can reach Technical Editor Maury Wright at 1-619-748-6785; fax 1-619-679-1861, ednwright@mcimail.com.

MEDIA CHOICES COMPLICATE PHYSICAL INTERFACE

Fibre Channel's unique ability to use several types of copper and optical cables introduces equally unique logistics challenges: How do you standardize on a connector, and how does a designer decide which connector to specify on an interface card? Over the decade of Fibre Channel development, several approaches have emerged that you can consider for your designs.

Early on, cable and card vendors placed most of the emphasis on an efficient optics connection scheme because it took some time for IC vendors to develop copper-based physical-interface chips that worked at 100-Mbyte/sec rates. An external module that included the transceiver resulted in a "Gigabit Link Module" (GLM). GLMs depended on a parallel interface between the card and the transceiver module, and designers could choose the GLM that matched their choice of media.

Unfortunately, the GLM approach meant that designers who chose copper cable still had to purchase an external module. As IC vendors shipped transceivers for 100-Mbyte/sec copper media, the Fibre Channel community turned to the media-interface-adapter (MIA). The community standardized on a connector for copper media and relied on an external MIA module when an application required optical cable. This development moved the transceiver onto the card and is now by far the most popular approach. The most prevalent deployments in data-storage applications will remain copper-based for some time.

Still, the high end of the industry desired a more elegant way than the donglelike MIA to connect optical cable. This desire led to the GigaBit Interface Converter (GBIC) module. Electrically and optically, GBICs work like MIA modules. Physically, however, GBICs slide completely into an interface card or hub, much like a PC Card slides into a notebook computer. The GBIC approach hides the module and reduces potential cable breaks. Unfortunately, GBICs also add cost, and, therefore, vendors will not deploy them in many mainstream applications.

Table 2–Fibre Channel Products

	Circle No.	Prokocol ICs	Physical-layer ICs	Adapter cards (PCI, EISA, ISA, Sbus, etc)	Adapter cards (VME, PMC, etc)	RAID controllers	Disk drives	Disk subsystems	RAID subsystems	Servers	FC-to-SCSI bridges and routers	Hubs	Switches and fabrics	SAN systems and software	Test and development systems	GBICs, MIAs, and GLMs	Transceiver modules	Connectors	Cables	Enclosures
Adaptec	301	√		√		√															
AMCC	302		√																		
American Megatrends	303			√		√															
Amp	304															√	√	√	√		
Ancor Communications	305			√									√								
Ancot	306										√				√						
Artecon	307							√													
ATTO Technology	308			√							√	√									
Box Hill Systems	309							√	√												
Brocade Communications Systems	310												√								
Ciprico	311							√	√	√											
Clariion	312							√	√												√
Computer Network Technology	313													√							
Crossroads Systems	314										√				√						
CS Electronics	315																		√		
Distributed Processing Technology	316			√		√															
DY 4 Systems	317				√																
Emulex	318	√		√								√	√								
Eurologic	320							√	√												
Finisar	321														√		√				
Fujikura	322															√	√	√	√		
Fujitsu Compound Semiconductor	323		√																		

Table 2–Fibre Channel Products

	Circle No.	Protocol ICs	Physical-layer ICs	Adapter cards (PCI, EISA, ISA, Sbus, etc)	Adapter cards (VME, PMC, etc)	RAID controllers	Disk drives	Disk subsystems	RAID subsystems	Servers	FC-to-SCSI bridges and routers	Hubs	Switches and fabrics	SAN systems and software	Test and development systems	GBICs, MIAs, and GLMs	Transceiver modules	Connectors	Cables	Enclosures
Fujitsu Computer Products	324						√					√	√								
Gadzoox Networks	325											√	√								
Genroco	326			√	√																√
G2 Networks	328											√					√				
Hewlett-Packard	329	√	√	√												√	√				
Hitachi America	330						√														
I-Tech	331														√						
IBM	332			√									√								
Infortrend Technology	333							√													
Intercon Systems	334																			√	
Interphase	335	√		√	√																
Jaycor Networks	336			√								√									
JMR Electronics	337																				√
LSI Logic	338	√	√																		
Maxstrat	339									√											
McData	340												√								
Megadrive Systems	341							√	√			√									√
Meltek	342								√												
Methode Electronics	343															√	√	√			
Molex	344																√	√	√		
Mylex	345			√		√															
Myriad Logic	346				√																

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nStor	347							√	√											√
OneofUs Company	348					√														
Performance Technologies	349			√																
Prisa Networks	350			√							√		√							
QLogic	351	√	√	√																
Quantum	352						√													
Raidtec	353			√				√	√											
Seagate Technology	354						√													
SGS-Thomson	355		√																	
Storage Concepts	356							√	√											
Storage Dimensions	357							√	√											
SWS/Storagepath	358							√	√											√
Symbios	359	√		√		√														
Syred Data Systems	360					√														
Systran	361			√	√															
Texas Instruments	362		√																	
Transoft Technology	363			√							√	√								
Vitesse Semiconductor	364		√																	
Vixel	365										√	√			√					
VLSI Technology	366	√																		
Volex	367																	√		
Xyratex	368							√						√						

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