USB and Firewire: Two Standards, Only One World

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The popularity of USB and Firewire connectivity standards has ballooned since their inception in 1995. For the consumer they have greatly simplified the task of connecting PC peripherals and consumer electronic devices to the PC and to each other. As a result, traditional serial, parallel, and SCSI PC ports are being relegated to obsolescence, with the next victim possibly being PS2. In the past two years, the standards body for each connectivity solution has formulated improved specifications with larger bandwidths and increased networking ability, opening up new markets for each, as well as making them more competitive with one another. Since the beginning each of these standards have been carving out their own niche, allowing them to continue rightfully claiming their own place on the PC interface, and remain excellent solutions for PC peripheral and consumer electronics connectivity.

USB (Universal Serial Bus) is popular for most PC peripherals (electronics specifically purposed to interface to a PC), such as mice, keyboards, joysticks, printers, scanners, external data storage, PC speakers and PC cameras. On the other hand, Firewire (or IEEE 1394) is popular for many consumer electronic products - a category including digital camcorders, digital cameras, set top boxes, DVD players, and digital TVs, as well as portables such as MP3 players, PDAs and cell phones. These devices serve a specific purpose apart from a PC and may, or may not, need connectivity to it. The conclusion is that USB and Firewire will peacefully coexist in the next few years, but not without some competitive battles written into the storyline.

USB and Firewire are tremendous improvements over legacy PC connectivity solutions. In the past PC I/O interfaces were problematic for the consumer. There was serial, parallel, SCSI and other legacy port interfaces that all required their own proprietary cables, which had limited run lengths and could be costly as well. A major limitation was that of one peripheral per port. To add a port the consumer might have to install an add-in card to the system's internal bus, requiring them to disassemble the housing from the desktop PC box and dive into the hardware, which many are hesitant to do. Another hassle was the required system re-boot each time a connection was added or dropped. In response to these difficulties, USB and Firewire answered the call. The year was 1995.

Each standard provided true 'plug-and-play' capability, was cheaper, faster and had longer cable run-lengths. The cables were also cheaper and had small connectors, made possible because of the small number of wires needed for a serial bus, and they did not

need to be terminated. A huge added value was branching capability, allowing numerous dvices to be connected together as well as connecting numerous devices to a single host port on the PC. These two serial bus standards greatly simplified connectivity for the consumer. However, beyond simplification for the user, each standard was initially developed with a different purpose in mind.

It is worth noting that USB and Firewire simplicity and convenience for the consumer came at a price. Analogous to the second law of thermodynamics, this complexity didn't just disappear: It ended up in the lap of the developer. The developer has to make only a few wires in a serial bus perform the tasks of error handling, arbitration between devices, differing transfer speeds and types, and configuration or enumeration. It is no surprise that the complexity of the specifications, the software drivers, and the silicon itself are comparable between the standards. To help customers most vendors offer a plethora of reference design kits with complete node and peripheral hardware, application software and firmware.

USB: What is it?

Intel conceived USB specifically as the solution to the PC I/O legacy connectivity issues already noted. USB's emergence into the market was primarily driven by Intel, who began selling USB host controllers as part of their PC chipsets. On the bandwagon were companies such as Microsoft, Compaq, NEC, Digital, IBM and Nortel. They spearheaded the formulation of the USB-IF (Implementers' Forum), an organization that promotes USB, delivers the specifications and oversees compliance testing. As of October 2002, the board of directors is Intel, Microsoft, NEC, Agere Systems, Hewlett-Packard, NEC and Philips, with 100s of other member companies. The USB-IF designed the standard as a PC-centric serial bus, enabling data transfers between the PC's host controller and its peripherals. Up to 127 devices can be connected to the PC in the form of a tiered or star topology, where hubs add branching capability (see Fig. 1.)

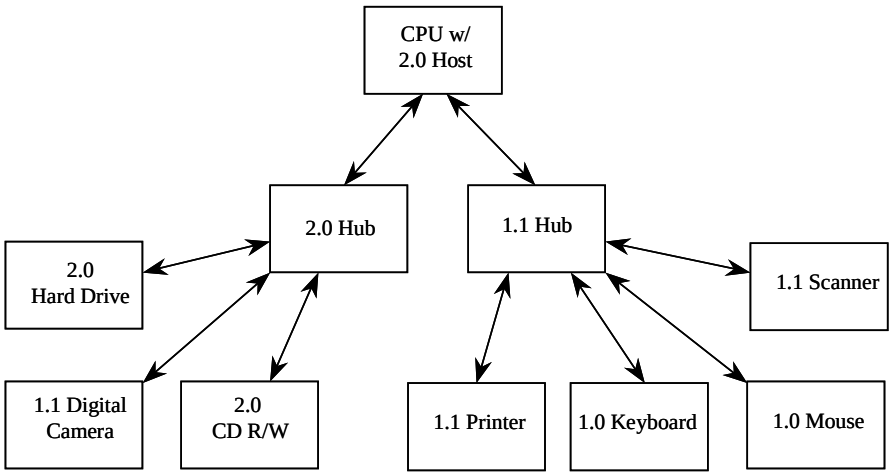

Fig. 1: Example of USB Network

USB 1.0 and 1.1 define transfer bandwidths of 1.5 Mbit/s and 12 Mbit/s, also known as low-speed and full-speed. USB 1.1 is fully backwards compatible with USB 1.0. Hubs also aid in compatibility - they translate transfers between devices of different bandwidths. In April of 2000, the USB-IF introduced High-Speed USB 2.0, which increased bandwidth by 40x to a blazing 480 Mbit/s enabling the user to choose from even more USB devices. USB 2.0 can handle uncompressed digital video and high-speed data storage, drawing it into some potential competition with Firewire. It is also fully backwards compatible to the existing USB 1.x consumer base - a great asset to market acceptance since all earlier devices, cables, connectors and software still work! The silicon is also real: PC add-in cards equipped with USB 2.0 began shipping in March of 2001, PCs with built-in USB 2.0 host controllers began shipping in January of 2002, and Intel announced in May 2002 the integration of USB 2.0 into its core logic chipset.

USB supports 4 data transfer types: Isochronous, bulk, control and interrupt transfers. Isochronous transfers are for cases where the continuous delivery of data is more important than the integrity of it, such as streaming audio or video. The host tries to guarantee bandwidth for isochronous transfers, providing up to 90% of available bus bandwidth. Bulk data is for burst-like transfers where data integrity is most important (e.g. transfers to/from an external hard drive) using bandwidth left over from the isochronous transfers. Interrupt transfers are for low-bandwidth applications where the device notifies the host if data needs to be sent back or if control is needed (e.g. a mouse or keyboard.) Finally, control transfers are for command and status operations. The host initiates control transfers during enumeration, which is bus configuration after a device is added to the bus. This is where the host gathers the requirements and capabilities of the new device and configures itself and the device for proper communications. Hot-plugging a device into the network will not interrupt data transfers already in progress.

The maximum cable length for USB 2.0 signaling is 5 m. Devices can be bus-powered as well, with the host providing a maximum of 500 mA (examples are keyboards and mice.)

Introduced in December 2001, USB OTG (On-The-Go) is the latest work of the USB-IF. It addressed a very notable limitation of traditional USB, the inability to allow point-to-point communication between devices away from a PC. USB-OTG breaks this barrier for portables, freeing them from the PC-centric data transfer that has defined USB. PDAs, cell phones, digital cameras, MP3 players and other portables also need lower power and smaller connectors: USB-OTG meets that need. Many OTG devices will be designed with limited host capabilities for a selected set of USB devices, but they will have peripheral capabilities as well: Host PCs or other OTG devices with host capabilities will be able to control them. These OTG devices, with both host and peripheral capabilities, are called Dual-role devices (DRDs.)

Similar to traditional USB networks, one OTG device will control the bus, while the other acts as a peripheral, and all three transfer rates will be supported. However, the protocol allows for the swapping of bus control between connected DRDs. Furthermore, more than two devices can actually reside in a USB-OTG network. The network can take on that of a star topology as in traditional USB with hubs providing branching (see Fig. 2

for the most common, initial, uses). The DRD controlling the network is only required to source 8 mA, which aims at sparing the battery life of portable devices. A physical deviation from the traditional standard is that new cables and connectors are needed for interoperability with traditional ports, slightly complicating a consumer's USB cable inventories. However, all the connectors are keyed, preventing erroneous connections. OTG definitely has market interest: the first OTG reference design was released by Cypress Semiconductor the same day the spec was ratified and some OTG enabled devices such as PDAs may begin shipping in Q4 2002.

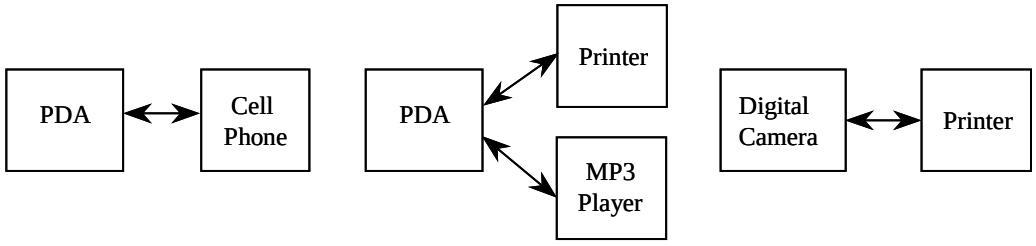

Fig. 2: USB OTG Networks

Firewire: What is it?

Apple Computer is the innovator of Firewire, traditionally known as IEEE 1394. In May 2002, the 1394 TA (Trade Association) adopted Firewire as the official name of the standard honoring its parent, Apple Computer. The standard was developed with high-bandwidth data transfer in mind, particularly streaming digital video and data storage. An additional goal was true peer-to-peer connectivity, including the PC as one of the peers. The 1394 TA oversees Firewire much like the way the USB-IF oversees USB: defining new specifications and compliance testing. Organized in 1994, the 1394 TA now has almost 200 members, including respected electronics companies such as Apple, Sony, Intel, Microsoft, JVC, Matsushita, Compaq, NEC, Philips and Samsung. In 1995 the 1394 TA formalized 1394-1995, which defined data transfers of approximately 100, 200 and 400 Mbit/s (termed S100, S200, and S400.) The S400 speed allowed for real-time transfers of uncompressed digital video enabling users to overcome the video and still-image degradation inherent in analog data transfers and editing. In 2000 the 1394 TA formalized 1394a, making the bus more efficient. Now in 2002 we have 1394b-2002, which comes with a new data transfer protocol, additional media support, and increased home-networking capabilities. It specifies 800 and 1600 Mbit/s (S800 and S1600) transfers, as well as a future-minded spec of 3200 Mbit/s. There also came a new transfer protocol different from 1394a, but a bi-lingual mode is specified to which either a 1394a or 1394b device can be attached, ensuring backward compatibility. TI led the charge, unveiling the first 1394b-compliant silicon in August of 2001 with a bi-lingual node, making it capable of bridging the newer and older networks. The 1394 TA is now awaiting an announcement from TI for production silicon.

Although PCs are common to most Firewire networks, it is inherent in the specification that a PC does not need to be involved: From Firewire's perspective, it is just another

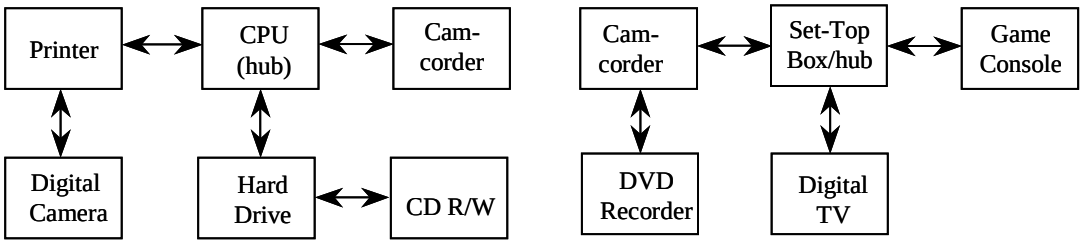

Fig. 3: Firewire Networks

node in a true peer-to-peer network; it is unsupervised and all devices have fair access. A total of 63 devices can be interconnected with examples being PCs, digital camcorders and external hard drives (see Fig. 3.) Firewire's terminology uses that of a tree: The root node controls arbitration; a single port device is a leaf; a two-or-more port device is a branch (however, a 3 or-more port device is also called a hub); and bus configuration a Tree ID. The root node is chosen by the network during this bus configuration.

Maximum cable run lengths between devices is 4.5 m for 1394 and 1394a. A total of 16 connections, or hops, can be made for a total network length of 72 m. IEEE 1394b greatly expands media options, which includes CAT-5 and optical fiber. 100 m of CAT-5 can handle S100 transfers and 100 m of glass fiber can handle transfers of S1600! Devices can be bus-powered along copper media, with the network capable of carrying 1.5 A, with a voltage range of 8 to 40 V (8 to 30 V for 1394b.) Due to the new data transfer protocol, connectors are re-defined for 1394b, but they are all keyed, ensuring consumers will properly connect 1394/a, 1394b and bi-lingual devices within the network.

Firewire supports isochronous and asynchronous data transfers. The isochronous transfers are much like USB - continuously streaming data, such as video - which is Firewire's hallmark. Isochronous transfer bandwidth is guaranteed by the root node, providing up to 80% of the available bus. Asynchronous transfers are for bus control and device arbitration, as well as non-time-sensitive data such as disk drives and printers. Hot-plugging a device into the network will cause the bus to initiate a reset cycle for re-configuration, but current transfers already taking place will not be interrupted.

USB and Firewire: Their market performance, coexistence, and competition

USB has established itself as the most popular PC connectivity solution ever. There are well over 1.1 billion USB-enabled PCs, peripherals and consumer electronics in the consumer base today.[1] Most of these are USB 1.x products, but with 2.0 taking root, and OTG on the horizon, USB will continue to grow and enjoy immense popularity. By mid-2004, about half of all PC peripherals sold will be USB.[2] No longer can Firewire proponents scoff at USB as being inadequate for streaming digital video or data storage. Now with OTG becoming a reality, Firewire proponents can no longer scoff at USB needing a PC to hold its hand. Does this mean that the dominant player in PC peripherals has enough ammunition to play in Firewire's backyard? Yes, but only to a point.

It may seem that USB has caught up to Firewire to some degree, but Firewire is not resting on its laurels. Release of 800 Mbit/s 1394b production silicon is imminent, which

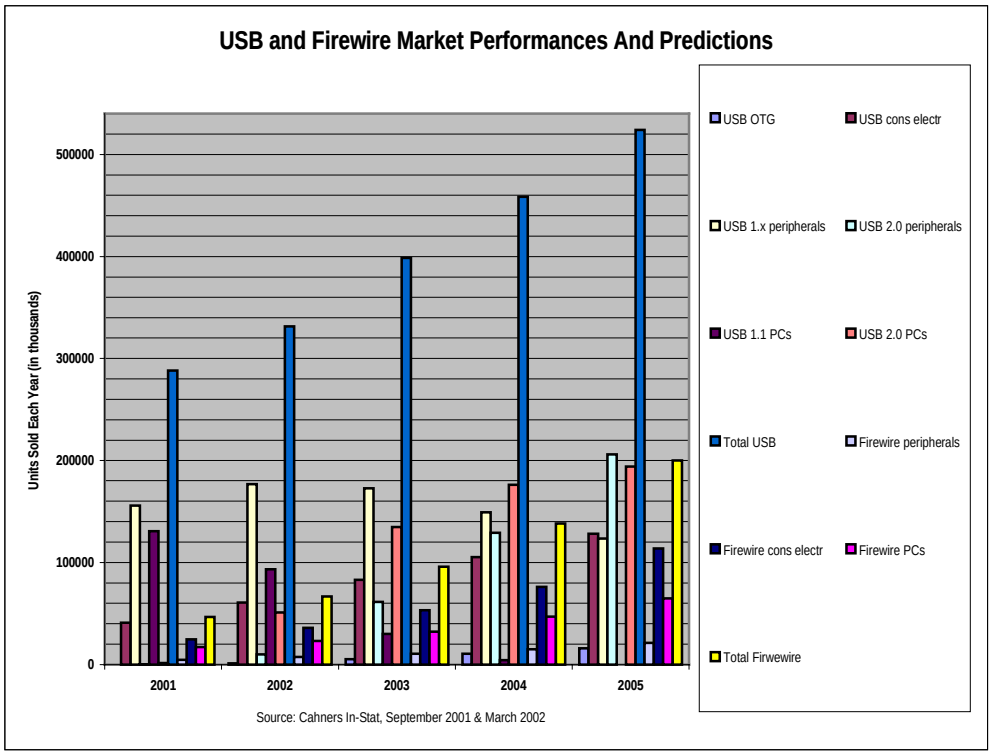

Fig. 4: Chart of USB and FireWire Units Sold and Predicted By Year

will open up more markets. Firewire can soon start to push into home networks, RAID systems and storage networking. However, there is one laurel that Firewire can definitely rest on: The digital camcorder market. Across all brands it has become the standalone connectivity standard for the camcorder's streaming video. It has also succeeded well in PC peripheral data storage and Sony's Playstation II.[3] In the home-networking market, Firewire will gain a lot of popularity in set-top boxes, DTVs and DVD recorders.[4]

Current total consumer purchases of USB devices outpace Firewire by approximately 5:1. That ratio is expected to change to about 4:1 by the end of 2003 and 3:1 by the end of 2004. However, this statistic is mostly an indicator of each standard carving out its own niche, rather than being a measure of competitive results. Cahners' In-Stat shows market performance and predictions for each standard in Fig. 4 and the following Table is a side-by-side comparison and contrast of the two standards.

USB and Firewire Specification Comparison					
	1394/1394a	USB 1.x	1394b	USB 2.0	USB OTG
original purpose	high bandwidth consumer electronics, esp. digital video	low to medium bandwidth PC peripherals	high bandwidth, home networking	high bandwidth peripherals and consumer electronics	point-to-point communication for portable devices
network topology	peer-to-peer, dasiy chained	PC-centric host-peripheral	peer-to-peer, dasiy chained	PC-centric host-peripheral	host-peripheral, peer-to-peer like
serial or parallel	serial	serial	serial	serial	serial
bandwidths (Mbps)	100, 200, 400	1.5, 12	800 now, 1600 and 3200 in future	480	1.5, 12, (480 optional)
max # devices connected	63	127	63	127	127
supervised/ unsupervised?	unsupervised	supervised	unsupervised	supervised	supervised
signalling	DC level unencoded, data is unidirectional	DC level unencoded, unidirectional	Hybrid 8B/10B encoding, full duplex	DC level unencoded, unidirectional	DC level unencoded, unidirectional
transfer types	iso, async	iso, bulk, interrupt, control	iso, async	iso, bulk, interrupt, control	iso, bulk, interrupt, control
iosochronous bandwdth guarantee	80%	90%	80%	90%	90%
bandwidth allocation	negotiated at beginning of each transfer	host controlled and predicted	set for each device when connected to network	host controlled and predicted	host controlled and predicted
hot-pluggable	yes	yes	yes	yes	yes
plug and play	yes	yes	yes	yes	yes
media	proprietary	proprietary	proprietary, CAT5, optical fiber	proprietary	proprietary
max cable run lengths (meters)	4.5	USB 1.0 : 3 USB 1.1 : 4	up to 100 for CAT5 and glass fiber	5	4
bus-powered devices?	yes w/ 6 ckt cable, no w/ 4 ckt cable	yes	yes, but media dependent	yes	yes
max bus current (mA)	1500 (@ 8-40V)	500	1500 (@8-30V)	500	8 minimum
# cable types	3	3	5 for proprietary media, more for other media	3	6 and 2 adapters
keyed connectors	yes	yes	yes	yes	yes
silicon cost	comparible to USB 2.0	< 5$	$10+	comparible to 1394a	< 5$
availablility to consumer	1394: 1995 1394a: 2000	1995	Q4-2002	Q2-2001	Q4-2002

Each standard does well in areas that the other was never intended to work with, but they have leveraged their successes and innovations to edge into each other's market. It all started in April of 2000 when the USB-IF ratified High-Speed USB 2.0. Interestingly enough it was theoretically 20% faster than Firewire 1394a, fast enough to make the market notice. However, Firewire was already established in the market place with 20 million enabled devices, including over 5 million camcorders and 10 million PCs.[6] It enjoyed native driver support from Windows 2000, and Microsoft announced in April of 2001 that it would continue to support Firewire in their Windows XP release. At the same time came the news that Microsoft would not initially support USB 2.0. The USB silicon was not yet ready to be shipped with PCs. Meanwhile, Firewire continued to gain audio/video and PC storage market share because of its peer-to-peer abilities and blazing speed. The USB-IF had to wait until February 2002, when Microsoft announced their release of the USB 2.0 service pack, which was one month after Gateway announced the

industry's first USB 2.0-equipped PC. To USB's benefit, 2.0 silicon came in at about the same price as 1394a. However, 1394a was first to market and the number of PCs equipped with it was significantly larger than those with USB 2.0.[7] Nevertheless, with the backward compatibility to the installed 1.x base in its favor, the prediction is that USB 2.0 will catch 1394 in PC shipments in early 2003, and it will then far surpass 1394 in the following years.[8] In the thick of this unfolding drama, the IEEE's 1394 TA was coming out with its own improvement, namely IEEE 1394b. This standard was ratified by the IEEE in April 2002, opening up new markets, as discussed earlier.

Originally USB was never intended for high-bandwidth applications such as streaming digital video or high-bandwidth PC storage. It was also never intended to exist apart from the PC, as USB OTG does now. Firewire was never intended to cater to low- to medium-bandwidth applications such as mice, keyboards, scanners and printers. Anyway, because of their initially different intentions, the niches they have carved out in the marketplace make it tough for the other to break in. For instance, no digital camcorder sold today has a USB 2.0 interface for uncompressed streaming video, even though silicon has been available for over a year. This is because all the camcorder designers gave the 1394a silicon access to the internal video data bus. Giving USB 2.0 access to this bus would involve a redesign that the manufacturers aren't convinced is necessary.[9] Will USB-OTG, with its peer-to-peer like qualities, break into the audio/video market dominated by Firewire? Not really. Firewire has a strong lock on this area and USB OTG's specifications are primarily suited for portable device data exchange anyway.

Firewire 1394b will, however, have competition in the home networking market but it won't be from USB. Its competitors will be HomePNA, Wireless 802.11 and Ethernet. While each network meets different specific needs for the consumer, 1394b's blazing speed, its isochronous audio/video transfers, long cable runs and peer-to-peer operability make it quite attractive (note: Gigabit Ethernet does not support isochronous transfers.) Conversely, many multimedia companies are rightfully concerned about copyright protection of digital video. These issues are being addressed in part by the 1394 TA. Firewire will eventually carve out its niche among the competition, and imagine its ability to network a home entertainment system, storage network and home office (including PC), at 800 Mbit/s?

One notable arena in the PC peripherals category where USB 2.0 and Firewire duke it out directly is PC data storage. USB 1.1 was inadequate for moving large amounts of data in a timely manner, allowing 1394a with its 400 Mbit/s to enjoy first-to-market successes. Now, USB 2.0 storage devices are becoming popular and are about the same price to the consumer (or even 5% cheaper.) Cahners' In-Stat predicts that sales in USB storage will overtake Firewire storage in 2003, potentially shipping double that of Firewire by end of 2005.[10] This, of course, will be aided by the proliferation of USB 2.0 hosts on PCs.

A second arena of competition, which is in the consumer electronics category, is for the digital camera interface. Again, Firewire's 400 Mbit/s gave it more market share than USB's traditional 12 Mbit/s. Even with USB-enabled cameras transitioning to the 2.0 standard, Firewire will still lead the charge in this market through 2005.[11]

In the end, USB and Firewire will continue to claim their rightful places as PC-based and/or consumer electronics I/O. Even though these relatives of the serial bus compete in some arenas, they generally address different market needs. USB has proliferated throughout the PC environment and will grow even more popular as it leverages its dominance of low- to medium-bandwidth applications. Firewire is established as the consumer electronics connectivity of choice and consumers love its true peer-to-peer capabilities. In the near future it is the differences in USB and Firewire that will continue to be their collective asset - it will be the reason for their largely peaceful coexistence.

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Biography

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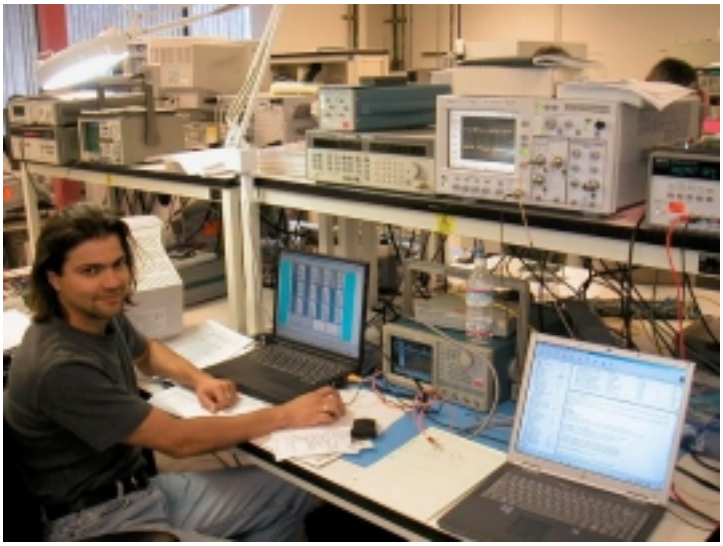
Mr. Faris earned a BEE in Electrical Engineering at Michigan State University in 1997 and from 1997–1999 he worked in the Radar Design Lab. at Raytheon Electronics. There he developed hardware for radar control systems for the Army. From 1999–2001 he worked for Unique Electronics as an FAE specializing in programmable logic.



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