Software Architects Inc.

White Paper

The Universal Disk Format
UDF

UDF White Paper
06 August 1998

Data interchange independent of hardware platforms, operating systems or software. Pipe dreams or reality? In September 1995, the Optical Storage Technology Association (OSTA), published specifications for a read/write file system known as Universal Disk Format (UDF), designed to be a single file system interchange standard for computer-based applications. An implementation of the International Standards Organization (ISO) interchange standard for non-sequential recording of data (ISO 13346), UDF was engineered to make optical storage solutions independent of the data system.

UDF is OSTA's response to the need in the optical storage industry for a practical, fully compliant implementation subset of the ISO 13346 standard. Correctly implemented, UDF represents a means of reducing the time required to develop compliant products, while promoting reliable, economically competitive data storage and retrieval.

UDF and DVD

The relevance of UDF was quickly recognized by the major electronics manufacturers developing digital video disks (DVDs). UDF appeared to be ideally-suited to facilitate information interchange between read-only, write-once and rewritable optical drives, while enabling cross-compatibility between TV and computer-based applications. DVDs incorporating UDF were seen as the most effective way to enable home entertainment systems to become integrated with personal computers—a level of compatibility unachievable with proprietary-based solutions.

Do We Need UDF?

While the significance of UDF is readily seen, understanding the intricacies of its successful implementation cannot be understated. The ISO-9660 file system, as a read-only implementation, assured first generation CD-ROM interchange across multiple operating systems, but it proved inadequate for the second generation of recordable, rewritable, high-capacity disks, including DVD. As the computer and entertainment industry has evolved over the years, the similarities and differences between each has become apparent. Each relies on the ability to access, store and disseminate information. Yet, each developed its own unique ways to accomplish this, sometimes resulting in fragmentation within their own industry—Betamax and VHS for example in the entertainment industry; phase-change and magneto-optical within the optical storage industry. All viable solutions, yet each incompatible with the other. The result is market segmentation, not unification.

The process of transferring files from one format to another is fraught with problems. Certain file attributes inherent to one platform or format might prove incompatible with another. UDF, as a specification for a file system, is designed to provide universal access to foreign files regardless of their origin without loss to any of their original attributes. File name, file size, the number of data streams, and volume size are a few of the attributes defined by a file system. The goal of the UDF is to provide a file system that can handle all the attributes of common file systems both today and in the future.

A collaborative effort between OSTA and the DVD Forum produced the Video specification for DVD disks. This specification was based on the 1.0.2 version of UDF and enforces certain restrictions on the file system. These restrictions detail the format of the video and audio data.

The Evolution of File System Standards

PRODUCT EVOL
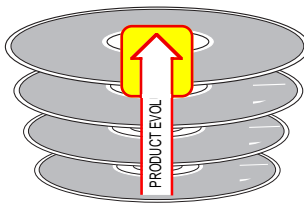
UDF - *read/write* (CD, CD-R, DVD, CD-RW, MO, PD...)

UDF/ISO 9660 - *read/write* (CD, CD-R, CD-RW)

DVD Video Specification/ISO 9660 - *read-only* (CD-R, DVD)

ISO-9660 - *read-only* (CD, CD-R)

CD-UDF provides a "bridge" from the current ISO-9660 specification used on today's CD-ROMs and the UDF file system. This hybrid format will allow recordable disks to have upward compatibility from the ISO-9660 standard to the UDF standards for both installed base and future implementations. CD-UDF's support of the ISO-9660 standard ensures backward compatibility with an installed base of CD-ROMs reportedly exceeding 50 million.

Using CD-UDF, disks can be mastered that both DVD and CD-ROM drives can read, while supporting the write capabilities of CD-R and DVD-R disks. It should be noted that because of a physical limitation the laser used for DVD records at an incompatible frequency for writing to CD-R media.

The UDF specification version 1.5 addresses the requirements of sequential recorded media such as CD-R, CD-RW, and DVD-R. The 1.5 specification dictates extra information to be recorded to the media, such as the Virtual Allocation Table (VAT) and possibly the Sparing Table.

In addition to ISO-9660, CD-UDF will provide support for Macintosh HFS, DOS FAT, and other proprietary file systems. This will allow providers to master a disk that can be read not only by the CD-UDF file system, but any other file systems as well. CD-UDF is engineered to support both multi-session and packet writing recording.

Specifications and Features of UDF

Large capacity - A UDF-compliant file system will be able to store more data (exceeding the terabyte level), and a larger number of files than current operating systems. This expanded storage space allotment enables UDF to be usable by all current operating systems.

Efficient space allocation - UDF supports volume sizes greater than the size allowed by the original operating system. Small files written to a UDF disk would not take up extra space. e.g.: A 512 byte file on a 2 GB Macintosh HFS volume takes up 32KB of space. The same file on an optical disk formatted with UDF would only take up 512 bytes.

Use of the UniCode character set - By supporting UniCode—a character set comprised of 65,536 possible characters—UDF supports characters from multiple languages including double-byte character sets like Japanese. In comparison, the most commonly used character set today is ASCII which has a limit of 256. UniCode support provides for easy adoption of multiple programming languages for cost-effective global implementation.

File names up to 255 characters - UDF supports all current naming conventions. File names will not have to be truncated when accessed outside their native operating system.

Retention of extended file system attributes - This feature permits flexible multiple Operating System mastering capabilities without compromising the integrity of the originating Operating System.

Multiple volume set support - The UDF file system can handle multiple volume sets allowing users to take advantage of the performance gains and increased storage space obtained through spanning multiple disks.

System-independent archival medium - Adherence to the UDF specification ensures data access regardless of future operating system implementations.

Maximum volume size - As high as 128 terabytes.

Maximum file size - Equal to the size of the volume.

Maximum length of file name - 255 characters.

DVD represents a unification of the Multi-Media CD (MMCD) proposal authored by Sony and Philips, and the Super Disc (SD) proposal penned by Toshiba, Time Warner and an alliance of other manufacturers.

DVD Media - This is the physical medium to which the data is stored. It is defined to be the same dimensions as a CD disk, but has other characteristics that are a big improvement over CD disks. The most notable improvement is that storage capacity, rather than 650 MB for a CD-ROM disc, can range from 4.7GB up to 17GB for DVD media.

Media Format	Capacity
Single-Sided, Single-Layer	4.7GB
Single-Sided, Double-Layer	8.5GB
Double-Sided, Single-Layer	9.4GB
Double-Sided, Double-Layer	17GB
DVD-R	3.8GB/side
DVD-RAM	2.6GB/side
DVD-Video (Single-Sided, Single-Layer)	133 minutes of video *

* Using MPEG2 compression. Can have 3 audio language tracks and multiple language subtitles.

DVD media is more durable than CD media. The layer that is written to is sandwiched between two clear layers. With current CD media the layer written to is on one side. This gives two direct benefits.
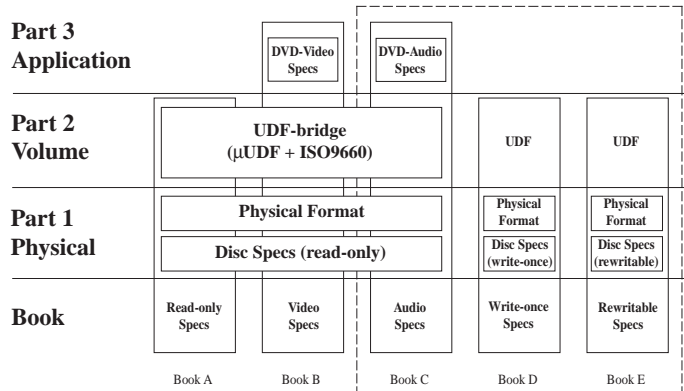
1. The data layer is more protected against scratching.

2. DVD media is symmetric and will resist warping due to heat and other environmental factors much better than CD media.

Sustained Data Transfer Rate
DVD-ROM : 1,350 KB/sec.

DVD Format Specifications

DVD Format Specs

	Book A	Book B	Book C	Book D	Book E
Part 3 Application		DVD-Video Specs	DVD-Audio Specs		
Part 2 Volume	UDF-bridge (μUDF + ISO9660)			UDF	UDF
Part 1 Physical	Physical Format			Physical Format	Physical Format
	Disc Specs (read-only)			Disc Specs (write-once)	Disc Specs (rewritable)
Book	Read-only Specs	Video Specs	Audio Specs	Write-once Specs	Rewritable Specs

Book A - DVD-ROM (Read Only) - Lead by Toshiba
Book B - DVD-Video (Read Only)
Book C - DVD-Audio (Read Only)
Book D - DVD-WO (Write Once) - Lead by Pioneer
Book E - DVD-RAM - (Read/Write) - Lead by Hitachi

Drive/Media Compatibility

This chart shows which drives are physically able to read which form of media—the first and most important step in determining drive/media interchange compatibility.

			Media			
Drive		CD	CD-R	CD-RW	DVD-ROM	DVD-R	DVD-RAM
	CD [with MultiRead]	R	R	- [R]	-	-	-
	CD-R [with MultiRead]	R	R/W	- [R]	-	-	-
	CD-RW	R	R/W	R/W	-	-	-
	DVD-ROM	R	R	R	R	R	R†
	DVD-R	R	R	R	R	R/W	R
	DVD-RAM	R	R	R	R	R	R/W

† Future Support

File System/Media Compatibility
This chart illustrates the standard and compatible file system implementations and corresponding media types.

File System

	ISO 9660	UDF
CD-ROM	S	C
CD-ROM	S	C
CD-R/W	C	S
DVD-ROM	C	S
DVD-R	C	S
DVD-RAM	C	S

Media

S = Standard Useage
C = Compatible
The current version of UDF is 2.0

To maintain the maximum forward and backward compatibility between different implementations of DVD, it is important to consider all aspects of DVD: the media, the drive, and the file system. If one manufacturer claims that they are compatible because they are using the UDF file system yet put it on non-standard media, the media may not be readable on another manufacturer's drive.

The goals of UDF is to create a means of data interchange that is platform-, operating system-, and content-independent. Proprietary implementations of parts of the UDF or DVD technologies are counterproductive to these goals. Solutions that work towards the goals of UDF to provide the highest level of compatibility will be usable by the largest potential market.

Architects of the Standard
One company that has been a part of the evolution of UDF since its inception, is Software Architects, Inc. (SAI) of Bothell, Washington. Software Architects' introduction to the technology that would ultimately become UDF began in 1991 while collaborating with Hewlett-Packard on non-sequential recording on optical media.

In June of 1996, Software Architects announced the release of Write UDF!™, an updatable file system providing complete read/write support of the Universal Disk Format. Write UDF! represents the first in a family of products to deliver UDF support. Using Write UDF!, users can

format a disk in a UDF format from a Macintosh or Windows-based PC and transfer files to and from this disk. This universal disk could then be used to backup files onto a common format readable by either computer without losing any of the Native operating system file attributes. File names would not be changed, the Mac's data fork and resource fork would be intact, and the file extension or Type and Creator would be preserved so that either operating system would recognize what type of file was stored. Write UDF! supports all forms of block addressable, rewritable media including fixed and removable hard drives, rewritable optical including magneto-optical, phase-change and Phase-Dual (PD), as well as Syquest, Iomega, and Bernoulli disks.

Software Architects has followed up the inital release with a full native file system under Windows 95. Users are able to read and write to their drive in a UDF format without using any special applications or utilities. Files can simply be dragged to and from the disk using standard windows protocols.

Software Architects continues to broaden its support of UDF and will be announcing support for more operating systems in the near future.

Both Microsoft and Apple have released a UDF file system with their latest operating systems, Windows 98 and Mac OS 8.1 respectively. Unfortunately, these implementations are read-only and can not support new drives, such as the DVD-RAM drives.

For more information on DVD, UDF and Software Architects' complete line of UDF-compliant solutions including Write DVD!, Format UDF!, and Write UDF! contact Rich Vasse, Vice President of Engineering (richv@softarch.com), at Software Architects, Inc. (425) 487-0122.

About Software Architects, Inc.
As a member of OSTA's Board of Directors and an active participant of OSTA's Technical Committee, Software Architects has been involved with UDF since its inception. "Software Architects has been developing file system technology for file interchange using optical media since 1991," said Bob Zollo, president of Software Architects, Inc. "The combined efforts of the DVD Forum, OSTA and key computer OEMs to adopt a single file system standard will accelerate the adoption of DVD technology in the consumer and computer industries." Mr. Zollo continues, "Customers of both product categories will receive better performance and value, and will be assured of having their investment in content protected for future use in these new DVD devices as a result of these efforts."

About OSTA
The Optical Storage Technology Association (OSTA), a non-profit organization, was incorporated as an international trade association in 1992 to promote the use of writable optical technologies and products for storage of computer data. The organization's membership, comprising optical product manufacturers from three continents and representing more than 70 percent of worldwide writable optical product shipments, works to shape the future of the industry through regular meetings of CD-R, market development, planning and technical committees. Interested companies worldwide are invited to join the organization and participate in its programs by contacting an OSTA representative at (805) 963-3853.

About the DVD Forum
The DVD Forum is a consortium of computer and electronic manufacturers as well as key members in the entertainment industry formed to facilitate the exchange and dissemination of technical information concerning the DVD Format in order to encourage the broad acceptance of hardware and software using the DVD Format. Members include Hitachi. Ltd., Matsushita Electric Industrial Co. Ltd., Mitsubishi Electric Corporation, Pioneer Electronic Corporation, Sony Corporation, Thomson Multimedia, Time Warner, Inc., Toshiba Corporation and Victor Company of Japan, Limited.

Glossary of Terms

API	Application Program Interface. This is a code module or set of modules that other programs can make calls to or "ask to perform specific functions."
CD	Compact Disk. A media that uses a single track, like phongraph records. This layout of data makes random access of data take longer, this is commonly referred to as a long seek time. CD's have a capacity of 640MB.
CD-R	Compact Disk, Recordable. A technology defining a way for CD media to be written to once. CD-R media looks almost like a standard CD. CD-R drives have the ability to write to CDR media. Capacity of 640MB.
CDR-RW	Improves upon CD-R. Drives that support CDR-RW can write packets of data to the media minimizing over-run problems. To avoid over-run with standard CD-R media, data must be streamed to the drive at a constant rate, any interuptions will mean that the whole batch failed.
CD-UDF	See UDF-bridge.
DVD	This is a standard for a type of optical media that will use the UDF file system. DVD disk will look a lot like CD's, but they will be a disk layed out in sectors to allow for "true" random access of the data. "Seek" times will improve greatly when searching for the correct file to read. (See CD.) Capacities for single sided is 4.7GB's for single layer and 8.5GB's for dual-layer disks. Capacities for double sided is 9.4GB's for single layer and 17GB's for dual-layer disks.
DVD Forum	A collection of organizations that contributed to the DVD definition. Members include Hitachi Ltd., Matsushita Electric Industrial Co. Ltd., Mitsubishi Electric Corporation, Pioneer Electric Corporation, Sony Corporation, Thomson Multimedia, Time Warner, Inc., Toshiba Corporation, and Victor Company of Japan Ltd.
DVD-RAM	This is true Read/Write media. Data can be over-written on the media without erasing it first. DVD RAM will use a technology based on Phase Change technology. (Capacity of approx. 2.8GB)
DVD-R	DVD Recordable. Same write once concepts as CD-R but with the benefits of DVD media. Single-sided, single-layer media capacity of approx. 3.6GB)
ECMA 167	A predecessor to the ISO 13346 Specification.
File System	An "organized" defined way to store and catalog files on a disk. A file system is used by the computer to find and store files.
Fork	As in resource-fork and data-fork. Essentially a separate sub-file of the actual total file. At a low level each fork is actually a separate file. This allows a separation between different types of information that can be grouped together and accessed by just looking at "one file". The Mac uses two forks for each file. Windows NT can have many "data-forks" for each file.
ISO-13346	International Standards Organization spec # 13346. This is a set of standards that OSTA looked at and pulled from to develop UDF.
ISO-9660	A file system that has been used for CD's to provide a standard that Mac's, PC's, and Unix machines could read. ISO 9660 is inadaquate for the higher capacity record-able and erasable DVDs.
Magneto Optical	A technology for optical storage that depends on a laser and a magnet. The magnet of the drive head reads the media and writes to the media. The laser heats the area to be written to, to a high enough temperature so that the magnetic polarity of the area can be changed.

MMCD	MultiMedia CD. Sony's term for their DVD disks.
MPEG2	Moving Picture Experts Group. The second set of flexible compression standards created by this group is called MPEG2. This set of standards takes advantage of the fact that over 95% of digital video is redundant, however some portions are much less redundant. MPEG2 handles this by using higher bit rates for more complex pictures and lower bit rates for simple pictures. With MPEG2 only about 4 or 5 minutes (depending on quality) of video would fit on a 4.7GB DVD.
Native	As in Native file system or PowerMac Native. This term is used to refer to the specific machines standard way of doing something. The Native file system of a operating system is the file system that the operating system has built in.
OSTA	Optical Storage Technology Association. OSTA is a non-profit organization, incorporated as an international trade association in 1992 to promote the use of writable optical technologies and products for storage of computer data. OSTA played a large role in defining UDF. They hold the trademark for UDF. OSTA does not create standards, but it helps the optical storage industry define practical implementations of standards to assure compatibility of resulting products.
Packets	In this glossary, packets refers to a small chunk of data (about 16KB) as opposed to the complete set of data that can be up to the size of the media being written to (CD's hold 640MB)
Phase-Change	A technology for optical storage that only depends on the laser light. (As opposed to Magneto Optical.) Drives that use this technology do not need a magnet. The media shifts the "phase" of the laser light when reading and the laser changes the media to reflect the laser differently when writing.
Seek Time	This refers to the amount of time it takes to find the correct position on storage media so that data can start to be read.
TWG	Technical Working Group. Comprised of Hewlett-Packard, Compaq Computer, Apple Computer, Kodak, IBM, and Microsoft Corporation. These companies established the basic requirements of DVD. The requirements include: single interchange standard; backward read compatibility with existing CDs; forward compatibility with future read/write and write-once discs; single file system for all disc types; low cost; no mandatory container; reliable data storage and retrieval; high on-line capacity; and high performance for sequential and non-sequential data.
UDF	Universal Disk Format. A spec for a file system that OSTA had a big part in outlining. This file system was designed to be able to handle files from all other common file systems (computers). i.e. It can handle Mac resource forks and Windows95 long file names. UDF was also defined to be able to be enhanced for future systems. NSR ECMA 167 and ISO 13346 are predecessors to UDF.
UDF-bridge	Allows a link between ISO 9660 and UDF. Using UDF Bridge one copy of a set of data can be put on a piece of media and both ISSO 9660 compatible readers and UDF readers will be able to access the information. Also known as CD-UDF or CD-RW.
Write UDF!™	This is SAI's implementation of the UDF file system specification. It is the only implementation that we know about that is available today that can be used on personal computers. It is designed as an "API" and we have applications to demonstrate its capabilities. The applications allow the user to exchange files between the computers native file system and UDF. (Some native file systems are HFS (Mac), FAT (DOS, Windows).) The volume and file size maximum capacity is currently 4GB, although larger capacities are currently under constuction.
Write DVD!™	This is SAI's implementation for Windows 95/98 native file system. User's can use standard O/S protocol, such as the explorer to access a disk formatted in the UDF format..