DVD Technology Seminar Notes

Douglas Dixon
Manifest Technology® LLC

May 2005

www.manifest-tech.com

DVD Technology

- **DVD Technology**
  - Recordable formats
- **DVD-Video Format**
  - File structure, Directory structure, Data streams
  - Video formats, Aspect ratios, Audio formats, Subtitles
  - Navigation
- **DVD Content Protection**
  - Copy protection, analog & digital, Copy management
  - Regional codes, Parental management
- **DVD-Video Internals**
  - Title hierarchy, Navigation commands

Recordable DVD Formats

- **DVD-R**
  - Organic dye technology, like CD-R
  - Compatible with most DVD drives and players
  - DVD-R(G) – General - intended for home use
  - Cheaper 650-nm laser, same as DVD-RAM
  - DVD-R(A) - Authoring - intended for professional development - 635-nm laser
- **DVD-RW**
  - Phase-change erasable format
  - Can be rewritten about 1,000 times
- **DVD-RAM**
  - Phase-change dual (PD) technology with some magneto-optic (MO) features
    - Defect management and zoned CLV format for rapid access.
  - Not compatible with most drives and players
  - Single-sided with or without cartridges (must use for write)
    - Type 1 cartridges sealed, type 2 allows disc to be removed
  - Can be rewritten more than 100,000 times
- **DVD+RW and DVD+R**
  - DVD+R – Dye-based medium, like DVD-R
  - DVD+RW – Erasable phase-change format based on CD-RW technology
  - Allows for CLV for sequential video access or CAV for random access
    - Only CLV can be read in standard DVD drives, DVD+R record only in CLV

DVD-Video – Summary

- **DVD-Video**
  - Up to 9 video streams
  - Up to 8 audio streams
  - Up to 32 subtitle (subpicture) streams
- **Video**
  - Up to NTSC 720x480, 29.97 fps; or PAL 720x576, 25 fps
  - MPEG-2, MPEG-1 compression
- **Audio**
  - Multi-channel, surround
  - Uncompressed PCM
  - Dolby Digital (AC-3), MPEG
  - DTS, SDDS optional

DVD File Structure

- **File Systems**
  - ISO-9660 – CD-ROM file system
  - UDF – Universal Disc Format) – DVD file system used for (condensed micro-UDF)
  - UDF Bridge – ISO-9660 for CD and micro-UDF for DVD, backward compatibility
- **DVD Folders**
  - DVD Volume – DVD disc directory structure and files
    - Video Object (VOB) files with actual multimedia data, video and audio
    - Associated navigation information (IFO) and backup (BUP) files that describe contents
    - Created for each Video Title Set (VTS), split into multiple VOB files no larger than 1GB
  - VIDEO_TS – Root directory of DVD-Video production stored on a DVD disc
  - AUDIO_TS – Root directory of DVD-Audio production stored on a DVD disc
- **DVD Files**
  - VTS files – Video Title Set – Video contents (VOB) and navigational info (IFO)
  - IFO file – Navigation information file for a title set
  - BUP file – Backup for the IFO navigation file of a title set
  - Video Object (VOB) – MPEG program stream
    Includes multiplexed video, audio, subpictures, and control information.
  - VOB file – Video Object file – Video clips (VRO recorders, fragmented)
  - DAT file –Video data file on Video CD disc. Contains MPEG-1 video

DVD Directory Structure

- **Optional main menu**
- **Up to 99 titles (Video Title Set) - each with main menu**

- **VIDEO_TS** **Video zone - DVD-Video**
  Main Menu

VIDEO_TS.IFO	Main menu information Video Manager Information (VMGI) Video Manager Title Set (VMTS)
VIDEO_TS.VOB	Video Manager (VMG) menu
VIDEO_TS.BUP	Backup of IFO file (VMGI)
	VTS Menu
VTS_tt_0.IFO/.BUP	Video Title Set Information (VTSI) - VTS Menu
VTS_tt_0.VOB	Video Objects (VOB) - VTS Menu
	Title Sets (01 - 99)
VTS_tt_n.IFO/.BUP	Video Title Set Information (VTSI)
VTS_tt_n.VOB	Video Objects (VOB) - 1 - 9 per title set

- **AUDIO_TS** **DVD-Audio**
- **DVD_RTAV** **Recording**
- **JACKET_P** **Jacket Picture**

DVD Data Streams

- **Overall maximum bit rate - 10.08 Mbps, including control information**
- **Maximum stream bit rate - 9.8 Mbps for video, audio and subpictures**
- **Average video bit rate - 4.7 Mbps, for 133 minute playing time**
- **Stream Types**

Data type	#Streams	Max rate (Mbps)	Coding Format
Video	1	9.8	MPEG-1 or MPEG-2, including stills
Audio	8 max	6.144	Dolby Digital, MPEG, LPCM etc
Subpictures	32 max	3.360	2 bits/pixel run length encoded
Still pictures			
Navigation	1	-	Program Chains (PGCs) for interactivity

Video - MPEG-1 or MPEG-2 - standard MPEG elementary stream
Audio - MPEG-1 or MPEG-2 - standard MPEG elementary stream
PCI & DCI - MPEG private stream
Subpicture and all other audio - MPEG private streams

- **Stream Rates**

Stream type	Min Rate	Typical	Max Data Rate (Kbps)
MPEG-2 video	~1500	3500	9800
MPEG-1 video	~900	1150	1856
PCM audio	786	1536	6144
Dolby digital	64	384	448
MPEG-1 audio	64	192	384
MPEG-2 audio	64	384	912

DVD-Video – Video Formats

- **Maximum dimensions**
  - 720x480 (525/60 NTSC) or 720x576 (625/50 PAL/SECAM)
- **Allowable picture resolutions:**
  - MPEG-2, 525/60 (NTSC): 720x480, 704x480, 352x480, 352x240
  - MPEG-2, 625/50 (PAL): 720x576, 704x576, 352x576, 352x288
  - MPEG-1, 525/60 (NTSC): 352x240
  - MPEG-1, 625/50 (PAL): 352x288

- **MPEG-2 maximum video bit rate 9.8 Mbps**
  Typical video bit rate around 4 Mbps
- **MPEG-1 video rate limited to 1.856 Mbps**
  Typical video 1.15 Mbps

DVD Aspect Ratios

- **DVD Aspect Ratios**
  - Standard TV 4:3 (1.33)
  - Widescreen 16:9 (1.78)
- **DVD Playback Modes – one for 4:3 video and three for 16:9 video**
  - Full frame (4:3 video for 4:3 display)
  - Auto letterbox (16:9 anamorphic video for 4:3 display)
  - Auto pan & scan (16:9 anamorphic video for 4:3 display)
  - Widescreen (16:9 anamorphic video for 16:9 display)
- **Anamorphic**
  - Stored squeezed horizontally to fit 4:3 rectangle
  - Unsqueezed during playback
- **Film**
  - Letterbox – Theatrical aspect - black bars, mattes at the top and bottom
  - Pan & scan - TV window pan and zoom across wider movie, crop sides
  - Most movies 1.66, 1.85 ("flat"), or 2.40 ("scope")
  - Most movies shot soft matte, full 1.33 aspect film frame
    (both 1.33 and 1.85 frame marks in viewfinder, allow for both formats

DVD-Video – Audio Formats

- **LPCM – Linear PCM – Pulse Code Modulation**
  - Uncompressed (lossless), 1 to 8 channels. Used for CD-Audio. Required
  - Sample rate 48 or 96 kHz; 16, 20, 24 bits (Audio CD to 44.1 kHz, 16 bits)
  - Bitrate 6.144 Mbps max
- **Dolby Digital – AC-3**
  - Multichannel surround-sound audio. Lossy. Required
  - Sample rate 48 kHz, up to 24 bits
  - Bitrate 64 to 448 kbps, 384 or 448 normal for 5.1, 192 for stereo
  - One to five full-range channels
    - ".1" for Low-Frequency Effects (LFE) channel, low bass sounds.
    - Front Left, Front Center, Front Right, Left Surround, Right Surround
- **MPEG audio – Moving Picture Experts Group**
  - Multichannel, digital audio. MPEG-1 and -2. Lossy. Required for PAL
  - Sample rate 48 kHz, 16 or 20 bits
  - Bitrate variable 32 to 912 kbps, normal average 384, MPEG-1 to 384 kbps
- **DTS – Digital Theater Systems**
  - Surround-sound. Used in movie theaters. Optional, sep. decoder
- **SDDS – Sony Dynamic Digital Sound**
  - Surround-sound. Used for cinemas. Optional, separate decoder

DVD-Video – Subtitles

- **DVD-Video – Subtitle / Subpicture Formats**
  - Up to 32 subpicture streams that overlay the video
  - Full-screen, run-length-encoded bitmaps, two bits per pixel
    four color values and four transparency values
  - Four colors from palette of 16, four transparency from 16 levels
    Reserved one for transparency (video show through), 3 left
  - Maximum data rate 3.36 Mbps, max size per frame 53220 bytes
  - Commands – Delay, scrolling, wipes & fades, animation
- **NTSC Closed Captions**
  - Closed Caption text stored in video stream as MPEG-2 user data
    (in packet headers)
  - Regenerated by player as line-21 analog waveform in video signal
  - Decoded by Closed Caption decoder in television

DVD Navigation

- **Title Menus**
  - Title (top) menu of title (in first VTS, with submenus)
  - Submenus:
    - Part of title (Chapter) submenu; Audio (Audio/language) submenu
    - Angle (Video angle) submenu; Subpicture (Subtitle/language) submenu
- **Remote Control Menu Keys**
  - "Title" of "Top" menu – Disc menu (VMGM, not current VTS)
  - "Menu" or Root or Digest menu – Local hierarchy (current VTSM)
  - "Return" or Go Up – Back/Prev to parent menu, or current title
- **Buttons**
  - Up to 36 rectangular buttons (18 / 12 for widescreen modes)
  - Highlight with subpictures - Color and opacity (can be invisible)
    Normal – Selected – Activated
  - Four directional links – Arrow keys
  - One command – Link, or to dummy PGC with more commands
  - Auto activate; Idle out – timeout – forced activation
- **User Operations (UOPs)**
  - Can restrict user's navigation options
  - Nested scope to disallow: Title, PGC, VOBU (PCI)

DVD Content Protection

- **Content Protection**
  - Copy protection, Copy management, encryption - Required
- **APS – Analog Protection System – Macrovision**
  - Distort video signal (AGC, colorburst) to prevent VCR copying
  - NTSC only, composite and s-video outputs. Required w/ CSS
- **CGMS – Copy Generation Management System**
  - Prevents initial copies or generational copies (copies of copies)
  - For recorders: Permitted copying: none, one, any number
- **CSS – Content Scrambling System**
  - Encrypt video, require authorized key
- **Regional Codes**
  - Authorize playback in 7 geographic locales or zones
- **Parental Management**
  - Block play, or alternate versions

Content Protection Requirements

- **Content protection system architecture**
  - Encryption, watermarking, protect analog and digital outputs
  - Guard against casual copying
    "keep the honest people honest“, can't stop well-equipped pirates
- **DVD Requirements**
  - Macrovision, CGMS, CSS, and CPPM optional for disc producer
    Don’t need to protect your content
  - CSS decryption optional for hardware and software playback products
    Don’t need to play protected content
  - DVD-ROM drives and computers must support Macrovision, CGMS, CSS
  - Establish a secure connection between drive and decoder hardware
  - CPRM handled automatically by DVD recorders, optional
  - PC video cards with TV outputs must support Macrovision
  - DTCP and HDCP handled by DVD players with digital video outputs
  - Computers with IEEE 1394/FireWire must support the final DCPS
  - Computers with HDMI (DVI) connections must support HDCP output

Content Protection Mechanisms

- **Content Protection for Recordable Media (CPRM)**
  - Ties recording to the media on which it is recorded
  - Supported by some DVD recorders, not by many DVD players
  - Blank recordable has a unique 64-bit media ID etched in BCA
  - Protected recorded content encrypted using media ID
- **Copy Generation Management System (CGMS)**
  - Equipment making copy must recognize and respect CGMS info
  - Analog standard (CGMS-A) encodes on NTSC line 21 or 20
    Most digital camcorders and some computer capture cards
  - Digital standard (CGMS-D) included in DTCP and HDMI
    for digital connections such as IEEE 1394/FireWire

Content Protection Mechanisms

- **Content Protection for Prerecorded Media (CPPM) – DVD-Audio**
  - Improvement to CSS
- **Digital Copy Protection System (DCPS)**
  - For next gen digital TVs, digital receivers, digital video recorders
  - Require new DVD players with digital connectors
  - Encryption done by the player, no changes to existing discs.
  - Five digital copy protection systems proposed to the CEA
- **High-Bandwidth Digital Content Protection (HDCP, DVI, and HDMI)**
  - HDCP similar to DTCP, designed for digital video monitor interfaces
  - Digital Visual Interface (DVI)
    - 4.95 Gbps, can support 1600×1200 (UXGA), all HDTV resolutions
  - HDCP / HDMI
    - Intel proposed HDCP as a security component for DVI
    - HDMI combines DVI and HDCP

DVD Regional Codes

- **Seven regions (aka locales or zones) assigned a number (cover marked with region number on world globe)**
  - 1: U.S., Canada, U.S. Territories
  - 2: Japan, Europe, South Africa, and Middle East (including Egypt)
  - 3: Southeast Asia and East Asia (including Hong Kong)
  - 4: Australia, New Zealand, Pacific Islands, Central America, Mexico, South America, Caribbean
  - 5: Eastern Europe (Former Soviet Union) Indian subcontinent, Africa, North Korea, Mongolia
  - 6: China
  - 7: Reserved
  - 8: Special international venues (airplanes, cruise ships, etc.)
- **Optional - one byte on the disc that the player checks**
  - Only DVD-Video, not DVD-Audio, DVD-ROM, or recordable DVD
- **All-region discs can be played on any player**
  - Manual code-switchable players, modify to "code-free" (all region)
  - Auto-switching players, “smart" discs programmed region code checking

DVD-Video Title Hierarchy

- **Disc Structure**
  - VMG — Video Manager (optional VTS)
  - VTS 1 [- n] — Video Title Sets (title)
  - Disc contains multiple Video Title Sets (VTS)
  - Optional first VMG title set - Main menu, title menu, top menu
- **Disc Hierarchy**

Video Title Set (VTS)	99 per disc	- Title, Tracks same format
Video Object Sets (VOBS)	99 per VTS	- For seamless branch
VOB	32767 per VOBS	- MPEG-2 program stream
Cell	255 per VOB	- Smallest address chunk
Video Object Units (VOBU)		- Smallest unit of playback
Pack (PCK)	2048 bytes	
Packet (PKT)		

DVD-Video Title Elements

- **Video Title Set (VTS)**
  - First VOBS can be optional root menu - VTSM
  - Contains title information: menu pointers, time maps, cell addresses, etc.
  - Applies to all titles in set- same number and format of tracks
- **Video Object Sets (VOBS)**
  - Group or interleave VOBs for seamless branching and camera angles
  - Contains attributes for video, audio, subpictures; Language codes
  - Same format: MPEG-1 or MPEG-2 video, NTSC or PAL TV system, aspect ratio Display mode letterbox, pan and scan, or both; 4:3 letterboxed
- **Video Object (VOB)**
  - All or part of an MPEG-2 program stream
  - Cells linked by Program Chains (PGCs) with programming instructions
- **Cell**
  - Smallest addressable chunk
  - Group of pictures or audio blocks, From 1 second to entire movie
- **Video Object Units (VOBU)**
  - Smallest unit of playback
  - Integer number of fields, 0.4 to 1 seconds - last to 1.2 seconds
  - Usually contains one GOP, can be zero or more
- **Pack (PCK)**
  - MPEG program stream, 2048 bytes
  - Stored in recording order, identify associated stream
  - Different packs for video, audio, subpicture, navigation

DVD Navigation Controls

- **Control**
  - Format (NTSC/PAL)
  - Language
  - Audio stream
  - Subpicture stream
  - Parental management
  - Karaoke
  - Display mode and aspect
- **Navigation**
  - General parameters
  - System parameters
  - Navigation timer
  - Buttons
- **PGCI Search (jump to menu)**
  - Title (disc menu - VMG)
  - Root (local menu - VTS)
  - Audio (Audio/language submenu)
  - Subpicture (Subtitle/language submenu)
  - Angle (Video angle submenu)
  - Part of title (Chapter submenu)
- **Presentation Data Search**
  - Title
  - Part of title (chapter)
  - Program (next/previous)
  - Time
  - Angle
  - VOBU (trick play)

DVD Navigation Commands

- **Max 128 commands, stored in table, index by number (can repeat)**
  - PGC – Pre-command(s); Cells (w/ one optional post) ...; Post-command(s)
  - Menu button - One command, stored in PCI
- **Links and jumps limited by the current and destination domains**
  - Cannot link directly between PGC or VTS in different domains
  - Use dummy PGCs in the VMGM as switching points
- **Programming commands**
  - Math operations: add, subtract, multipley, divide, modulo, random
  - Logical (bitwise) operations: and, or, xor
  - Comparisons: [not] equal, greater, less than [or equal to]
  - Register operations: load, move, swap; Program flow: goto, break
  - Video presentation control: link, jump, call, resume, exit
- **System Parameters (SPRMs)**
  - 24 system registers, 16-bit
  - Player state (read-only) - parental level, language code, ...
  - Player control (r/w) - video, audio, subpicture, angles; Countdown timer
- **General Parameters (GPRM)**
  - 16 general-use registers, 16-bit
  - Cleared on title search, title play, stop, eject, off

DVD Navigation - Presentation

- **Presentation Data Structure**
  - Logical hierarchy – Grouping of video sequences, playback order each video block
- **Presentation Data**
  - Menu (VMG) - or Autoplay PGC
  - Title 99 per disc
  - Parental Block (PB) Parental management
  - Program Chain (PGC) ... 999 / title, 16 / parental block
  - (Part of Title (PTT) 999 / title, 99 / one-seq.-PGC title
  - Program Chain Information (PGCI) ...
  - Program (PG) ... 99 / PGC – Groupings of Cells in VOBs
  - Cell pointers ... 255 / PGC
- **Title**
  - Monolithic - Play straight through; Multiple PGCs for varying program flow
  - Part-of-Title (PTT) marker - Chapter - Marker or branch point
- **Program Chains (PGC)**
  - PGCs control playback of Cells in VOBs
    - Video, audio and subtitles, display menus, respond to user commands
    - Different sequences through cells - reuse cells, seamless branching
  - First is Entry PGC – Title menu and each root menu
  - Dummy PGC - no Programs (no VOBs) - only navigation commands

For More Information

Manifest Technology®
www.manifest-tech.com

The Manifest Technology site by Douglas Dixon contains over 150 articles and technical references on multimedia technology, especially digital video editing and DVD authoring.