

APFS File System Format Reference Sheet

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 FOR518 - Mac and iOS Forensic Analysis & Incident Response - for518.com



Object Header (obj_phys_t)

Offset	Size (in bytes)	Field	Notes
0	8	o_cksum	Fletcher 64 Checksum
8	8	o_oid	Object ID
16	8	o_xid	Transaction ID
24	2	o_type.type	Object Type
26	2	o_type.flags	Object Flags
28	4	o_subtype	Object Subtype

Object Type (Hex)	Object Type (Dec)	Object Type/Subtype
0x0000	0	None
0x0100	1	Container Super Block
0x0200	2	B-Tree
0x0300	3	B-Tree Node
0x0500	5	Spaceman
0x0B00	11	Object Map (OMAP)
0x0D00	13	File System (Volume Super Block)
0x0E00	14	File System Tree

Container Super Block (nx_superblock_t)

Offset	Size (in bytes)	Field	Notes
32	4	magic "NXSB"	Container Magic Number: 0x4E585342 = "NXSB"
36	4	nx_block_size	Block Size (ie: 4096)
40	8	nx_block_count	Block Count (Block Count*Block Size = Container Size in Bytes)
48	8	nx_features	Features
56	8	nx_read_only_compatible_features	Read-only Compatible Features
64	8	nx_incompatible_features	Incompatible Features
72	16	nx_uuid	Container UUID (diskutil info /dev/disk#)
88	8	nx_next_oid	Next Object ID (OID)
96	8	nx_next_xid	Next Transaction ID (XID)
104	4	nx_xp_desc_blocks	Blocks used by Checkpoint Descriptor Area
108	4	nx_xp_data_blocks	Blocks used by Checkpoint Data Area
112	8	nx_xp_desc_base	Base address of Checkpoint Descriptor Area or Physical Object ID
120	8	nx_xp_data_base	Base address of Checkpoint Data Area or Physical Object ID
128	4	nx_xp_desc_next	Next Index for Checkpoint Descriptor Area
132	4	nx_xp_data_next	Next Index for Checkpoint Data Area
136	4	nx_xp_desc_index	Index for first item in Checkpoint Descriptor Area
140	4	nx_xp_desc_len	Number of blocks in Checkpoint Descriptor Area Used
144	4	nx_xp_data_index	Index for first item in Checkpoint Data Area
148	4	nx_xp_data_len	Number of blocks in Checkpoint Data Area Used
152	8	nx_spaceman_oid	Space Manager Object ID (OID)
160	8	nx_omap_oid	Container Object Map Object ID (OID)
168	8	nx_reaper_oid	Reaper Object ID (OID)
176	4	nx_test_type	Reserved for Testing
180	4	nx_max_file_systems	Maximum Number of Volumes in this Container
184	8	nx_fs_oid[0]	Array of OIDs for Volumes in this Container

Volume Super Block (apfs_superblock_t)

Offset	Size (in bytes)	Field	Notes
32	4	apfs_magic "APSB"	Volume Magic Number 0x41505342 = "APSB"
36	4	apfs_fs_index	Index in Volume Array
40	8	apfs_features	Features
48	8	apfs_readonly_compatible_features	Read-only Incompatible Features
56	8	apfs_incompatible_features	Incompatible Features
64	8	apfs_unmount_time	Timestamp when volume was last unmounted
72	8	apfs_reserve_block_count	Block Pre-allocated for Volume (Default is none)
80	8	apfs_fs_quota_block_count	Maximum Block Allocated (Default is none)
88	8	apfs_fs_alloc_count	Number of blocks currently allocated
96	2	wrapped_crypto_state.t.	Key Encryption Metadata – Major Version
		wrapped_crypto_state.major_version	
98	2	wrapped_crypto_state.t.	Key Encryption Metadata – Minor Version
		wrapped_crypto_state.minor_version	
100	4	wrapped_crypto_state.t.	Key Encryption Metadata – Encryption State Flags
		wrapped_crypto_state.cpfags	
104	4	wrapped_crypto_state.t.	Key Encryption Metadata – Protection Class
		wrapped_crypto_state.persistent_class	
108	4	wrapped_crypto_state.t.	Key Encryption Metadata – Creator OS Version
		wrapped_crypto_state.key_os_version	0x39004313 = 19 C 57 – 19C57 – Catalina 10.15.2
112	2	wrapped_crypto_state.t.	Key Encryption Metadata – Key Version
		wrapped_crypto_state.key_revision	
114	2	wrapped_crypto_state.t.	Key Encryption Metadata – Key Size (0 for no Encryption)
		wrapped_crypto_state.key_len	
N/A	0	wrapped_crypto_state.t.	Key Encryption Metadata – Wrapped Key
		wrapped_crypto_state.persistent_key	No Key field is null, see key_len above
116	4	apfs_root_tree_oid_type	Type of Root File System Tree = B-Tree
120	4	apfs_extntref_tree_oid_type	Type of Extent Reference Tree = B-Tree, Physical
124	4	apfs_snap_meta_tree_oid_type	Type of Snapshot Metadata Tree = B-Tree, Physical
128	8	apfs_omap_oid	Physical Object ID (OID) of Object Map
136	8	apfs_root_tree_oid	Virtual Object ID (OID) of Root File System Tree
144	8	apfs_extntref_tree_oid	Physical Object ID (OID) of Extent Reference Tree
152	8	apfs_snap_meta_tree_oid	Virtual Object ID (OID) of Snapshot Metadata Tree
160	8	apfs_revert_to_xid	Transaction ID (XID) that volume will revert to
168	8	apfs_revert_to_sblock_oid	Virtual Object ID (OID) of Volume Superblock to revert to
176	8	apfs_next_obj_id	Next Object ID (OID)
184	8	apfs_num_files	Number of Regular Files
192	8	apfs_num_directories	Number of Directories
200	8	apfs_num_symlinks	Number of Symbolic Links
208	8	apfs_num_other_fsobjects	Number of Other Files
216	8	apfs_num_snapshots	Number of Snapshots
224	8	apfs_total_blocks_allocated	Blocks Allocated by Volume
232	8	apfs_total_blocks_freed	Blocked Freed by Volume
240	16	apfs_vol_uuid	Volume UUID (diskutil info /dev/disk# [Volume])
256	8	apfs_last_mod_time	Last Modified Timestamp
264	8	apfs_fs_flags	Flags
272	32	apfs_modified_by_t.formatted_by.id[]	Format Program and Version
304	8	apfs_modified_by_t.formatted_by.timestamp	Format Timestamp
312	8	apfs_modified_by_t.formatted_by.last_xid	Format Transaction ID (XID)
320	32	apfs_modified_by_t.modified_by.id[]	Last Modified Program and Version
352	8	apfs_modified_by_t.modified_by.timestamp	Last Modified Timestamp
360	8	apfs_modified_by_t.modified_by.last_xid	Last Modified Transaction ID (XID)
368	336	apfs_modified_by_t.modified_by[1-7]	Array of apfs_modified_by_t[8]
704	256	apfs_volname	APFS Volume Name
960	4	apfs_next_doc_id	Next Document ID
964	2	apfs_role	APFS Role (None, System, Data, Preboot, VM, Recovery)
966	2	apfs_reserved	Reserved
976	8	apfs_root_to_xid	Transaction ID (XID) of Snapshot to Root
984	8	apfs_er_state_oid	Current State of Encryption/Decryption

B-Tree Node (btree_node_phys_t)

Offset	Size (in bytes)	Field	Notes
32	2	btn_flags	Flags (Leaf Node)
34	2	btn_level	Number of Child Levels below this Node
36	4	btn_nkeys	Number of Keys
40	2	btn_table_space.off	Offset to Table of Contents (after btree_node_phys_t)
42	2	btn_table_space.len	Length of Table of Contents
44	2	btn_freespace.off	Offset Key/Value Free Space
46	2	btn_freespace.len	Length of Key/Value Free Space
48	2	btn_key_free_list.off	Offset to Free Key Space
50	2	btn_key_free_list.len	Length of Free Key Space
52	2	btn_val_free_list.off	Offset to Free Value Space
54	2	btn_val_free_list.len	Length of Free Value Space

B-Tree Node – Table of Contents

Offset	Size (in bytes)	Field	Notes
TOC Entry + 2	2	key_offset	Key Offset
TOC Entry + 4	2	key_length	Key Length
TOC Entry + 6	2	value_offset	Value Offset
TOC Entry + 8	2	value_length	Value Length

B-Tree Node – File System Key

Offset	Size (in bytes)	Field
0	7	Object ID – Inode Number
7	1	Entry Kind
		0x30 – Inode
		0x60 – Data Stream
		0x40 – Xattr (2 byte Name Length + Variable Xattr Name)
		0x60 – File Extent (8 byte Logical Address)

Value - Inode File Metadata

Offset	Size (in bytes)	Field	Notes
0	8	parent_id	Parent Inode Number
8	8	private_id	Inode Number
16	8	create_time	Create Timestamp
24	8	mod_time	Modification Timestamp
32	8	change_time	Change Timestamp
40	8	access_time	Access Timestamp
48	8	internal_flags	Internal Flags
56	4	nchildren or nlink	Children or Links
60	4	default_protection_class	Default Protection Class
64	4	write_generation_counter	Write Generation Counter
68	4	bsd_flags	BSD Flags
72	4	owner	Owner
76	4	group	Group
80	2	mode	File Mode
82	2	pad1	Pad1
84	8	pad2	Pad2
92	2	xf_num_exts	Number of Extended Fields
94	2	xf_used_data	Extended Fields Data Used
96	x_field_t[] = 4 bytes Each	Extended Field: x_type (1 byte), x_flags (1 byte), x_size (2 bytes)	
96	4		EXAMPLE EXTENDED FIELD: 0x04 = 4, 0x02 (Do Not Copy), 0x1100 = 17 (File Name)
100	4		EXAMPLE EXTENDED FIELD: 0x08 = 8, 0x20 (System Field), 0x2800 = 40 (Data Stream)
104	{17}	File Name	smudge_yoda.jpeg (w/1 padding bytes 0x00), 17 total bytes
120	{40}	Data Stream	0x0000000000000000 – 7 unused bytes (Size: First 8 bytes, Allocated: Next 8 bytes) Size: 0x261C020000000000 = 138278 bytes Allocated: 0x0020020000000000 = 139264

Value – Inode File Extent

Offset	Size (in bytes)	Field
0	8	File Size
8	8	Physical Block Location
16	8	Crypto ID

APFS Format References:

- Apple File System Reference (Apple Developer Documentation)
- 2019-02-07

APFS is Little Endian & 64-bit

SANS FOR518 Reference Sheet

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Directory Commands

cd ..	Change Directory...up one directory (../.. - two directories up)
cd /var/log	Change Directory...to /var/log
cd -	Change Directory...to your home directory
cd /	Change Directory...to the root directory
ls	List Directory (Short Listing)
ls -l	List Directory (Long Listing)
ls -a	List Directory items...including hidden items (files beginning with ".")
ls -lh	List Directory items...with human readable sizes
ls -R	List Directory items...recursively
open .	Open Current Directory
pwd	Print Working Directory
mkdir	Create a Directory
rmdir	Remove a Directory
rm -r	Remove a Directory (and its contents)
.	Current Directory
..	Parent Directory

File Commands

pico <filename>	Open a file in a simple text editor (q - to quit editor)
xxd <filename>	Open a file in a hex editor
open <filename>	Opens a file in the default program
open -a <programname> <filename>	Opens a file in a specified program
cat <filename>	Concatenate a file to the terminal screen
<command> more	Pipe command output to more to show contents screen by screen
<command> less	Pipe command output to less to show contents screen by screen (and be able to go back and forth)
rm <filename>	Remove File
cp <filename> <newfilename>	Copy File
mv <filename> <newfilename>	Move File
<command> > <filename>	Redirect command output to a file
<command> >> <filename>	Append command output to a file
touch <filename>	Create an empty file
head <filename>	Show first 10 lines of a file
tail <filename>	Show last 10 lines of a file (-f to watch appended input)
strings <filename>	Show the strings of a file
exiftool <filename>	Show the exif/metadata of the file
plutil -p <propertylist>	Print the contents of a property list
file <filename>	Show a file signature type
grep -i <searchterm> <filename>	Search for term within a file (case-insensitive)
python <file>.py	Execute a Python program

Miscellaneous Commands

sudo <command>	Execute program as another user (default is root user)
sudo -s	Open a privileged shell
su -	Substitute User to root
whoami / id	Display Effective User ID / Show UID/GID Info
history	Command History
man <command>	Command Manual (q - to exit manual)

Terminal Shortcuts

Control + A	Jump to beginning of line
Control + E	Jump to end of line
Tab	Tab Completion
Control + C	Kill Current Command
Command + K or Control + L	Clear Screen (or clear command)
Command + T	New Terminal Tab
Command + W	Close Terminal Tab
Command +/-	Increase or Decrease Terminal Font Size
Option + Left/Right Arrow	Move back/forth by word
Option + Click in Command Line	Put command line cursor where mouse cursor is.

Generic Tool Compilation and Installation

```
tar -xvf <archive>.tar.gz
./configure
make
sudo make install
```

Disk Arbitration

```
sudo launchctl load /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist Enable
sudo launchctl unload /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist Disable
ps auxw | grep diskarbitrationd Determine Status
```

Live Response date	Local System Time (-u for UTC)
hostname	System Hostname
uname -a	OS & Architecture Information
sw_vers	macOS Version & Build
netstat -an	Active Network Connections
lsof -i	Active Network Connections (by process)
netstat -rn	Routing Table
arp -an ndp -an	ARP Table (IPv4 IPv6)
ifconfig	Network Interface Configuration
lsof	List Open Files
who -a, w	List Logged On Users
last	List user logins
ps aux	List Processes
system_profiler -xml -detaillevel full > file.spdx	System Profiler (XML, Full Detail Level), open with System Information.app

Disk & Partitions

/dev/	Device Directory
diskutil list	List Connected Disks
diskutil info <disk>	Disk Information (use Disks /dev/disk#, disk#, or partitions /dev/disk#s)
diskutil cs ap list	List partitions using CoreStorage (cs) or APFS Containers (ap)
gpt -r show [-l]	List partitions using GUID Partition Table Format (-l to show label rather than GUID) - 10.13+ SIP must be disabled.
csrutil disable enable	Disable/Enable SIP, must reboot into Recovery Mode (Reboot, Cmd+Option+R)
mmfs <diskimage>	Display partitions using The Sleuth Kit
hdiutil imageinfo *.dmg	Disk Image Information including Partition Data

Keychains

security list-keychains	List Keychains on a system for a logged in user
security dump-keychains -d <keychain>	Dump contents of a Keychain

Extended Attributes

xattr -xl <file>	Show Extended Attributes of a file
xattr -p <attribute name> <file> xxd -r -p	Extract embedded binary property list from extended attribute.
istat /dev/disk# <CNID>	Use The Sleuth Kit to view file information including extended attributes.
icat /dev/disk# <CNID>-<TSK Attribute Number>	View a specific extended attribute using The Sleuth Kit

Log Analysis

bzcat system.log.1.bz2	Create a "all-in-one" system.log file. Can also be used with gzcat for Gzip compressed log files.
system.log.0.bz2 >> system_all.log	
cat system.log >> system_all.log	
syslog -f <file> -d <directory>	View ASL File or Directory of ASL files
syslog -T utc -F raw -d	Output ASL files the /var/log/asl directory and output in raw format with UTC timestamps.
/var/log/asl	
praudit -xn /var/audit/*	View audit logs in XML format without user/group resolution.
sudo log collect	Create a logarchive bundle on live system, root required
log show	View logs in logarchive bundle (use with --predicate to filter)
log stream	View live logs (use with --predicate to filter)

Time Machine

tmutil uniquesize <machinedirectory_path>/*	Show the unique sizes of each snapshot
tmutil calculatedrift	Show the size changes (added/removed/changed) between each snapshot.
<machinedirectory_path>	
tmutil compare <snapshotdirectory1> <snapshotdirectory2>	Compare the file changes (added/removed/changed) between two snapshots..

Memory Analysis & Encrypted Containers

vol.py --profile=<profile> -f <memory image>	Volatility Usage
<plugin>	
hdiutil attach -readonly -nomount -stdinpass filevault2image.dmg	Mount a FileVault volume using a password
security unlock-keychain FileVaultMaster.keychain	Access and mount a FileVault volume using a master password
diskutil corestorage unlockvolume <UUID> -recoverykeychain FileVaultMaster.keychain	
diskutil corestorage unlockvolume <UUID> -passphrase <recovery key>	Mount a FileVault volume using the Recovery Key
hdiutil attach -readonly -nomount -stdinpass sekretstuff_USB.dmg	Mount an Encrypted DMG File
strings <MemoryImage> sort -u > dictionary.txt	Create a dictionary file

Spotlight

mdls <file>	List the Spotlight metadata for a file
mdfind " <attribute_name> == *"	Find files based on a specific metadata query
mdfind -onlyin /Volumes/mounted_disk	Find files only in a certain directory or mounted image.
mdimport -X -A	Print a list of attributes that can be queried.

Image Mount & Eject	
APFS with xmount (xmount v.0.7.*)	\$ sudo mkdir /Volumes/galaga_image/ \$ sudo mkdir /Volumes/galaga_mounted/ \$ sudo xmount --in ewf ~/FOR518/galaga.E01 --out dmg /Volumes/galaga_image/ \$ hdiutil attach -nomount /Volumes/galaga_image/galaga.dmg \$ sudo mount_apfs -o ronly,noexec,noowners /dev/disk# /Volumes/galaga_mounted/
HFS+ Method 1 - xmount (xmount v.0.7.*)	\$ mkdir /Volumes/dademurphy_image/ \$ mkdir /Volumes/dademurphy_mounted/ \$ sudo xmount --in ewf ~/FOR518/dademurphy.E01 --out dmg /Volumes/dademurphy_image/ \$ hdiutil attach -nomount /Volumes/dademurphy_image/dademurphy.dmg \$ mount_hfs -j -o ronly,noexec,noowners /dev/disk# /Volumes/dademurphy_mounted/
Eject Disk	\$ diskutil list \$ diskutil eject /dev/disk# \$ mount \$ sudo umount /Volumes/galaga_image/

Timestamp Formats

APFS	64-bit - Number of Seconds from 1/1/1970 00:00:00 UTC
HFS+/MacOS	32-bit - Number of seconds from 1/1/1904 00:00:00 UTC
UNIX Epoch	32-bit - Number of seconds from 1/1/1970 00:00:00 UTC
Mac Epoch/Mac Absolute/Cocoa/WebKit	32-bit - Number of seconds from 1/1/2001 00:00:00 UTC
Property List Dates in Xcode	Local Host System Time

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Number of 512-byte Blocks Used

```
nibble:/sledwards$ ls -la
total 1014190
drwxr-xr-x@ 41 root wheel 1462 Feb 16 21:14 .
drwxr-xr-x@ 41 root wheel 1462 Feb 16 21:14 ..
d--x--x--x+ 8 root wheel 272 Nov 5 01:11 .DocumentRevisions-V100
d-wx-wx-wt 2 root wheel 68 Nov 4 21:05 .Trashes
-rw-r--r--+ 1 sledwards admin 312 Mar 9 2013 .apdisk
srwxrwxrwx 1 root wheel 0 Feb 15 21:29 .dbfseventsd
lrwxr-xr-x@ 1 root wheel 11 Sep 23 08:47 etc -> private/etc
-rwxr-xr-x@ 1 root wheel 8393032 Sep 29 22:39 mach_kernel
```

Labels for the ls output:

- Entry Type
- Permissions
- Owner-Name
- Group Name
- File Size(bytes)
- Last Modified Timestamp
- File / Directory

GPT Header			GPT Reference		
Offset	Size (bytes)	Field	GPT Table Entry		
0	8	Signature (EFI PART)	Offset	Size (bytes)	Field
8	4	Revision (1.0)	0	16	Partition Type GUID
12	4	Size of Header (bytes)	16	16	Unique Partition GUID
16	4	Header CRC32	32	8	Starting LBA (Little Endian)
20	4	Reserved	40	8	Ending LBA (Little Endian)
24	8	LBA of GPT Header	48	8	Attributes
32	8	LBA of Backup GPT Header	56	72	Partition Name
40	8	First Usable LBA	128	Rest	Reserved
48	8	Last Usable LBA	Type Common GPT Partition GUIDs		
56	16	Disk GUID	EFI System Partition	C12A7328-F81F-11D2-BA4B-00A0C93EC93B	
72	8	Starting LBA of GUID Partition Table (Little Endian)	HFS+ Partition	48465300-0000-11AA-AA11-00306543ECAC	
80	4	Number of Partition Entries Available (Little Endian)	Apple Boot Partition	426F6F74-0000-11AA-AA11-00306543ECAC	
84	4	Size of Partition Entry	Apple CoreStorage (possible FileVault or Fusion Drive)	53746F72-6167-11AA-AA11-00306543ECAC	
88	4	Partition Entry Array CRC32	APFS Partition	7C3457EF-0000-11AA-AA11-00306543ECAC	
92	Rest	Reserved	Basic Data Partition (Boot Camp)	EBD0A0A2-B9E5-4433-87C0-68B6B72699C7	