OpenCore

Reference Manual

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1 Introduction

This document provides information on OpenCore user configuration file format used to setup the correct functioning of macOS operating system.

1.1 Known defects

For OpenCore issues please refer to Acidanthera Bugtracker. Currently this file has the following entries not completed:

• Not all NVRAM variables are properly described (e.g. boot-args).

2 Generic Terms

- plist Subset of ASCII Property List format written in XML, also know as XML plist format version 1. Uniform Type Identifier (UTI): com.apple.property-list. Plists consist of plist objects, which are combined to form a hierarchical structure. Due to plist format not being well-defined, all the definitions of this document may only be applied after plist is considered valid by running plutil -lint. External references: https://www.apple.com/DTDs/PropertyList-1.0.dtd, man plutil.
- plist type plist collections (plist array, plist dictionary, plist key) and primitives (plist string, plist data, plist date, plist boolean, plist integer, plist real).
- plist object definite realisation of plist type, which may be interpreted as value.
- plist array array-like collection, conforms to array. Consists of zero or more plist objects.
- plist dictionary map-like (associative array) collection, conforms to dict. Consists of zero or more plist keys.
- plist key contains one plist object going by the name of plist key, conforms to key. Consists of printable 7-bit ASCII characters.
- plist string printable 7-bit ASCII string, conforms to string.
- plist data base64-encoded blob, conforms to data.
- plist date ISO-8601 date, conforms to date, unsupported.
- plist boolean logical state object, which is either true (1) or false (0), conforms to true and false.
- plist integer possibly signed integer number in base 10, conforms to integer. Fits in 64-bit unsigned integer in two's complement representation, unless a smaller signed or unsigned integral type is explicitly mentioned in specific plist object description.
- plist real floating point number, conforms to real, unsupported.
- plist metadata value cast to data by the implementation. Permits passing plist string, in which case the result is represented by a null-terminated sequence of bytes (aka C string), plist integer, in which case the result is represented by 32-bit little endian sequence of bytes in two's complement representation, plist boolean, in which case the value is one byte: 01 for true and 00 for false, and plist data itself. All other types or larger integers invoke undefined behaviour.

3 Overview

3.1 Configuration Terms

- OC config OpenCore Configuration file in plist format named config.plist. It has to provide extensible way to configure OpenCore and is structured to be separated into multiple named sections situated in the root plist dictionary. These sections are permitted to have plist array or plist dictionary types and are described in corresponding sections of this document.
- valid key plist key object of OC config described in this document or its future revisions. Besides explicitly described valid keys, keys starting with # symbol (e.g. #Hello) are also considered valid keys and behave as comments, effectively discarding their value, which is still required to be a valid plist object. All other plist keys are not valid, and their presence yields to undefined behaviour.
- valid value valid plist object of OC config described in this document that matches all the additional requirements in specific plist object description if any.
- invalid value valid plist object of OC config described in this document that is of other plist type, does not conform to additional requirements found in specific plist object description (e.g. value range), or missing from the corresponding collection. Invalid value is read with or without an error message as any possible value of this plist object in an undetermined manner (i.e. the values may not be same across the reboots). Whilst reading an invalid value is equivalent to reading certain defined valid value, applying incompatible value to the host system may yield to undefined behaviour.
- optional value valid value of OC config described in this document that reads in a certain defined manner provided in specific plist object description (instead of invalid value) when not present in OC config. All other cases of invalid value do still apply. Unless explicitly marked as optional value, any other value is required to be present and reads to invalid value if missing.
- fatal behaviour behaviour leading to boot termination. Implementation must stop the boot process from going any further until next host system boot. It is allowed but not required to perform cold reboot or show any warning message.
- undefined behaviour behaviour not prescribed by this document. Implementation is allowed to take any
 measures including but not limited to fatal behaviour, assuming any states or values, or ignoring, unless these
 measures negatively affect system security in general.

3.2 Configuration Processing

OC config is guaranteed to be processed at least once if it was found. Depending on OpenCore bootstrapping mechanism multiple OC config files may lead to reading any of them. No OC Config may be present on disk, in which case all the values read follow the rules of invalid value and optional value.

OC config has size, nesting, and key amount limitations. OC config size does not exceed 16 MBs. OC config has no more than 8 nesting levels. OC config has up to 16384 XML nodes (i.e. one plist dictionary item is counted as a pair of nodes) within each plist object.

Reading malformed OC config file leads to undefined behaviour. Examples of malformed OC config cover at least the following cases:

- files non-conformant to plist DTD
- files with unsupported or non-conformant plist objects found in this document
- files violating size, nesting, and key amount limitations

It is recommended but not required to abort loading malformed OC config and continue as if no OC config was present. For forward compatibility it is recommended but not required for the implementation to warn about the use of invalid values. Recommended practice of interpreting invalid values is to conform to the following convention where applicable:

Type	Value
plist string	Empty string (<string></string>)
plist data	Empty data (<data></data>)

Type	Value
plist integer plist boolean plist tristate	O (<integer>0</integer>) False (<false></false>) False (<false></false>)

3.3 Configuration Structure

OC config is separated into following sections, which are described in separate sections of this document. By default it is tried to not enable anything and optionally provide kill switches with Enable property for plist dict entries. In general the configuration is written idiomatically to group similar actions in subsections:

- Add provides support for data addition.
- Block provides support for data removal or ignorance.
- Patch provides support for data modification.
- Quirks provides support for specific hacks.

Root configuration entries consist of the following:

- ACPI
- DeviceProperties
- Kernel
- Misc
- NVR.AM
- PlatformInfo
- UEFI

Note: Currently most properties try to have defined values even if not specified in the configuration for safety reasons. This behaviour should not be relied upon, and all fields must be properly specified in the configuration.

3.4 Directory Structure

When directory boot is used the directory structure used should follow the description on Directory Structure figure. Available entries include:

• B00Tx64.efi

Initial booter, which loads OpenCore.efi unless it was already started as a driver.

ACPI

Directory used for storing supplemental ACPI information for ACPI section.

Drivers

Directory used for storing supplemental UEFI drivers for UEFI section.

Kexts

Directory used for storing supplemental kernel information for Kernel section.

OpenCore.efi

Main booter driver responsible for operating system loading.

vault.plist

Hashes for all files potentially loadable by OC Config.

• config.plist

OC Config.

• vault.sig

Signature for vault.plist.



Figure 1. Directory Structure

3.5 Contribution

OpenCore can be compiled as an ordinary EDK II package with UDK 2018.

The only officially supported toolchain is XCODE5. Other toolchains might work, but are neither supported, nor recommended. Contribution of clean patches is welcome. Please do follow EDK II C Codestyle.

Required external package dependencies include EfiPkg, MacInfoPkg, and OcSupportPkg.

To compile with XCODE5, besides Xcode, one should also install NASM and MTOC. Example command sequence may look as follows:

```
git clone https://github.com/tianocore/edk2 -b UDK2018 UDK
cd UDK
git clone https://github.com/acidanthera/EfiPkg
git clone https://github.com/acidanthera/MacInfoPkg
git clone https://github.com/acidanthera/OcSupportPkg
git clone https://github.com/acidanthera/OcSupportPkg
git clone https://github.com/acidanthera/OpenCorePkg
source edksetup.sh
make -C BaseTools
build -a X64 -b RELEASE -t XCODE5 -p OpenCorePkg/OpenCorePkg.dsc
```

Listing 1: Compilation Commands

NOOPT or DEBUG build modes instead of RELEASE can produce a lot more debug output. With NOOPT source level debugging with GDB or IDA Pro is also available. For GDB check OcSupport Debug page. For IDA Pro you will need IDA Pro 7.3 or newer.

For IDE usage Xcode projects are available in the root of the repositories. Another approach could be Sublime Text with EasyClangComplete plugin. Add .clang_complete file with similar content to your UDK root:

- -I/UefiPackages/MdePkg
- -I/UefiPackages/MdePkg/Include
- -I/UefiPackages/MdePkg/Include/X64
- -I/UefiPackages/EfiPkg
- -I/UefiPackages/EfiPkg/Include
- -I/UefiPackages/EfiPkg/Include/X64
- -I/UefiPackages/AptioFixPkg/Include
- -I/UefiPackages/AppleSupportPkg/Include
- -I/UefiPackages/OpenCorePkg/Include
- -I/UefiPackages/OcSupportPkg/Include
- -I/UefiPackages/IntelFrameworkPkg/Include
- -I/UefiPackages/MacInfoPkg/Include
- -IInclude
- -include

/UefiPackages/MdePkg/Include/Uefi.h

- -fshort-wchar
- -Wall
- -Wextra
- Wno-unused-parameter
- -Wno-missing-braces
- -Wno-missing-field-initializers
- -Wno-tautological-compare
- -Wno-sign-compare
- -Wno-varargs
- Wno-unused-const-variable

Listing 2: ECC Configuration

4 ACPI

4.1 Introduction

ACPI (Advanced Configuration and Power Interface) is an open standard to discover and configure computer hardware. ACPI specification defines the standard tables (e.g. DSDT, SSDT, FACS, DMAR) and various methods (e.g. _DSM, _PWR) for implementation. Modern hardware needs little changes to maintain ACPI compatibility, yet some of those are provided as a part of OpenCore.

4.2 Properties

1. Add

Type: plist array Default value: Empty

Description: Load selected tables from OC/ACPI/Custom directory.

Designed to be filled with plist dict values, describing each block entry. See Add Properties section below.

2. Block

Type: plist array Default value: Empty

Description: Remove selected tables from ACPI stack.

Designed to be filled with plist dict values, describing each block entry. See Block Properties section below.

3. Patch

Type: plist array Default value: Empty

Description: Perform binary patches in ACPI tables before table addition or removal.

Designed to be filled with plist dictionary values describing each patch entry. See Patch Properties section below.

4. Quirks

Type: plist dict

Description: Apply individual ACPI quirks described in Quirks Properties section below.

4.3 Add Properties

1. Comment

Type: plist string

Default value: Empty string

Description: Arbitrary ASCII string used to provide human readable reference for the entry. It is implementation defined whether this value is used.

2. Enabled

Type: plist boolean Default value: false

Description: This ACPI table will not be added unless set to true.

3. Path

Type: plist string

Default value: Empty string

 $\textbf{Description} : \ File\ paths\ meant\ to\ be\ loaded\ as\ ACPI\ tables.\ Example\ values\ include\ \texttt{DSDT.aml}, \ \texttt{SubDir/SSDT-8.aml}, \ \texttt{SubDir/$

SSDT-USBX.aml, etc.

ACPI table load order follows the item order in the array. All ACPI tables load from OC/ACPI/Custom directory.

Note: All tables but tables with DSDT table identifier (determined by parsing data not by filename) insert new tables into ACPI stack. DSDT, unlike the rest, performs replacement of DSDT table.

4.4 Block Properties

1. All

Type: plist boolean Default value: false

Description: If set to true, all ACPI tables matching the condition will be dropped. Otherwise only first

matched table.

2. Comment

Type: plist string

Default value: Empty string

Description: Arbitrary ASCII string used to provide human readable reference for the entry. It is implementation

defined whether this value is used.

3. Enabled

Type: plist boolean Default value: false

Description: This ACPI table will not be removed unless set to true.

4. OemTableId

Type: plist data, 8 bytes Default value: All zero

Description: Match table OEM ID to be equal to this value unless all zero.

5. TableLength

Type: plist integer Default value: 0

Description: Match table size to be equal to this value unless 0.

6. TableSignature

Type: plist data, 4 bytes Default value: All zero

Description: Match table signature to be equal to this value unless all zero.

4.5 Patch Properties

1. Comment

Type: plist string

Default value: Empty string

 $\textbf{Description:} \ \ \text{Arbitrary ASCII string used to provide human readable reference for the entry.} \ \ \text{It is implementation}$

defined whether this value is used.

2. Count

Type: plist integer Default value: 0

Description: Number of patch occurrences to apply. 0 applies the patch to all occurrences found.

3. Enabled

Type: plist boolean Default value: false

Description: This ACPI patch will not be used unless set to true.

 $4. \; {\tt Find}$

Type: plist data

Default value: Empty data

Description: Data to find. Must equal to Replace in size.

5. Limit

Type: plist integer Default value: 0

Description: Maximum number of bytes to search for. Can be set to 0 to look through the whole ACPI table.

6. Mask

Type: plist data

Default value: Empty data

Description: Data bitwise mask used during find comparison. Allows fuzzy search by ignoring not masked (set

to zero) bits. Can be set to empty data to be ignored. Must equal to Replace in size otherwise.

7. OemTableId

Type: plist data, 8 bytes Default value: All zero

Description: Match table OEM ID to be equal to this value unless all zero.

8. Replace

Type: plist data

Default value: Empty data

Description: Replacement data of one or more bytes.

9. ReplaceMask

Type: plist data

Default value: Empty data

Description: Data bitwise mask used during replacement. Allows fuzzy replacement by updating masked (set

to non-zero) bits. Can be set to empty data to be ignored. Must equal to Replace in size otherwise.

10. Skip

Type: plist integer Default value: 0

Description: Number of found occurrences to be skipped before replacement is done.

11. TableLength

Type: plist integer Default value: 0

Description: Match table size to be equal to this value unless 0.

12. TableSignature

Type:

textttplist data, 4 bytes **Default value**: All zero

Description: Match table signature to be equal to this value unless all zero.

In the majority of the cases ACPI patches are not useful and harmful:

- Avoid renaming devices with ACPI patches. This may fail or perform improper renaming of unrelated devices (e.g. EC and ECO), be unnecessary, or even fail to rename devices in select tables. For ACPI consistency it is much safer to rename devices at I/O Registry level, as done by WhateverGreen.
- Avoid patching _OSI to support a higher level of feature sets unless absolutely required. Commonly this enables a number of hacks on APTIO firmwares, which result in the need to add more patches. Modern firmwares generally do not need it at all, and those that do are fine with much smaller patches.
- Try to avoid hacky changes like renaming _PWR or _DSM whenever possible.

Several cases, where patching actually does make sense, include:

- Refreshing HPET (or another device) method header to avoid compatibility checks by _OSI on legacy hardware. _STA method with if ((OSFL () == Zero)) { If (HPTE) ... Return (Zero) content may be forced to always return 0xF by replacing AO 10 93 4F 53 46 4C 00 with A4 0A 0F A3 A3 A3 A3 A3.
- To provide custom method implementation with in an SSDT, for instance, to report functional key presses on a laptop, the original method can be replaced with a dummy name by patching _Q11 with XQ11.

Tianocore AcpiAml.h source file may help understanding ACPI opcodes.

4.6 Quirks Properties

1. FadtEnableReset

Type: plist boolean

Default value: false

Description: Provide reset register and flag in FADT table to enable reboot and shutdown on legacy hardware. Not recommended unless required.

2. IgnoreForWindows

Type: plist boolean Default value: false

Description: Disable all sorts of ACPI modifications when booting Windows operating system.

This flag implements a quick workaround for those, who made their ACPI tables incompatible with Windows, but need it right now. Not recommended, as ACPI tables must be compatible with any operating system regardless of the changes.

Note: This option may be removed in the future.

3. NormalizeHeaders

Type: plist boolean Default value: false

Description: Cleanup ACPI header fields to workaround macOS ACPI implementation bug causing boot crashes. Reference: Debugging AppleACPIPlatform on 10.13 by Alex James aka theracermaster. The issue is fixed in macOS Mojave (10.14).

4. RebaseRegions

Type: plist boolean Default value: false

Description: Attempt to heuristically relocate ACPI memory regions. Not recommended.

ACPI tables are often generated dynamically by underlying firmware implementation. Among the position-independent code, ACPI tables may contain physical addresses of MMIO areas used for device configuration, usually grouped in regions (e.g. OperationRegion). Changing firmware settings or hardware configuration, upgrading or patching the firmware inevitably leads to changes in dynamically generated ACPI code, which sometimes lead to the shift of the addresses in aforementioned OperationRegion constructions.

For this reason it is very dangerous to apply any kind of modifications to ACPI tables. The most reasonable approach is to make as few as possible changes to ACPI and try to not replace any tables, especially DSDT. When this is not possible, then at least attempt to ensure that custom DSDT is based on the most recent DSDT or remove writes and reads for the affected areas.

When nothing else helps this option could be tried to avoid stalls at PCI Configuration Begin phase of macOS booting by attempting to fix the ACPI addresses. It does not do magic, and only works with most common cases. Do not use unless absolutely required.

5 DeviceProperties

5.1 Introduction

Device configuration is provided to macOS with a dedicated buffer, called EfiDevicePropertyDatabase. This buffer is a serialised map of DevicePaths to a map of property names and their values.

Property data can be debugged with gfxutil. To obtain current property data use the following command in macOS:

```
ioreg -lw0 -p IODeviceTree -n efi -r -x | grep device-properties |
   sed 's/.*<//;s/>.*//' > /tmp/device-properties.hex &&
   gfxutil /tmp/device-properties.hex /tmp/device-properties.plist &&
   cat /tmp/device-properties.plist
```

5.2 Properties

1. Add

Type: plist dict

Description: Sets device properties from a map (plist dict) of deivce paths to a map (plist dict) of variable names and their values in plist metadata format. Device paths must be provided in canonic string format (e.g. PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x0)). Properties will only be set if not present and not blocked.

Note: Currently properties may only be (formerly) added by the original driver, so unless a separate driver was installed, there is no reason to block the variables.

2. Block

Type: plist dict

Description: Removes device properties from a map (plist dict) of deivce paths to an array (plist array) of variable names in plist string format.

5.3 Common Properties

Some known properties include:

• device-id

User-specified device identifier used for I/O Kit matching. Has 4 byte data type.

• vendor-id

User-specified vendor identifier used for I/O Kit matching. Has 4 byte data type.

• AAPL,ig-platform-id

Intel GPU framebuffer identifier used for framebuffer selection on Ivy Bridge and newer. Has 4 byte data type.

• AAPL, snb-platform-id

Intel GPU framebuffer identifier used for framebuffer selection on Sandy Bridge. Has 4 byte data type.

• layout-id

Audio layout used for AppleHDA layout selection. Has 4 byte data type.

6 Kernel

6.1 Introduction

This section allows to apply different kinds of kernelspace modifications on Apple Kernel (XNU). The modifications currently provide driver (kext) injection, kernel and driver patching, and driver blocking.

6.2 Properties

1. Add

Type: plist array Default value: Empty

Description: Load selected kernel drivers from OC/Kexts directory.

Designed to be filled with plist dict values, describing each driver. See Add Properties section below. Kernel driver load order follows the item order in the array, thus the dependencies should be written prior to their consumers.

2. Block

Type: plist array Default value: Empty

Description: Remove selected kernel drivers from prelinked kernel.

Designed to be filled with plist dictionary values, describing each blocked driver. See Block Properties section below.

3. Patch

Type: plist array Default value: Empty

Description: Perform binary patches in kernel and drivers prior to driver addition and removal.

Designed to be filled with plist dictionary values, describing each patch. See Patch Properties section below.

4. Quirks

Type: plist dict

Description: Apply individual kernel and driver quirks described in Quirks Properties section below.

6.3 Add Properties

1. BundlePath

Type: plist string

Default value: Empty string

Description: Kext bundle path (e.g. Lilu.kext or MyKext.kext/Contents/PlugIns/MySubKext.kext).

2. Comment

Type: plist string

Default value: Empty string

Description: Arbitrary ASCII string used to provide human readable reference for the entry. It is implementation

defined whether this value is used.

3. Enabled

Type: plist boolean Default value: false

Description: This kernel driver will not be added unless set to true.

4. ExecutablePath

Type: plist string

Default value: Empty string

Description: Kext executable path relative to bundle (e.g. Contents/MacOS/Lilu).

5. MatchKernel

Type: plist string

Default value: Empty string

Description: Blocks kernel driver on selected macOS version only. The selection happens based on prefix match with the kernel version, i.e. 16.7.0 will match macOS 10.12.6 and 16. will match any macOS 10.12.x version.

6. PlistPath

Type: plist string

Default value: Empty string

Description: Kext Info.plist path relative to bundle (e.g. Contents/Info.plist).

6.4 Block Properties

1. Comment

Type: plist string

Default value: Empty string

Description: Arbitrary ASCII string used to provide human readable reference for the entry. It is implementation

defined whether this value is used.

2. Enabled

Type: plist boolean Default value: false

Description: This kernel driver will not be blocked unless set to true.

3. Identifier

Type: plist string

Default value: Empty string

Description: Kext bundle identifier (e.g. com.apple.driver.AppleTyMCEDriver).

4. MatchKernel

Type: plist string

Default value: Empty string

Description: Blocks kernel driver on selected macOS version only. The selection happens based on prefix match with the kernel version, i.e. 16.7.0 will match macOS 10.12.6 and 16. will match any macOS 10.12.x version.

6.5Patch Properties

1. Base

Type: plist string

Default value: Empty string

Description: Selects symbol-matched base for patch lookup (or immediate replacement) by obtaining the address of provided symbol name. Can be set to empty string to be ignored.

2. Comment

Type: plist string

Default value: Empty string

Description: Arbitrary ASCII string used to provide human readable reference for the entry. It is implementation defined whether this value is used.

3. Count

Type: plist integer Default value: 0

Description: Number of patch occurrences to apply. 0 applies the patch to all occurrences found.

4. Enabled

Type: plist boolean Default value: false

Description: This kernel patch will not be used unless set to true.

5. Find

Type: plist data

Default value: Empty data

Description: Data to find. Can be set to empty for immediate replacement at Base. Must equal to Replace in

size otherwise.

6. Identifier

Type: plist string

Default value: Empty string

Description: Kext bundle identifier (e.g. com.apple.driver.AppleHDA) or kernel for kernel patch.

7. Limit

Type: plist integer Default value: 0

Description: Maximum number of bytes to search for. Can be set to 0 to look through the whole kext or kernel.

8. Mask

Type: plist data

Default value: Empty data

Description: Data bitwise mask used during find comparison. Allows fuzzy search by ignoring not masked (set to zero) bits. Can be set to empty data to be ignored. Must equal to Replace in size otherwise.

9. MatchKernel

Type: plist string

Default value: Empty string

Description: Adds kernel driver to selected macOS version only. The selection happens based on prefix match with the kernel version, i.e. 16.7.0 will match macOS 10.12.6 and 16. will match any macOS 10.12.x version.

10. Replace

Type: plist data

Default value: Empty data

Description: Replacement data of one or more bytes.

11. ReplaceMask

Type: plist data

Default value: Empty data

Description: Data bitwise mask used during replacement. Allows fuzzy replacement by updating masked (set to non-zero) bits. Can be set to empty data to be ignored. Must equal to Replace in size otherwise.

12. Skip

Type: plist integer Default value: 0

Description: Number of found occurrences to be skipped before replacement is done.

6.6 Quirks Properties

1. AppleCpuPmCfgLock

Type: plist boolean Default value: false

 $\begin{tabular}{ll} \textbf{Description:} Disables PKG_CST_CONFIG_CONTROL~(0xE2)~MSR~modification~in~AppleIntelCPUPowerManagement.kext, commonly causing early kernel panic, when it is locked from writing. \\ \end{tabular}$

Note: This option should avoided whenever possible. Modern firmwares provide CFG Lock setting, disabling which is much cleaner. More details about the issue can be found in VerifyMsrE2 notes.

$2. \ {\tt AppleXcpmCfgLock}$

Type: plist boolean Default value: false

Description: Disables PKG_CST_CONFIG_CONTROL (0xE2) MSR modification in XNU kernel, commonly causing early kernel panic, when it is locked from writing (XCPM power management).

Note: This option should avoided whenever possible. Modern firmwares provide CFG Lock setting, disabling which is much cleaner. More details about the issue can be found in VerifyMsrE2 notes.

$3. \ {\tt ExternalDiskIcons}$

Type: plist boolean Default value: false

Description: Apply icon type patches to IOAHCIPort.kext to force internal disk icons for all AHCI disks.

Note: This option should avoided whenever possible. Modern firmwares usually have compatible AHCI controllers.

4. ThirdPartyTrim

Type: plist boolean Default value: false

Description: Patch IOAHCIFamily.kext to force TRIM command support on AHCI SSDs.

Note: This option should avoided whenever possible. NVMe SSDs are compatible without the change. For AHCI SSDs on modern macOS version there is a dedicated built-in utility called trimforce.

5. XhciPortLimit

Type: plist boolean Default value: false

Description: Patch various kexts (AppleUSBXHCI.kext, AppleUSBXHCIPCI.kext, IOUSBHostFamily.kext) to remove USB port count limit of 15 ports.

Note: This option should avoided whenever possible. USB port limit is imposed by the amount of used bits in locationID format and there is no possible way to workaround this without heavy OS modification. The only valid solution is to limit the amount of used ports to 15 (discarding some). More details can be found on AppleLife.ru.

7 Misc

7.1 Introduction

This section contains miscellaneous configuration entries for OpenCore behaviour that does not go to any other sections

7.2 Properties

1. Boot

Type: plist dict

Description: Apply boot configuration described in Boot Properties section below.

2. Debug

Type: plist dict

Description: Apply debug configuration described in Debug Properties section below.

3. Security

Type: plist dict

Description: Apply security configuration described in Security Properties section below.

7.3 Boot Properties

1. ConsoleMode

Type: plist string

Default value: Empty string

Description: Sets console output mode as specified with the WxH (e.g. 80x24) formatted string. Set to empty string not to change console mode. Set to Max to try to use largest available console mode.

2. ConsoleBehaviourOs

Type: plist string

Default value: Empty string

Description: Set console control behaviour upon operating system load.

Console control is a legacy protocol used for switching between text and graphics screen output. Some firmwares do not provide it, yet select operating systems require its presence, which is what ProvideConsoleControl UEFI quirk is for.

When console control is available, OpenCore can be made console control aware, and and set different modes for the operating system booter (ConsoleBehaviourOs), which normally runs in graphics mode, and its own user interface (ConsoleBehaviourUi), which normally runs in text mode. Possible behaviours, set as values of these options, include:

- Empty string Do not modify console control mode.
- Text Switch to text mode.
- Graphics Switch to graphics mode.
- ForceText Switch to text mode and preserve it (requires ProvideConsoleControl).
- ForceGraphics Switch to graphics mode and preserve it (require ProvideConsoleControl).

Hints:

- Unless empty works, firstly try to set ConsoleBehaviourOs to Graphics and ConsoleBehaviourUi to Text.
- On APTIO IV (Haswell and earlier) it is usually enough to have ConsoleBehaviourOs set to Graphics and ConsoleBehaviourUi set to ForceText to avoid visual glitches.
- On APTIO V (Broadwell and newer) ConsoleBehaviourOs set to ForceGraphics and ConsoleBehaviourUi set to Text usually works best.

Note: IgnoreTextInGraphics may need to be enabled for select firmware implementations.

3. ConsoleBehaviourUi

Type: plist string

Default value: Empty string

Description: Set console control behaviour upon OpenCore user interface load. Refer to ConsoleBehaviourOs description for details.

4. HideSelf

Type: plist boolean Default value: false

 $\textbf{Description:} \ \ \text{Hides own boot entry from boot picker.} \ \ \text{This may potentially hide other entries, for instance, when}$

another UEFI OS is installed on the same volume and driver boot is used.

5. Resolution

Type: plist string

Default value: Empty string

Description: Sets console output screen resolution as specified with the WxH@Bpp (e.g. 1920x1080@32) or WxH (e.g. 1920x1080) formatted string. Set to empty string not to change screen resolution. Set to Max to try to use largest available screen resolution.

Note: This will fail when console handle has no GOP protocol. When the firmware does not provide it, it can be added with ProvideConsoleGop UEFI quirk set to true.

6. ShowPicker

Type: plist boolean Default value: false

Description: Show simple boot picker to allow boot entry selection.

7. Timeout

Type: plist integer, 32 bit

Default value: 0

Description: Timeout in seconds in boot picker before automatic booting of the default boot entry.

7.4 Debug Properties

1. DisplayDelay

Type: plist integer Default value: 0

Description: Delay in microseconds performed after every printed line visible onscreen (i.e. console).

2. DisplayLevel

Type: plist integer, 64 bit

Default value: 0

Description: EDK II debug level bitmask (sum) showed onscreen. Unless Target enables console (onscreen) printing, onscreen debug output will not be visible. The following levels are supported (discover more in DebugLib.h):

- 0x00000002 DEBUG_WARN in DEBUG, NOOPT, RELEASE.
- 0x00000040 DEBUG_INFO in DEBUG, NOOPT.
- 0x00400000 DEBUG_VERBOSE in custom builds.
- 0x80000000 DEBUG_ERROR in DEBUG, NOOPT, RELEASE.

3. ExposeBootPath

Type: plist boolean Default value: false

Description: Expose printable booter path to OpenCore.efi or its booter (depending on the load order) as an UEFI variable.

To obtain booter path use the following command in macOS:

nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:boot-path

To use booter path for mounting booter volume use the following command in macOS:

u=(nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:boot-path | sed 's/.*GPT,\([^,]*\),.*/\1/'); \ if ["\$u" != ""]; then sudo diskutil mount \$u ; fi

4. Target

Type: plist integer

Default value: 0

Description: A bitmask (sum) of enabled logging targets. By default all the logging output is hidden, so this option is required to be set when debugging is necessary.

The following logging targets are supported:

- 0x01 Enable logging, otherwise all log is discarded.
- 0x02 Enable basic console (onscreen) logging.
- 0x04 Enable logging to Data Hub.
- 0x08 Enable serial port logging.
- 0x10 Enable UEFI variable logging.
- 0x20 Enable non-volatile UEFI variable logging.
- 0x40 Enable logging to file.

Console logging prints less than all the other variants. Depending on the build type (RELEASE, DEBUG, or NOOPT) different amount of logging may be read (from least to most).

Data Hub log will not log kernel and kext patches. To obtain Data Hub log use the following command in macOS:

```
\mathbf{ioreg} \text{ -lw0 -p IODeviceTree} \mid \mathbf{grep} \text{ boot-log} \mid \mathbf{sort} \mid \mathbf{sed} \text{ 's/.*} < \backslash (.* \backslash) > .* / \backslash 1 / \text{'} \mid xxd \text{ -r -p } \rangle
```

UEFI variable log may get truncated on some firmwares. Using non-volatile flag will write the log to NVRAM flash after every printed line. To obtain UEFI variable log use the following command in macOS:

```
nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:boot-log | awk '{gsub(/%0d%0a%00/,"");gsub(/%0d%0a/,"\n")}1'
```

Note: File logging is currently not implemented.

7.5 Security Properties

1. HaltLevel

Type: plist integer, 64 bit

Default value: 0x80000000 (DEBUG_ERROR)

Description: EDK II debug level bitmask (sum) causing CPU to halt (stop execution) after obtaining a message of HaltLevel. Possible values match DisplayLevel values.

2. RequireSignature

Type: plist boolean
Default value: true

Description: Require vault.sig signature file for vault.plist in OC directory.

This file should contain a raw 256 byte RSA-2048 signature from SHA-256 hash of vault.plist. The signature is verified against the public key embedded into OpenCore.efi.

To embed the public key you should do either of the following:

- Provide public key during the OpenCore.efi compilation in OpenCoreVault.c file.
- Binary patch OpenCore.efi replacing zeroes with the public key between =BEGIN OC VAULT= and ==END OC VAULT== ASCII markers.

RSA public key 520 byte format description can be found in Chromium OS documentation. To convert public key from X.509 certificate or from PEM file use RsaTool.

Note: vault.sig is used regardless of this option when public key is embedded into OpenCore.efi. Setting it to true will only ensure configuration sanity, and abort the boot process when public key is not set but was supposed to be used for verification.

3. RequireVault

Type: plist boolean Default value: true

Description: Require vault.plist file present in OC directory.

This file should contain SHA-256 hashes for all files used by OpenCore. Presence of this file is highly recommended to ensure that unintentional file modifications (including filesystem corruption) do not happen unnoticed. To create this file automatically use create_vault.sh script.

Regardless of the underlying filesystem, path name and case must match between config.plist and vault.plist.

Note: vault.plist is tried to be read regardless of the value of this option, but setting it to true will ensure configuration sanity, and abort the boot process.

The complete set of commands to:

- Create vault.plist.
- Create a new RSA key (always do this to avoid loading old configuration).
- Embed RSA key into OpenCore.efi.
- Create vault.sig.

Can look as follows:

```
cd /Volumes/EFI/EFI/OC
/path/to/create_vault.sh .
/path/to/RsaTool -sign vault.plist vault.sig vault.pub
off=$(($(strings -a -t d OpenCore.efi | grep "=BEGIN OC VAULT=" | cut -f1 -d' ')+16))
dd of=OpenCore.efi if=vault.pub bs=1 seek=$off count=520 conv=notrunc
rm vault.pub
```

Note: While it may appear obvious, but you have to use an external method to verify OpenCore.efi and BOOTx64.efi for secure boot path. For this you are recommended to at least enable UEFI SecureBoot with a custom certificate, and sign OpenCore.efi and BOOTx64.efi with your custom key. More details on customising secure boot on modern firmwares can be found in Taming UEFI SecureBoot paper (in Russian).

8 NVRAM

8.1 Introduction

Has plist dict type and allows to set volatile UEFI variables commonly referred as NVRAM variables. Refer to man nvram for more details. macOS extensively uses NVRAM variables for OS — Bootloader — Firmware intercommunication, and thus supplying several NVRAM is required for proper macOS functioning.

Each NVRAM variable consists of its name, value, attributes (refer to UEFI specification), and its GUID, representing which 'section' NVRAM variable belongs to. macOS uses several GUIDs, including but not limited to:

- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14 (APPLE_VENDOR_VARIABLE_GUID)
- 7C436110-AB2A-4BBB-A880-FE41995C9F82 (APPLE_BOOT_VARIABLE_GUID)
- 8BE4DF61-93CA-11D2-AAOD-00E098032B8C (EFI_GLOBAL_VARIABLE_GUID)
- 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102 (OC_VENDOR_VARIABLE_GUID)

Note: Some of the variables may be added by PlatformNVRAM or Generic subsections of PlatformInfo section. Please ensure that variables of this section never collide with them, as behaviour is undefined otherwise.

8.2 Properties

1. Add

Type: plist dict

Description: Sets NVRAM variables from a map (plist dict) of GUIDs to a map (plist dict) of variable names and their values in plist metadata format. GUIDs must be provided in canonic string format in upper or lower case (e.g. 8BE4DF61-93CA-11D2-AAOD-00E098032B8C).

Created variables get EFI_VARIABLE_BOOTSERVICE_ACCESS and EFI_VARIABLE_RUNTIME_ACCESS attributes set. Variables will only be set if not present and not blocked. To overwrite a variable add it to Block section. This approach enables to provide default values till the operating system takes the lead.

Note: If plist key does not conform to GUID format, behaviour is undefined.

2. Block

Type: plist dict

Description: Removes NVRAM variables from a map (plist dict) of GUIDs to an array (plist array) of variable names in plist string format.

To read NVRAM variable value from macOS one could use nvram by concatenating variable GUID and name separated by: symbol. For example, nvram 7C436110-AB2A-4BBB-A880-FE41995C9F82:boot-args.

A continuously updated variable list can be found in a corresponding document: NVRAM Variables.

8.3 Mandatory Variables

Warning: These variables may be added by PlatformNVRAM or Generic subsections of PlatformInfo section. Using PlatformInfo is the recommend way of setting these variables.

The following variables are mandatory for macOS functioning:

- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeatures
 32-bit FirmwareFeatures. Present on all Macs to avoid extra parsing of SMBIOS tables
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeaturesMask 32-bit FirmwareFeaturesMask. Present on all Macs to avoid extra parsing of SMBIOS tables.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:MLB
 BoardSerialNumber. Present on newer Macs (2013+ at least) to avoid extra parsing of SMBIOS tables, especially in boot.efi.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ROM
 Primary network adapter MAC address or replacement value. Present on newer Macs (2013+ at least) to avoid accessing special memory region, especially in boot.efi.

8.4 Recommended Variables

The following variables are recommended for faster startup or other improvements:

- 7C436110-AB2A-4BBB-A880-FE41995C9F82:csr-active-config 32-bit System Integrity Protection bitmask. Declared in XNU source code in csr.h.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14: ExtendedFirmwareFeatures
 Combined FirmwareFeatures and ExtendedFirmwareFeatures. Present on newer Macs to avoid extra parsing of SMBIOS tables
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ExtendedFirmwareFeaturesMask

 Combined FirmwareFeaturesMask and ExtendedFirmwareFeaturesMask. Present on newer Macs to avoid extra parsing of SMBIOS tables.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW_BID Hardware BoardProduct (e.g. Mac-35C1E88140C3E6CF). Not present on real Macs, but used to avoid extra parsing of SMBIOS tables, especially in boot.efi.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW_MLB Hardware BoardSerialNumber. Override for MLB. Present on newer Macs (2013+ at least).
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW_ROM Hardware ROM. Override for ROM. Present on newer Macs (2013+ at least).
- 7C436110-AB2A-4BBB-A880-FE41995C9F82:prev-lang:kbd
 ASCII string defining default keyboard layout. Format is lang-COUNTRY:keyboard, e.g. ru-RU:19456 for Mac keyboard. Also accepts short forms: ru:19456 or ru:0. Full decoded list of keyboards in AppleKeyboardLayouts-L.dat can be found on AppleLife.
- 7C436110-AB2A-4BBB-A880-FE41995C9F82: security-mode
 ASCII string defining FireWire security mode. Legacy, can be found in IOFireWireFamily source code in
 IOFireWireController.cpp. It is recommended not to set this variable, which may speedup system startup. Setting
 to full is equivalent to not setting the variable and none disables FireWire security.
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:UIScale 8-bit integer defining boot.efi user interface scaling. Should be 1 for normal screens and 2 for HDPI screens.

8.5 Other Variables

The following variables may be useful for certain configurations or troubleshooting:

- 7C436110-AB2A-4BBB-A880-FE41995C9F82:boot-args
 - Kernel arguments, used to pass configuration to Apple kernel and drivers. There are many arguments, which may be found by looking for the use of PE parse boot argn function in the kernel or driver code.
 - FIXME: document several known values! debug, keepsyms, slide, -v, -s, -x, cpus=x, io=x, kextlog=x, -nehalem error disable -no compat check nvda drv=1, etc?
- 7C436110-AB2A-4BBB-A880-FE41995C9F82:bootercfg

Booter arguments, similar to boot-args but for boot.efi. Accepts a set of arguments, which are hexadecimal 64-bit values with or without 0x prefix primarily for logging control:

- log=VALUE
 - $*\ 1 AppleLoggingConOutOrErrSet/AppleLoggingConOutOrErrPrint\ (classical\ ConOut/StdErr)$
 - *~2 -- AppleLoggingStdErrSet/AppleLoggingStdErrPrint~(StdErr~or~serial?)
 - $*~4 -- {\it AppleLoggingFilePrint}~(BOOTER.LOG/BOOTER.OLD~file~on~EFI~partition)$
- debug=VALUE
 - * 1 enables print something to BOOTER.LOG (stripped code implies there may be a crash)
 - * 2 enables perf logging to /efi/debug-log in the device three
 - * 4 enables timestamp printing for styled printf calls
- level=VALUE Verbosity level of DEBUG output. Everything but 0x80000000 is stripped from the binary, and this is the default value.
- kc-read-size=VALUE Chunk size used for buffered I/O from network or disk for prelinkedkernel reading and related. Set to 1MB (0x100000) by default, can be tuned for faster booting.
- 7C436110-AB2A-4BBB-A880-FE41995C9F82:bootercfg-once

Booter arguments override removed after first launch. Otherwise equivalent to bootercfg.

- 7C436110-AB2A-4BBB-A880-FE41995C9F82:fmm-computer-name
- 7C436110-AB2A-4BBB-A880-FE41995C9F82:nvda_drv

9 PlatformInfo

Platform information is comprised of several identification fields generated or filled manually to be compatible with macOS services. The base part of the configuration may be obtained from MacInfoPkg package, which itself generates a set of interfaces based on a database in YAML format. These fields are written to three select destinations:

- SMBIOS
- Data Hub
- NVRAM

Most of the fields specify the overrides in SMBIOS, and their field names conform to EDK2 SmBios.h header file. However, several important fields reside in Data Hub and NVRAM. Some of the values can be found in more than one field and/or destination, so there are two ways to control their update process: manual, where one specifies all the values (the default), and semi-automatic, where (Automatic) only select values are specified, and later used for system configuration.

9.1 Properties

1. Automatic

Type: plist boolean Default value: false

Description: Generate PlatformInfo based on Generic section instead of using values from DataHub, NVRAM, and SMBIOS sections.

Enabling this option is useful when Generic section is flexible enough. When enabled SMBIOS, DataHub, and PlatformNVRAM data is unused.

2. UpdateDataHub

Type: plist boolean Default value: false

Description: Update DataHub fields. These fields are read from Generic or DataHub sections depending on Automatic value.

3. UpdateNVRAM

Type: plist boolean Default value: false

Description: Update NVRAM fields related to platform information.

These fields are read from Generic or PlatformNVRAM sections depending on Automatic value. All the other fields are to be specified with NVRAM section.

If UpdateNVRAM is set to false the aforementioned variables can be updated with NVRAM section. If UpdateNVRAM is set to true the behaviour is undefined when any of the fields are present in NVRAM section.

4. UpdateSMBIOS

Type: plist boolean Default value: false

Description: Update SMBIOS fields. These fields are read from **Generic** or **SMBIOS** sections depending on **Automatic** value.

5. UpdateSMBIOSMode

Type: plist string
Default value: Auto

Description: Update SMBIOS fields approach:

- Auto Overwrite if new size is <= than the page-aligned original and there are no issues with legacy region unlock. Create otherwise.
- Create Replace the tables with newly allocated EfiReservedMemoryType at AllocateMaxAddress without any fallbacks.
- Overwrite Overwrite existing gEfiSmbiosTableGuid and gEfiSmbiosTable3Guid data if it fits new size. Abort with unspecified state otherwise.
- Custom Write first SMBIOS table (gEfiSmbiosTableGuid) to gOcCustomSmbiosTableGuid to workaround firmwares overwriting SMBIOS contents at ExitBootServices. Otherwise equivalent to Create. Requires

patching AppleSmbios.kext and AppleACPIPlatform.kext to read from another GUID: "EB9D2D31" -> "EB9D2D35" (in ASCII).

6. Generic

Type: plist dictonary

Optional: When Automatic is false

Description: Update all fields. This section is read only when Automatic is active.

7. DataHub

Type: plist dictonary

Optional: When Automatic is true

Description: Update Data Hub fields. This section is read only when Automatic is not active.

8. PlatformNVRAM

Type: plist dictonary

Optional: When Automatic is true

Description: Update platform NVRAM fields. This section is read only when Automatic is not active.

9. SMBIOS

Type: plist dictonary

Optional: When Automatic is true

Description: Update SMBIOS fields. This section is read only when Automatic is not active.

9.2 Generic Properties

1. SystemProductName

Type: plist string
Default value: MacPro6,1

Description: Refer to SMBIOS SystemProductName.

2. SystemSerialNumber

Type: plist string

Default value: OPENCORE_SN1

Description: Refer to SMBIOS SystemSerialNumber.

 $3. \; {\tt SystemUUID}$

Type: plist string, GUID Default value: OEM specified

Description: Refer to SMBIOS SystemUUID.

 $4.\ \mathrm{MLB}$

Type: plist string

Default value: OPENCORE_MLB_SN11

Description: Refer to SMBIOS BoardSerialNumber.

5. ROM

Type: plist data, 6 bytes Default value: all zero

Description: Refer to 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ROM.

9.3 DataHub Properties

1. PlatformName

Type: plist string

Default value: Not installed

Description: Sets name in gEfiMiscSubClassGuid. Value found on Macs is platform in ASCII.

2. SystemProductName

Type: plist string

Default value: Not installed

 $\textbf{Description}: \ Sets \ \texttt{Model} \ in \ \texttt{gEfiMiscSubClassGuid}. \ \ Value \ found \ on \ Macs \ is \ equal \ to \ SMBIOS \ \texttt{SystemProductName}$

in Unicode.

$3. \ {\tt SystemSerialNumber}$

Type: plist string

Default value: Not installed

 $\textbf{Description} : \textbf{Sets SystemSerialNumber in gEfiMiscSubClassGuid}. \ \ Value \ found \ on \ Macs \ is \ equal \ to \ SMBIOS$

SystemSerialNumber in Unicode.

 $4. \; {\tt SystemUUID}$

Type: plist string, GUID Default value: Not installed

Description: Sets system-id in gEfiMiscSubClassGuid. Value found on Macs is equal to SMBIOS SystemUUID.

5. BoardProduct

Type: plist string

Default value: Not installed

 $\textbf{Description}: \ Sets\ \textbf{board-id}\ in\ \textbf{gEfiMiscSubClassGuid}.\ \ Value\ found\ on\ Macs\ is\ equal\ to\ SMBIOS\ \textbf{BoardProduct}$

in ASCII.

6. BoardRevision

Type: plist data, 1 byte

Default value: 0

Description: Sets board-rev in gEfiMiscSubClassGuid. Value found on Macs seems to correspond to internal

board revision (e.g. 01).

7. StartupPowerEvents

Type: plist integer, 64-bit

Default value: 0

Description: Sets StartupPowerEvents in gEfiMiscSubClassGuid. Value found on Macs is power management state bitmask, normally 0. Known bits read by X86PlatformPlugin.kext:

- 0x00000001 Shutdown cause was a PWROK event (Same as GEN_PMCON_2 bit 0)
- 0x00000002 Shutdown cause was a SYS PWROK event (Same as GEN PMCON 2 bit 1)
- 0x00000004 Shutdown cause was a THRMTRIP# event (Same as GEN PMCON 2 bit 3)
- 0x00000008 Rebooted due to a SYS RESET# event (Same as GEN_PMCON_2 bit 4)
- 0x00000010 Power Failure (Same as GEN_PMCON_3 bit 1 PWR_FLR)
- 0x00000020 Loss of RTC Well Power (Same as GEN_PMCON_3 bit 2 RTC_PWR_STS)
- 0x00000040 General Reset Status (Same as GEN_PMCON_3 bit 9 GEN_RST_STS)
- Oxffffff80 SUS Well Power Loss (Same as GEN_PMCON_3 bit 14)
- 0x00010000 Wake cause was a ME Wake event (Same as PRSTS bit 0, ME WAKE STS)
- 0x00020000 Cold Reboot was ME Induced event (Same as PRSTS bit 1 ME_HRST_COLD_STS)
- 0x00040000 Warm Reboot was ME Induced event (Same as PRSTS bit 2 ME HRST WARM STS)
- 0x00080000 Shutdown was ME Induced event (Same as PRSTS bit 3 ME_HOST_PWRDN)
- 0x00100000 Global reset ME Wachdog Timer event (Same as PRSTS bit 6)
- 0x00200000 Global reset PowerManagment Wachdog Timer event (Same as PRSTS bit 15)

8. InitialTSC

Type: plist integer, 64-bit

Default value: 0

Description: Sets InitialTSC in gEfiProcessorSubClassGuid. Sets initial TSC value, normally 0.

 $9. \ {\tt FSBFrequency}$

Type: plist integer, 64-bit Default value: Automatic

Description: Sets FSBFrequency in gEfiProcessorSubClassGuid. Sets CPU FSB frequency.

10. ARTFrequency

Type: plist integer, 64-bit Default value: Not installed

 $\textbf{Description:} \ \ \textbf{Sets} \ \ \textbf{ARTFrequency} \ \ \textbf{in} \ \ \textbf{gEfiProcessorSubClassGuid.} \ \ \textbf{Sets} \ \ \textbf{CPU} \ \ \textbf{ART} \ \ \textbf{frequency,} \ \ \textbf{Skylake} \ \ \textbf{and} \ \ \textbf{Sets} \ \ \textbf{CPU} \ \ \textbf{ART} \ \ \textbf{frequency,} \ \ \textbf{Skylake} \ \ \textbf{and} \ \ \textbf{Sets} \ \ \textbf{CPU} \ \ \textbf{ART} \ \ \textbf{frequency,} \ \ \textbf{Skylake} \ \ \textbf{and} \ \ \textbf{Sets} \ \ \textbf{CPU} \ \ \textbf{ART} \ \ \textbf{Sets} \ \ \textbf{CPU} \ \ \textbf{ART} \ \ \textbf{Sets} \ \ \textbf{$

newer.

11. DevicePathsSupported

Type: plist data, 1 byte

Default value: Not installed

Description: Sets DevicePathsSupported in gEfiMiscSubClassGuid. Must be set to 01 for AppleACPIPlatform.kext to append SATA device paths to Boot#### and efi-boot-device-data variables. Set to 01 on all modern Macs.

12. SmcRevision

Type: plist data, 6 bytes Default value: Not installed

Description: Sets REV in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate

SMC REV key.

13. SmcBranch

Type: plist data, 8 bytes Default value: Not installed

Description: Sets RBr in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate

SMC RBr key.

14. SmcPlatform

Type: plist data, 8 bytes Default value: Not installed

Description: Sets RPlt in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to

generate SMC RPlt key.

9.4 PlatformNVRAM Properties

1. BID

Type: plist string

Default value: Not installed

Description: Specifies the value of NVRAM variable 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW BID.

 $2. \ {\tt ROM}$

Type: plist data, 6 bytes Default value: Not installed

Description: Specifies the values of NVRAM variables 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW_ROM and

4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ROM.

3. MLB

Type: plist string

Default value: Not installed

Description: Specifies the values of NVRAM variables 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW_MLB and

4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:MLB.

4. FirmwareFeatures

Type: plist data, 8 bytes Default value: Not installed

Description: This variable comes in pair with FirmwareFeaturesMask. Specifies the values of NVRAM variables:

• 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeatures

• 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ExtendedFirmwareFeatures

5. FirmwareFeaturesMask

Type: plist data, 8 bytes Default value: Not installed

Description: This variable comes in pair with FirmwareFeatures. Specifies the values of NVRAM variables:

- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeaturesMask
- 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ExtendedFirmwareFeaturesMask

9.5 SMBIOS Properties

1. BIOSVendor

Type: plist string

Default value: OEM specified

SMBIOS: BIOS Information (Type 0) — Vendor

Description: BIOS Vendor. All rules of SystemManufacturer do apply.

2. BIOSVersion

Type: plist string

Default value: OEM specified

SMBIOS: BIOS Information (Type 0) — BIOS Version

Description: Firmware version. This value gets updated and takes part in update delivery configuration and macOS version compatibility. This value could look like MM71.88Z.0234.B00.1809171422 in older firmwares, and is described in BiosId.h. In newer firmwares it should look like 236.0.0.0.0 or 220.230.16.0.0 (iBridge: 16.16.2542.0.0,0). iBridge version is read from BridgeOSVersion variable, and is only present on macs with T2.

Apple ROM Version

BIOS ID: MBP151.88Z.F000.B00.1811142212

Model: MBP151

EFI Version: 220.230.16.0.0 Built by: root@quinoa

Date: Wed Nov 14 22:12:53 2018

Revision: 220.230.16 (B&I)

ROM Version: F000_B00

Build Type: Official Build, RELEASE

Compiler: Apple LLVM version 10.0.0 (clang-1000.2.42)

UUID: E5D1475B-29FF-32BA-8552-682622BA42E1
UUID: 151B0907-10F9-3271-87CD-4BF5DBECACF5

3. BIOSReleaseDate

Type: plist string

Default value: OEM specified

SMBIOS: BIOS Information (Type 0) — BIOS Release Date

Description: Firmware release date. Similar to BIOSVersion. May look like 12/08/2017.

4. SystemManufacturer

Type: plist string

Default value: OEM specified

SMBIOS: System Information (Type 1) — Manufacturer

Description: OEM manufacturer of the particular board. Shall not be specified unless strictly required. Should *not* contain Apple Inc., as this confuses numerous services present in the operating system, such as firmware updates, eficheck, as well as kernel extensions developed in Acidanthera, such as Lilu and its plugins.

5. SystemProductName

Type: plist string

Default value: OEM specified

SMBIOS: System Information (Type 1), Product Name

Description: Preferred Mac model used to mark the device as supported by the operating system. This value must be specified by any configuration for later automatic generation of the related values in this and other SMBIOS tables and related configuration parameters. If SystemProductName is not compatible with the target operating system, -no_compat_check boot argument may be used as an override.

Note: If SystemProductName is unknown, and related fields are unspecified, default values should be assumed as being set to MacPro6,1 data. The list of known products can be found in MacInfoPkg.

6. SystemVersion

Type: plist string

Default value: OEM specified

SMBIOS: System Information (Type 1) — Version

Description: Product iteration version number. May look like 1.1.

7. SystemSerialNumber

Type: plist string

Default value: OEM specified

SMBIOS: System Information (Type 1) — Serial Number

Description: Product serial number in defined format. Known formats are described in macserial.

 $8. \; {\tt SystemUUID}$

Type: plist string, GUID Default value: OEM specified

SMBIOS: System Information (Type 1) — UUID

Description: A UUID is an identifier that is designed to be unique across both time and space. It requires no central registration process.

9. SystemSKUNumber

Type: plist string

Default value: OEM specified

SMBIOS: System Information (Type 1) — SKU Number

Description: Mac Board ID (board-id). May look like Mac-7BA5B2D9E42DDD94 or Mac-F221BEC8 in older

models. Sometimes it can be just empty.

10. SystemFamily

Type: plist string

Default value: OEM specified

SMBIOS: System Information (Type 1) — Family **Description**: Family name. May look like iMac Pro.

11. BoardManufacturer

Type: plist string

Default value: OEM specified

SMBIOS: Baseboard (or Module) Information (Type 2) - Manufacturer **Description**: Board manufacturer. All rules of SystemManufacturer do apply.

12. BoardProduct

Type: plist string

Default value: OEM specified

SMBIOS: Baseboard (or Module) Information (Type 2) - Product

Description: Mac Board ID (board-id). May look like Mac-7BA5B2D9E42DDD94 or Mac-F221BEC8 in older

models.

13. BoardVersion

Type: plist string

Default value: OEM specified

 $\mathbf{SMBIOS} :$ Baseboard (or Module) Information (Type 2) - Version

Description: Board version number. Varies, may match SystemProductName or SystemProductVersion.

14. BoardSerialNumber

Type: plist string

Default value: OEM specified

SMBIOS: Baseboard (or Module) Information (Type 2) — Serial Number

Description: Board serial number in defined format. Known formats are described in macserial.

 $15. \ {\tt BoardAssetTag}$

Type: plist string

Default value: OEM specified

SMBIOS: Baseboard (or Module) Information (Type 2) — Asset Tag

Description: Asset tag number. Varies, may be empty or Type2 - Board Asset Tag.

16. BoardType

Type: plist integer

Default value: OEM specified

SMBIOS: Baseboard (or Module) Information (Type 2) — Board Type

Description: Either OxA (Motherboard (includes processor, memory, and I/O) or OxB (Processor/Memory

Module), refer to Table 15 – Baseboard: Board Type for more details.

17. BoardLocationInChassis

Type: plist string

Default value: OEM specified

SMBIOS: Baseboard (or Module) Information (Type 2) — Location in Chassis

Description: Varies, may be empty or Part Component.

$18. \ {\tt ChassisManufacturer}$

Type: plist string

Default value: OEM specified

SMBIOS: System Enclosure or Chassis (Type 3) — Manufacturer

Description: Board manufacturer. All rules of SystemManufacturer do apply.

19. ChassisType

Type: plist integer

Default value: OEM specified

SMBIOS: System Enclosure or Chassis (Type 3) — Type

Description: Chassis type, refer to Table 17 — System Enclosure or Chassis Types for more details.

20. ChassisVersion

Type: plist string

Default value: OEM specified

SMBIOS: System Enclosure or Chassis (Type 3) — Version

Description: Should match BoardProduct.

21. ChassisSerialNumber

Type: plist string

Default value : OEM specified

SMBIOS: System Enclosure or Chassis (Type 3) — Version

Description: Should match SystemSerialNumber.

22. ChassisAssetTag

Type: plist string

Default value: OEM specified

SMBIOS: System Enclosure or Chassis (Type 3) — Asset Tag Number

Description: Chassis type name. Varies, could be empty or MacBook-Aluminum.

23. PlatformFeature

Type: plist integer Default value: 0

SMBIOS: APPLE_SMBIOS_TABLE_TYPE133 - PlatformFeature

Description: Platform features bitmask. Refer to AppleFeatures.h for more details.

24. FirmwareFeatures

Type: plist data, 8 bytes

Default value: 0

SMBIOS: APPLE_SMBIOS_TABLE_TYPE128 - FirmwareFeatures and ExtendedFirmwareFeatures

Description: 64-bit firmware features bitmask. Refer to AppleFeatures.h for more details. Lower 32 bits match

 ${\tt Firmware Features.}\ \ {\tt Upper}\ 64\ {\tt bits}\ {\tt match}\ {\tt Extended Firmware Features}.$

$25. \ {\tt FirmwareFeaturesMask}$

Type: plist data, 8 bytes

Default value: 0

 ${\bf SMBIOS: APPLE_SMBIOS_TABLE_TYPE128 - Firmware Features Mask } \ {\rm and} \ {\tt ExtendedFirmware Features Mask}$

Description: Supported bits of extended firmware features bitmask. Refer to AppleFeatures.h for more details. Lower 32 bits match FirmwareFeaturesMask. Upper 64 bits match ExtendedFirmwareFeaturesMask.

26. ProcessorType

Type: plist integer, 16-bit Default value: Automatic

SMBIOS: APPLE_SMBIOS_TABLE_TYPE131 - ProcessorType **Description**: Combined of Processor Major and Minor types.

27. MemoryFormFactor
Type: plist integer, 8-bit
Default value: OEM specified
SMBIOS: Memory Device (Type 17) — Form Factor
Description: Memory form factor. On Macs it should be DIMM or SODIMM.

10 UEFI

10.1 Introduction

UEFI (Unified Extensible Firmware Interface) is a specification that defines a software interface between an operating system and platform firmware. This section allows to load additional UEFI modules and/or apply tweaks for the onboard firmware.

10.2 Properties

1. ConnectDrivers

Type: plist boolean Default value: NO

Description: Perform UEFI controller connection after driver loading. This option is useful for loading filesystem drivers, which usually follow UEFI driver model, and may not start by themselves. While effective, this option is not necessary with e.g. APFS loader driver, and may slightly slowdown the boot.

2. Drivers

Type: plist array Default value: None

Description: Load selected drivers from OC/Drivers directory.

Designed to be filled with string filenames meant to be loaded as UEFI drivers. Depending on the firmware a different set of drivers may be required. Loading an incompatible driver may lead your system to unbootable state or even cause permanent firmware damage. Some of the known drivers include:

- ApfsDriverLoader APFS file system bootstrap driver adding the support of embedded APFS drivers in bootable APFS containers in UEFI firmwares.
- AppleUiSupport Apple-specific user interface support driver. This driver brings the support for FileVault 2 GUI, hotkey parsing (shift, cmd+v, etc.), language collation support, and certain other features important for normal macOS functioning. For hotkey support AppleKeyMapAggregator-compatible driver is required.
- AptioInputFix user input driver adding the support of AppleKeyMapAggregator protocols on top of different UEFI input protocols. Additionally resolves mouse input issues on select firmwares. This is an alternative to UsbKbDxe, which may work better or worse depending on the firmware.
- AptioMemoryFix a set of quirks for various firmwares. While it primarily targets APTIO firmwares, other
 firmwares may be compatible as well. Among the resolved issues are hibernation support, KASLR, Lilu
 NVRAM security enhancements, NVRAM, and UEFI Boot entry preservation.
- DataHubDxe Intel DataHub driver from IntelFrameworkModulePkg. It is believed that this driver is included in all UEFI firmwares, and is not required.
- EmuVariableRuntimeDxe NVRAM emulation driver from MdeModulePkg. NVRAM is supported by most modern firmwares. For firmwares with macOS incompatible NVRAM implementation an emulated driver may be used. This driver will not preserve NVRAM contents across the reboots.
- EnglishDxe Unicode collation driver from MdeModulePkg. This driver is a lightweight alternative to AppleUiSupport, which contains no Apple-specific code, and only provides unicode collation support. The driver is not recommended for use on any hardware but few original Macs.
- EnhancedFatDxe FAT filesystem driver from FatPkg. This driver is embedded in all UEFI firmwares, and cannot be used from OpenCore. It is known that multiple firmwares have a bug in their FAT support implementation, which leads to corrupted filesystems on write attempt. Embedding this driver within the firmware may be required in case writing to EFI partition is needed during the boot process.
- NvmExpressDxe NVMe support driver from MdeModulePkg. This driver is included in most firmwares starting with Broadwell generation. For Haswell and earlier embedding it within the firmware may be more favourable in case a NVMe SSD drive is installed.
- UsbKbDxe USB keyboard driver adding the support of AppleKeyMapAggregator protocols on top of a custom USB keyboard driver implementation. This is an alternative to AptioInputFix, which may work better or worse depending on the firmware.
- VirtualSmc UEFI SMC driver, required for proper FileVault 2 functionality and potentially other macOS specifics. An alternative, named SMCHelper, is not compatible with VirtualSmc and OpenCore, which is unaware of its specific interfaces. In case FakeSMC kernel extension is used, manual NVRAM variable addition may be needed and VirtualSmc driver should still be used.

• VBoxHfs — HFS file system driver with bless support. This driver is an alternative to a closed source HFSPlus driver commonly found in Apple firmwares. While it is feature complete, it is approximately 3 times slower and is yet to undergo a security audit.

To compile the drivers from TianoCore UDK use the same command you do normally use for OpenCore compilation, but choose a corresponding package:

git clone https://github.com/tianocore/edk2 -b UDK2018 UDK

cd UDK

source edksetup.sh

make -C BaseTools

build -a X64 -b RELEASE -t XCODE5 -p FatPkg/FatPkg.dsc

build -a X64 -b RELEASE -t XCODE5 -p MdeModulePkg/MdeModulePkg.dsc

build -a X64 -b RELEASE -t XCODE5 -p IntelFrameworkModulePkg/IntelFrameworkModulePkg.dsc

3. Protocols

Type: plist dict Default value: None

Description: Force builtin versions of select protocols described in Protocols Properties section below.

4. Quirks

Type: plist dict Default value: None

Description: Apply individual firmware quirks described in Quirks Properties section below.

10.3 Protocols Properties

1. AppleBootPolicy

Type: plist boolean Default value: false

Description: Reinstalls apple boot policy protocol with a builtin version. This may be used to ensure APFS compatibility on VMs or legacy Macs.

2. DeviceProperties

Type: plist boolean Default value: false

Description: Reinstalls device property protocol with a builtin version. This will drop all previous properties if it was already installed. This may be used to ensure full compatibility on VMs or legacy Macs.

10.4 Quirks Properties

1. DisableWatchDog

Type: plist boolean Default value: NO

Description: Select firmwares may not succeed in quickly booting the operating system, which results in watch dog timer aborting the process. This option turns off watch dog timer.

Note: This option is believed to be unnecessary on modern firmwares, yet may be safer to turn on as system performance across the boots is not constant.

2. IgnoreInvalidFlexRatio

Type: plist boolean
Default value: NO

Description: Select firmwares, namely APTIO IV, may contain invalid values in MSR_FLEX_RATIO (0x194) MSR register. These values may cause macOS boot failure on Intel platforms.

Note: While the option is not supposed to induce harm on unaffected firmwares, its usage is not recommended when it is not required.

3. IgnoreTextInGraphics

Type: plist boolean
Default value: NO

Description: Select firmwares output text onscreen in both graphics and text mode. This is normally unexpected, because random text may appear over graphical images and cause UI corruption. Setting this option to true will discard all text output when console control is in mode different from Text.

Note: While the option is not supposed to induce harm on unaffected firmwares, its usage is not recommended when it is not required. This option may hide onscreen error messages. ProvideConsoleControl is required to be set to true for this to work.

4. ProvideConsoleControl

Type: plist boolean Default value: NO

Description: macOS bootloader requires console control protocol for text output, some firmwares miss it. This option is required to be set when other console control options are used, such as IgnoreTextInGraphics, SanitiseClearScreen, and sometimes ConsoleBehaviourOs with ConsoleBehaviourUi).

5. ProvideConsoleGop

Type: plist boolean Default value: NO

Description: macOS bootloader requires GOP (Graphics Output Protocol) to be present on console handle. This option will install it if missing.

Note: Some drivers, like AptioMemoryFix, may provide equivalent functionality. These drivers are not guaranteed to adhere to the same logic, and if a quirk is necessary, this option is preferred.

6. ReleaseUsbOwnership

Type: plist boolean Default value: false

Description: Attempt to detach USB controller ownership from the firmware driver. While most firmwares manage to properly do that, or at least have an option for, select firmwares do not. As a result, operating system may freeze upon boot. Not recommended unless required.

7. RequestBootVarRouting

Type: plist boolean Default value: false

Description: Request NVRAM driver (or AptioMemoryFix) to redirect Boot prefixed variables from EFI_GLOBAL_VARIABLE_C to OC_VENDOR_VARIABLE_GUID.

This will set special boot-redirect variable, which a compatible driver will abide after booter start. The quirk lets default boot entry preservation at times when firmwares delete incompatible boot entries.

8. SanitiseClearScreen

Type: plist boolean Default value: false

Description: Some firmwares reset screen resolution to a failsafe value (like 1024x768) on the attempts to clear screen contents when large display (e.g. 2K or 4K) is used. This option attempts to apply a workaround.

Note: ProvideConsoleControl is required to be set to true for this to work. On all known affected systems ConsoleMode had to be set to empty string for this to work.

11 Troubleshooting

11.1 Tips and Tricks

1. How to debug boot failure?

Normally it is enough to obtain the actual error message. For this ensure that:

- You have a DEBUG or NOOPT version of OpenCore.
- Logging is enabled (1) and shown onscreen (2): Misc \rightarrow Debug \rightarrow Target = 3.
- Logged messages from at least DEBUG_ERROR (0x80000000), DEBUG_WARN (0x00000002), and DEBUG_INFO (0x000000040) levels are visible onscreen: Misc → Debug → DisplayLevel = 0x80000042.
- Critical error messages, like DEBUG_ERROR, stop booting: Misc → Security → HaltLevel = 0x80000000.
- Watch Dog is disabled to prevent automatic reboot: Uefi → Quirks → DisableWatchDog = true.
- Boot Picker (entry selector) is enabled: $Misc \rightarrow Boot \rightarrow ShowPicker = true$.

If there is no obvious error, check the available hacks in Quirks sections one by one.

2. How to customise boot entries?

OpenCore follows standard Apple Bless model and extracts the entry name from .contentDetails and .disk_label.contentDetails files in the booter directory if present. These files contain an ASCII string with an entry title, which may then be customised by the user.

3. What is the simplest way to install macOS?

Copy online recovery image (*.dmg and *.chunklist files) to com.apple.recovery.boot directory on a FAT32 partition with OpenCore. Load OpenCore Boot Picker and choose the entry, it will have a (dmg) suffix. Custom name may be created by providing .contentDetails file.

To download recovery online you may use Recovery tool from OcSupportPkg.