



OpenCore

Reference Manual (0.6.~~6~~.7)

[2021.02.14]

- **boot**
Duet bootstrap loader, which initialises UEFI environment on legacy BIOS firmware and loads `OpenCore.efi` similarly to other bootstrap loaders. Modern Duet bootstrap loader will default to `OpenCore.efi` on the same partition when present.
- **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.
- **Resources**
Directory used for storing media resources, such as audio files for screen reader support. See **UEFI Audio Properties** section for more details. This directory also contains image files for graphical user interface. See **OpenCanopy** section for more details.
- **Tools**
Directory used for storing supplemental tools.
- **OpenCore.efi**
Main booter application responsible for operating system loading. The directory `OpenCore.efi` resides is called the **root directory**. By default **root directory** is set to `EFI\OC`, however, when launching `OpenCore.efi` directly or through a custom launcher, other directories containing `OpenCore.efi` can also be supported.
- **config.plist**
OC Config.
- **vault.plist**
Hashes for all files potentially loadable by OC Config.
- **vault.sig**
Signature for `vault.plist`.
- **SysReport**
Directory containing system reports generated by `SysReport` option.
- **nvram.plist**
OpenCore variable import file.
- **opencore-YYYY-MM-DD-HHMMSS.txt**
OpenCore log file.
- **panic-YYYY-MM-DD-HHMMSS.txt**
Kernel panic log file.

Note: It is not guaranteed that paths longer than `OC_STORAGE_SAFE_PATH_MAX` (128 characters including [the](#) 0-terminator) will be accessible within OpenCore.

3.2 Installation and Upgrade

To install OpenCore, ~~reflect~~, [replicate](#) the Configuration Structure described in the previous section on a EFI volume of a GPT partition. While corresponding sections of this document do provide some information regarding external resources such as ACPI tables, UEFI drivers, or kernel extensions (kexts), completeness of the matter is out of the scope of this document. Information about kernel extensions may be found in a separate Kext List document available in [the](#) OpenCore repository. Vaulting information is provided in [the](#) Security Properties section of this document.

~~The OC config, just like any property lists file, as with any property list file,~~ can be edited with any ~~stock textual editor (e.g. nano, vim), but text editor such as nano and vim.~~ However, specialised software may provide [a](#) better experience. On macOS, the preferred GUI application is Xcode. For a lightweight cross-platform and open-source alternative, [the](#) ProperTree editor can be utilised.

For BIOS booting, a third-party UEFI environment provider will have to be used. `OpenDuetPkg` is one of the known UEFI environment providers for legacy systems. To run OpenCore on such a legacy system, `OpenDuetPkg` can be installed with a dedicated tool — `BootInstall` (bundled with OpenCore). Third-party utilities can be used to perform this on systems other than macOS.

For upgrade purposes ~~refer to,~~ [refer to the Differences.pdf document](#), ~~providing the information about the changes affecting the configuration which provides information about changes to the configuration as~~ compared to the previous release, ~~and as well as to the Changelog.md document, containing the which contains a~~ list of modifications across all published updates.

3.3 Contribution

OpenCore can be compiled as an ordinary EDK II package. Since UDK development was abandoned by TianoCore, OpenCore requires the use of EDK II Stable. ~~Currently~~The currently supported EDK II release is hosted in acidanthera/audk. ~~The required patches for the package are present in~~Required patches for this package can be found in the Patches directory.

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

To compile with XCODE5, besides Xcode, ~~one~~users should also install NASM and MTOC. The latest Xcode version is recommended for use despite the toolchain name. ~~Example command sequence may look~~An example command sequence is as follows:

```
git clone --depth=1 https://github.com/acidanthera/audk UDK
cd UDK
git submodule update --init --recommend-shallow
git clone --depth=1 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

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 the UDK root:

```
-I/UefiPackages/MdePkg
-I/UefiPackages/MdePkg/Include
-I/UefiPackages/MdePkg/Include/X64
-I/UefiPackages/MdeModulePkg
-I/UefiPackages/MdeModulePkg/Include
-I/UefiPackages/MdeModulePkg/Include/X64
-I/UefiPackages/OpenCorePkg/Include/AMI
-I/UefiPackages/OpenCorePkg/Include/Acidanthera
-I/UefiPackages/OpenCorePkg/Include/Apple
-I/UefiPackages/OpenCorePkg/Include/Apple/X64
-I/UefiPackages/OpenCorePkg/Include/Duet
-I/UefiPackages/OpenCorePkg/Include/Generic
-I/UefiPackages/OpenCorePkg/Include/Intel
-I/UefiPackages/OpenCorePkg/Include/Microsoft
-I/UefiPackages/OpenCorePkg/Include/VMware
-I/UefiPackages/OvmfPkg/Include
-I/UefiPackages/UefiCpuPkg/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
-DOC_TARGET_NOOPT=1
-DNO_MSABI_VA_FUNCS=1
```

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`, `_PRW`) for implementation. Modern hardware needs little changes to maintain ACPI compatibility, yet some of those are provided as a part of OpenCore.

To compile and disassemble ACPI tables iASL compiler can be used developed by ACPICA. GUI front-end to iASL compiler can be downloaded from Acidanthera/MaciASL.

ACPI changes apply globally (to every operating system) with the following effective order:

- `Patch` is processed.
- `Delete` is processed.
- `Add` is processed.
- `Quirks` are processed.

Applying the changes globally resolves the problems of incorrect operating system detection, which is not possible before the operating system boots according to the ACPI specification, operating system chainloading, and harder ACPI debugging. For this reason it may be required to carefully use `_OSI` method when writing the changes.

Applying the patches early makes it possible to write so called “proxy” patches, where the original method is patched in the original table and is implemented in the patched table.

There are many places providing ACPI tables and workarounds. Commonly used ACPI tables are provided with OpenCore, VirtualSMC, VoodooPS2, and WhateverGreen releases. Besides those there are several third-party instructions commonly found on AppleLife in Laboratory and DSDT subforums (e.g. Battery register splitting guide). A slightly more user-friendly explanation of some tables included with OpenCore can also be found in Dortania’s Getting started with ACPI guide. For more exotic cases there also are several other places including daliansky’s ACPI sample collection, but the quality of the suggested solutions will vary from case to case.

4.2 Properties

1. Add

Type: `plist array`

Failsafe: Empty

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

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

2. Delete

Type: `plist array`

Failsafe: Empty

Description: Remove selected tables from ACPI stack.

Designed to be filled with `plist dict` values, describing each delete entry. See Delete Properties section below.

3. Patch

Type: `plist array`

Failsafe: 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
Failsafe: Empty string
Description: Arbitrary ASCII string used to provide human readable reference for the entry. ~~It is implementation defined whether~~ Whether this value is used is implementation defined.
2. Enabled
Type: plist boolean
Failsafe: false
Description: This ACPI table will not be added unless set to **true**.
3. Path
Type: plist string
Failsafe: Empty string
Description: File paths meant to be loaded as ACPI tables. Example values include DSDT.aml, SubDir/SSDT-8.aml, SSDT-USBX.aml, etc.

ACPI table load order follows the item order in the array. All ACPI tables load from OC/ACPI 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 Delete Properties

1. All
Type: plist boolean
Failsafe: false
Description: If set to **true**, all ACPI tables matching the condition will be deleted. Otherwise only first matched table.
2. Comment
Type: plist string
Failsafe: Empty string
Description: Arbitrary ASCII string used to provide human readable reference for the entry. ~~It is implementation defined whether~~ Whether this value is used is implementation defined.
3. Enabled
Type: plist boolean
Failsafe: false
Description: This ACPI table will not be removed unless set to **true**.
4. OemTableId
Type: plist data, 8 bytes
Failsafe: All zero
Description: Match table OEM ID to be equal to this value unless all zero.
5. TableLength
Type: plist integer
Failsafe: 0
Description: Match table size to be equal to this value unless 0.
6. TableSignature
Type: plist data, 4 bytes
Failsafe: All zero
Description: Match table signature to be equal to this value unless all zero.

Note: Make sure not to specify table signature when the sequence needs to be replaced in multiple places. Especially when performing different kinds of renames.

4.5 Patch Properties

1. Comment
Type: plist string
Failsafe: Empty string
Description: Arbitrary ASCII string used to provide human readable reference for the entry. ~~It is implementation defined whether~~ Whether this value is used is implementation defined.
2. Count
Type: plist integer
Failsafe: 0
Description: Number of patch occurrences to apply. 0 applies the patch to all occurrences found.
3. Enabled
Type: plist boolean
Failsafe: false
Description: This ACPI patch will not be used unless set to true.
4. Find
Type: plist data
Failsafe: Empty data
Description: Data to find. Must be equal to Replace in size if set.
5. Limit
Type: plist integer
Failsafe: 0 (Search entire ACPI table)
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
Failsafe: Empty ~~data~~ (Ignored)
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~~ Must be equal to Replace in size ~~otherwise~~ if set.
7. OemTableId
Type: plist data, 8 bytes
Failsafe: All zero
Description: Match table OEM ID to be equal to this value unless all zero.
8. Replace
Type: plist data
Failsafe: Empty data
Description: Replacement data of one or more bytes.
9. ReplaceMask
Type: plist data
Failsafe: Empty ~~data~~ (Ignored)
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~~ Must be equal to Replace in size ~~otherwise~~ if set.
10. Skip
Type: plist integer
Failsafe: 0
Description: Number of found occurrences to be skipped before replacement is done.
11. TableLength
Type: plist integer
Failsafe: 0
Description: Match table size to be equal to this value unless 0.
12. TableSignature
Type: plist data, 4 bytes

Failsafe: 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 EC0), 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.
- Try to avoid patching `_OSI` to support a higher level of feature sets whenever possible. Commonly this enables a number of hacks on APTIO firmware, which result in the need to add more patches. Modern firmware generally does not need it, and those that do are fine with much smaller patches. However, laptop vendors usually rely on this method to determine the availability of functions such as modern I2C input support, thermal adjustment and custom feature additions.
- Avoid patching embedded controller event `_Qxx` just for enabling brightness keys. The conventional process to find these keys usually involves massive modification on DSDT and SSDTs and the debug kext is not stable on newer systems. Please switch to built-in brightness key discovery of BrightnessKeys instead.
- ~~Try to avoid hacky~~ Avoid making ad hoc changes such as renaming `_PRW` 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 `A0 10 93 4F 53 46 4C 00` with `A4 0A 0F A3 A3 A3 A3`.
- To provide custom method implementation with in an SSDT, for instance, to inject shutdown fix on certain computers, the original method can be replaced with a dummy name by patching `_PTS` with `ZPTS` and adding a callback to original method.

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

Note: Patches of different **Find** and **Replace** lengths are unsupported as they may corrupt ACPI tables and make the system unstable due to area relocation. If such changes are needed, the utilisation of “proxy” patching or the padding of NOP to the remaining area might be taken into account.

4.6 Quirks Properties

1. FadtEnableReset

Type: plist boolean

Failsafe: false

Description: Provide reset register and flag in FADT table to enable reboot and shutdown.

Mainly required on legacy hardware and few laptops. Can also fix power-button shortcuts. Not recommended unless required.

2. NormalizeHeaders

Type: plist boolean

Failsafe: 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).

3. RebaseRegions

Type: plist boolean

Failsafe: 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.

5.3 MmioWhitelist Properties

1. Address

Type: plist integer

Failsafe: 0

Description: Exceptional MMIO address, which memory descriptor should be left virtualised (unchanged) by DevirtualiseMmio. This means that the firmware will be able to directly communicate with this memory region during operating system functioning, because the region this value is in will be assigned a virtual address.

The addresses written here must be part of the memory map, have EfiMemoryMappedIO type and EFI_MEMORY_RUNTIME attribute (highest bit) set. To find the list of the candidates the debug log can be used.

2. Comment

Type: plist string

Failsafe: Empty string

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

3. Enabled

Type: plist boolean

Failsafe: false

Description: This address will be devirtualised unless set to true.

5.4 Patch Properties

1. Arch

Type: plist string

Failsafe: Any

Description: Booter patch architecture (Any, i386, x86_64).

2. Comment

Type: plist string

Failsafe: Empty string

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

3. Count

Type: plist integer

Failsafe: 0

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

4. Enabled

Type: plist boolean

Failsafe: false

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

5. Find

Type: plist data

Failsafe: Empty data

Description: Data to find. ~~This must~~ Must be equal to Replace in size if set.

6. Identifier

Type: plist string

Failsafe: ~~Empty string~~ Any (Match any booter)

Description: Apple for macOS booter (generally boot.efi); or a name with ~~suffix (e.g. a suffix, such as bootmgfw.efi)~~ for a specific booter; ~~or Any / empty string (failsafe) to match any booter.~~

7. Limit

Type: plist integer

Failsafe: 0 (Search the entire booter)

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

8. Mask

Type: plist data

Failsafe: Empty ~~data~~ (Ignored)

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~~ Must be equal to Find in size ~~otherwise~~ if set.
9. Replace

Type: plist data

Failsafe: Empty ~~data~~

Description: Replacement data of one or more bytes.
10. ReplaceMask

Type: plist data

Failsafe: Empty ~~data~~ (Ignored)

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~~ Must be equal to Replace in size ~~otherwise~~ if set.
11. Skip

Type: plist integer

Failsafe: 0

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

5.5 Quirks Properties

1. AllowRelocationBlock

Type: plist boolean

Failsafe: false

Description: Allows booting macOS through a relocation block.

Relocation block is a scratch buffer allocated in lower 4 GB to be used for loading the kernel and related structures by EfiBoot on firmwares where lower memory is otherwise occupied by the (assumed to be) non-runtime data. Right before kernel startup the relocation block is copied back to lower addresses. Similarly all the other addresses pointing to relocation block are also carefully adjusted. Relocation block can be used when:

- No better slide exists (all the memory is used)
- `slide=0` is forced (by an argument or safe mode)
- KASLR (slide) is unsupported (this is macOS 10.7 or older)

This quirk requires `ProvideCustomSlide` to also be enabled and generally needs `AvoidRuntimeDefrag` to work correctly. Hibernation is not supported when booting with a relocation block (but relocation block is not always used when the quirk is enabled).

Note: While this quirk is required to run older macOS versions on platforms with used lower memory it is not compatible with some hardware and macOS 11. In ~~this case one may try to use~~ such cases, consider using `EnableSafeModeSlide` instead.

2. AvoidRuntimeDefrag

Type: plist boolean

Failsafe: false

Description: Protect from boot.efi runtime memory defragmentation.

This option fixes UEFI runtime services (date, time, NVRAM, power control, etc.) support on firmware that uses SMM backing for select services such as variable storage. SMM may try to access physical addresses, but they get moved by boot.efi.

Note: Most types of firmware, apart from Apple and VMware, need this quirk.

3. DevirtualiseMmio

Type: plist boolean

Failsafe: false

Description: Remove runtime attribute from select MMIO regions.

This option reduces stolen memory footprint from the memory map by removing runtime bit for known memory regions. This quirk may result in the increase of KASLR slides available, but is not necessarily compatible with

7. Scheme

Type: plist dict

Description: Define kernelspace operation mode via parameters described in Scheme Properties section below.

7.3 Add Properties

1. Arch

Type: plist string

Failsafe: Any

Description: Kext architecture (Any, i386, x86_64).

2. BundlePath

Type: plist string

Failsafe: Emptystring

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

3. Comment

Type: plist string

Failsafe: Emptystring

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

4. Enabled

Type: plist boolean

Failsafe: false

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

5. ExecutablePath

Type: plist string

Failsafe: Emptystring

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

6. MaxKernel

Type: plist string

Failsafe: Emptystring

Description: Adds kernel driver on specified macOS version or older.

Kernel version can be obtained with `uname -r` command, and should look like 3 numbers separated by dots, for example 18.7.0 is the kernel version for 10.14.6. Kernel version interpretation is implemented as follows:

$$\begin{aligned} ParseDarwinVersion(\kappa, \lambda, \mu) &= \kappa \cdot 10000 && \text{Where } \kappa \in (0, 99) \text{ is kernel version major} \\ &+ \lambda \cdot 100 && \text{Where } \lambda \in (0, 99) \text{ is kernel version minor} \\ &+ \mu && \text{Where } \mu \in (0, 99) \text{ is kernel version patch} \end{aligned}$$

Kernel version comparison is implemented as follows:

$$\begin{aligned} \alpha &= \begin{cases} ParseDarwinVersion(\text{MinKernel}), & \text{If MinKernel is valid} \\ 0 & \text{Otherwise} \end{cases} \\ \beta &= \begin{cases} ParseDarwinVersion(\text{MaxKernel}), & \text{If MaxKernel is valid} \\ \infty & \text{Otherwise} \end{cases} \\ \gamma &= \begin{cases} ParseDarwinVersion(\text{FindDarwinVersion}()), & \text{If valid "Darwin Kernel Version" is found} \\ \infty & \text{Otherwise} \end{cases} \\ f(\alpha, \beta, \gamma) &= \alpha \leq \gamma \leq \beta \end{aligned}$$

Here *ParseDarwinVersion* argument is assumed to be 3 integers obtained by splitting Darwin kernel version string from left to right by the `.` symbol. *FindDarwinVersion* function looks up Darwin kernel version by locating "Darwin Kernel Version $\kappa.\lambda.\mu$ " string in the kernel image.

7. MinKernel

Type: plist string

Failsafe: Emptystring

Description: Adds kernel driver on specified macOS version or newer.

Note: Refer to Add MaxKernel description for matching logic.

8. PlistPath

Type: plist string

Failsafe: Emptystring

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

7.4 Block Properties

1. Arch

Type: plist string

Failsafe: Any

Description: Kext block architecture (Any, i386, x86_64).

2. Comment

Type: plist string

Failsafe: Emptystring

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

3. Enabled

Type: plist boolean

Failsafe: false

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

4. Identifier

Type: plist string

Failsafe: Emptystring

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

5. MaxKernel

Type: plist string

Failsafe: Emptystring

Description: Blocks kernel driver on specified macOS version or older.

Note: Refer to Add MaxKernel description for matching logic.

6. MinKernel

Type: plist string

Failsafe: Emptystring

Description: Blocks kernel driver on specified macOS version or newer.

Note: Refer to Add MaxKernel description for matching logic.

7.5 Emulate Properties

1. Cpuid1Data

Type: plist data, 16 bytes

Failsafe: All zero

Description: Sequence of EAX, EBX, ECX, EDX values to replace CPUID (1) call in XNU kernel.

This property primarily serves for three needs:

- Enabling support of an unsupported CPU model (e.g. Intel Pentium).
- Enabling support of a CPU model that is not yet supported by a specific version of macOS which usually is old.
- Enabling XCPM support for an unsupported CPU variant.

Note 1: It may also be the case that the CPU model is supported but there is no power management supported (e.g. virtual machines). In this case, MinKernel and MaxKernel can be set to restrict CPU virtualisation and dummy power management patches to the particular macOS kernel version.

Note 2: Normally it is only the value of **EAX** that needs to be taken care of, since it represents the full CPUID. The remaining bytes are to be left as zeroes. Byte order is Little Endian, so for example, **C3 06 03 00** stands for CPUID **0x0306C3** (Haswell).

Note 3: For XCPM support it is recommended to use the following combinations.

- Haswell-E (0x0306F2) to Haswell (0x0306C3):
Cpuid1Data: C3 06 03 00 00 00 00 00 00 00 00 00 00 00 00 00
Cpuid1Mask: FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00
- Broadwell-E (0x0406F1) to Broadwell (0x0306D4):
Cpuid1Data: D4 06 03 00 00 00 00 00 00 00 00 00 00 00 00 00
Cpuid1Mask: FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00

Note 4: Note that the following configurations are unsupported by XCPM (at least out of the box):

- Consumer Ivy Bridge (0x0306A9) as Apple disabled XCPM for Ivy Bridge and recommends legacy power management for these CPUs. `_xcpm_bootstrap` should manually be patched to enforce XCPM on these CPUs instead of this option.
- Low-end CPUs (e.g. Haswell+ Pentium) as they are not supported properly by macOS. Legacy hacks for older models can be found in the **Special NOTES** section of `acidanthera/bugtracker#365`.

2. Cpuid1Mask

Type: plist data, 16 bytes

Failsafe: All zero

Description: Bit mask of active bits in **Cpuid1Data**.

When each **Cpuid1Mask** bit is set to 0, the original CPU bit is used, otherwise set bits take the value of **Cpuid1Data**.

3. DummyPowerManagement

Type: plist boolean

Failsafe: false

Requirement: 10.4

Description: Disables **AppleIntelCpuPowerManagement**.

Note 1: This option is a preferred alternative to **NullCpuPowerManagement.kext** for CPUs without native power management driver in macOS.

Note 2: While this option is usually needed to disable **AppleIntelCpuPowerManagement** on unsupported platforms, it can also be used to disable this kext in other situations (e.g. with **Cpuid1Data** left blank).

4. MaxKernel

Type: plist string

Failsafe: Emptystring

Description: Emulates CPUID and applies **DummyPowerManagement** on specified macOS version or older.

Note: Refer to **Add MaxKernel** description for matching logic.

5. MinKernel

Type: plist string

Failsafe: Emptystring

Description: Emulates CPUID and applies **DummyPowerManagement** on specified macOS version or newer.

Note: Refer to **Add MaxKernel** description for matching logic.

7.6 Force Properties

1. Arch

Type: plist string

Failsafe: Any

Description: Kext architecture (Any, i386, x86_64).

2. BundlePath

Type: plist string

Failsafe: Emptystring

Description: Kext bundle path (e.g. `System/Library \Extensions \IONetworkingFamily.kext`).

3. Comment
Type: plist string
Failsafe: Emptystring
Description: Arbitrary ASCII string used to provide human readable reference for the entry. ~~It is implementation defined whether~~ Whether this value is used is implementation defined.
4. Enabled
Type: plist boolean
Failsafe: false
Description: This kernel driver will not be added when not present unless set to true.
5. ExecutablePath
Type: plist string
Failsafe: Emptystring
Description: Kext executable path relative to bundle (e.g. Contents/MacOS/IONetworkingFamily).
6. Identifier
Type: plist string
Failsafe: Emptystring
Description: Kext identifier to perform presence checking before adding (e.g. com.apple.iokit.IONetworkingFamily). Only drivers which identifiers are not be found in the cache will be added.
7. MaxKernel
Type: plist string
Failsafe: Emptystring
Description: Adds kernel driver on specified macOS version or older.
Note: Refer to Add Add MaxKernel description for matching logic.
8. MinKernel
Type: plist string
Failsafe: Emptystring
Description: Adds kernel driver on specified macOS version or newer.
Note: Refer to Add Add MaxKernel description for matching logic.
9. PlistPath
Type: plist string
Failsafe: Emptystring
Description: Kext Info.plist path relative to bundle (e.g. Contents/Info.plist).

7.7 Patch Properties

1. Arch
Type: plist string
Failsafe: Any
Description: Kext patch architecture (Any, i386, x86_64).
2. Base
Type: plist string
Failsafe: Empty string(Ignored)
Description: Selects symbol-matched base for patch lookup (or immediate replacement) by obtaining the address of the provided symbol name. ~~Can be set to empty string to be ignored.~~
3. Comment
Type: plist string
Failsafe: Emptystring
Description: Arbitrary ASCII string used to provide human readable reference for the entry. ~~It is implementation defined whether~~ Whether this value is used is implementation defined.
4. Count
Type: plist integer

Failsafe: 0

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

5. Enabled

Type: plist boolean

Failsafe: false

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

6. Find

Type: plist data

Failsafe: Empty ~~data~~ (Immediate replacement at Base)

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

7. Identifier

Type: plist string

Failsafe: Empty ~~string~~

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

8. Limit

Type: plist integer

Failsafe: 0 (Search entire kext or kernel)

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

9. Mask

Type: plist data

Failsafe: Empty ~~data~~ (Ignored)

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~~ Must be equal to Replace in size ~~otherwise~~ if set.

10. MaxKernel

Type: plist string

Failsafe: Empty ~~string~~

Description: Patches data on specified macOS version or older.

Note: Refer to Add MaxKernel description for matching logic.

11. MinKernel

Type: plist string

Failsafe: Empty ~~string~~

Description: Patches data on specified macOS version or newer.

Note: Refer to Add MaxKernel description for matching logic.

12. Replace

Type: plist data

Failsafe: Empty ~~data~~

Description: Replacement data of one or more bytes.

13. ReplaceMask

Type: plist data

Failsafe: Empty ~~data~~ (Ignored)

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~~ Must be equal to Replace in size ~~otherwise~~ if set.

14. Skip

Type: plist integer

Failsafe: 0

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

Failsafe: false
Requirement: 10.10
Description: Increases 32-bit PCI bar size in IOPCIFamily from 1 to 4 GBs.

Note: This option should be avoided whenever possible. In general the necessity of this option means misconfigured or broken firmware.

13. **LapicKernelPanic**
Type: plist boolean
Failsafe: false
Requirement: 10.6 (64-bit)
Description: Disables kernel panic on LAPIC interrupts.
14. **LegacyCommpage**
Type: plist boolean
Failsafe: false
Requirement: 10.4 - 10.6
Description: Replaces the default 64-bit commpage bcopy implementation with one that does not require SSSE3, useful for legacy platforms. This prevents a `commpage no match for last panic` due to no available 64-bit bcopy functions that do not require SSSE3.
15. **PanicNoKextDump**
Type: plist boolean
Failsafe: false
Requirement: 10.13 (not required for older)
Description: Prevent kernel from printing kext dump in the panic log preventing from observing panic details. Affects 10.13 and above.
16. **PowerTimeoutKernelPanic**
Type: plist boolean
Failsafe: false
Requirement: 10.15 (not required for older)
Description: Disables kernel panic on setPowerState timeout.

An additional security measure was added to macOS Catalina (10.15) causing kernel panic on power change timeout for Apple drivers. Sometimes it may cause issues on misconfigured hardware, notably digital audio, which sometimes fails to wake up. For debug kernels `setpowerstate_panic=0` boot argument should be used, which is otherwise equivalent to this quirk.

17. **SetApfsTrimTimeout**
Type: plist integer
Failsafe: -1
Requirement: 10.14 (not required for older)
Description: Set trim timeout in microseconds for APFS filesystems on SSDs.

APFS filesystem is designed in a way that the space controlled via spaceman structure is either used or free. This may be different in other filesystems where the areas can be marked as used, free, and *unmapped*. All free space is trimmed (unmapped/deallocated) at macOS startup. The trimming procedure for NVMe drives happens in LBA ranges due to the nature of DSM command with up to 256 ranges per command. The more fragmented the memory on the drive is, the more commands are necessary to trim all the free space.

Depending on the SSD controller and the drive fragmentation trim procedure may take considerable amount of time, causing noticeable boot slowdown APFS driver explicitly ignores previously unmapped areas and trims them on boot again and again. To workaround boot slowdown macOS driver introduced a timeout (9.999999 seconds) that stops trim operation when it did not manage to complete in time. On many controllers, such as Samsung, where the deallocation is not very fast, the timeout is reached very quickly. Essentially it means that macOS will try to trim all the same lower blocks that have already been deallocated, but will never have enough time to deallocate higher blocks once the fragmentation increases. This means that trimming on these SSDs will be broken soon after the installation, causing extra wear to the flash.

One way to workaround the problem is to increase the timeout to a very high value, which at the cost of slow boot times (extra minutes) will ensure that all the blocks are trimmed. ~~For this one can set this~~ Set this option

- **Short** — create a short boot option instead of a complete one. This variant is useful for some older firmwares, Insyde in particular, but possibly others, which cannot handle full device paths.

This option provides integration with third-party operating system installation and upgrade at the times they overwrite `\EFI\BOOT\BOOTx64.efi` file. By creating a custom option in this file path becomes no longer used for bootstrapping OpenCore. The path used for bootstrapping is specified in `LauncherPath` option.

Note 1: Some types of firmware may have faulty NVRAM, no boot option support, or other incompatibilities. While unlikely, the use of this option may even cause boot failures. This option should be used without any warranty exclusively on the boards known to be compatible. Check [acidanthera/bugtracker#1222](#) for some known issues with Haswell and other boards.

Note 2: Be aware that while NVRAM reset executed from OpenCore should not erase the boot option created in `Bootstrap`, executing NVRAM reset prior to loading OpenCore will remove it. For significant implementation updates (e.g. in OpenCore 0.6.4) make sure to perform NVRAM reset with `Bootstrap` disabled before reenabling.

5. `LauncherPath`

Type: plist string

Failsafe: Default

Description: Launch path for `LauncherOption`.

Default stays for launched `OpenCore.efi`, any other path, e.g. `\EFI\Launcher.efi`, can be used to provide custom loaders, which are supposed to load `OpenCore.efi` themselves.

6. `PickerAttributes`

Type: plist integer

Failsafe: 0

Description: Sets specific attributes for picker.

Different pickers may be configured through the attribute mask containing OpenCore-reserved (BIT0~BIT15) and OEM-specific (BIT16~BIT31) values.

Current OpenCore values include:

- 0x0001 — `OC_ATTR_USE_VOLUME_ICON`, provides custom icons for boot entries:
For Tools OpenCore will try to load a custom icon and fallback to the default icon:
 - `ResetNVRAM` — `Resources\Image\ResetNVRAM.icns` — `ResetNVRAM.icns` from icons directory.
 - `Tools\<TOOL_RELATIVE_PATH>.icns` — icon near the tool file with appended `.icns` extension.

For custom boot Entries OpenCore will try to load a custom icon and fallback to the volume icon or the default icon:

- `<ENTRY_PATH>.icns` — icon near the entry file with appended `.icns` extension.

For all other entries OpenCore will try to load a volume icon ~~and by searching as follows, and will~~ fallback to the default icon otherwise:

- `.VolumeIcon.icns` file at Preboot volume ~~directory in per-volume directory~~ (`/System/Volumes/Preboot/{GUID}/` when mounted at default location within macOS) for APFS (if present).
- `.VolumeIcon.icns` file at Preboot root (`/System/Volumes/Preboot/` when mounted at default location within macOS) for APFS (otherwise).
- `.VolumeIcon.icns` file at volume root for other filesystems.

~~Volume icons can be set in Finder. Note, that enabling this may result in external and internal icons to be indistinguishable.~~ *Note 1:* Apple's boot picker partially supports placing a volume icon file at the operating system's Data volume root (`/System/Volumes/Data/` when mounted at default location within macOS). This approach is broken: that file is not accessible either by OpenCanopy or by Apple's own boot picker when FileVault 2 is enabled, which should be most people's default choice. Therefore OpenCanopy does not try to support it. You may place a volume icon file at Preboot root for compatibility with both the Apple and OpenCanopy boot pickers, or use the Preboot per-volume location as above with OpenCanopy as a preferred alternative to Apple's existing approach.

Note 2: Be aware that using a volume icon on any drive overrides the normal boot picker behaviour for that drive of selecting the appropriate icon depending on whether the drive is internal or external.

- 0x0002 — `OC_ATTR_USE_DISK_LABEL_FILE`, provides custom rendered titles for boot entries:
 - `.disk_label` (`.disk_label_2x`) file near bootloader for all filesystems.

bootable. Operating systems shipped before the specified model was released will not boot. Valid values:

- **Default** — Recent available model, currently set to j137.
- **Disabled** — No model, Secure Boot will be disabled.
- j137 — iMacPro1,1 (December 2017). Minimum macOS 10.13.2 (17C2111)
- j680 — MacBookPro15,1 (July 2018). Minimum macOS 10.13.6 (17G2112)
- j132 — MacBookPro15,2 (July 2018). Minimum macOS 10.13.6 (17G2112)
- j174 — Macmini8,1 (October 2018). Minimum macOS 10.14 (18A2063)
- j140k — MacBookAir8,1 (October 2018). Minimum macOS 10.14.1 (18B2084)
- j780 — MacBookPro15,3 (May 2019). Minimum macOS 10.14.5 (18F132)
- j213 — MacBookPro15,4 (July 2019). Minimum macOS 10.14.5 (18F2058)
- j140a — MacBookAir8,2 (July 2019). Minimum macOS 10.14.5 (18F2058)
- j152f — MacBookPro16,1 (November 2019). Minimum macOS 10.15.1 (19B2093)
- j160 — MacPro7,1 (December 2019). Minimum macOS 10.15.1 (19B88)
- j230k — MacBookAir9,1 (March 2020). Minimum macOS 10.15.3 (19D2064)
- j214k — MacBookPro16,2 (May 2020). Minimum macOS 10.15.4 (19E2269)
- j223 — MacBookPro16,3 (May 2020). Minimum macOS 10.15.4 (19E2265)
- j215 — MacBookPro16,4 (June 2020). Minimum macOS 10.15.5 (19F96)
- j185 — iMac20,1 (August 2020). Minimum macOS 10.15.6 (19G2005)
- j185f — iMac20,2 (August 2020). Minimum macOS 10.15.6 (19G2005)
- x86legacy — Macs without T2 chip and VMs. Minimum macOS 11.0.1 (20B29)

Apple Secure Boot appeared in macOS 10.13 on models with T2 chips. Since **PlatformInfo** and **SecureBootModel** are independent, Apple Secure Boot can be used with any SMBIOS with and without T2. Setting **SecureBootModel** to any valid value but **Disabled** is equivalent to **Medium Security** of Apple Secure Boot. The **ApECID** value must also be specified to achieve **Full Security**. Check **ForceSecureBootScheme** when using Apple Secure Boot on a virtual machine.

Enabling Apple Secure Boot is more demanding to incorrect configurations, buggy macOS installations, and unsupported setups. Things to consider:

- (a) As with T2 Macs, unsigned kernel drivers and several signed kernel drivers, including NVIDIA Web Drivers, cannot be installed.
- (b) The list of cached drivers may be different, resulting in the need to change the list of **Added** or **Forced** kernel drivers. For example, **I080211Family** cannot be injected in this case.
- (c) System volume alterations on operating systems with sealing, such as macOS 11, may result in the operating system being unbootable. Do not try to disable system volume encryption unless Apple Secure Boot is disabled.
- (d) If the platform requires certain settings, but they were not enabled, because the obvious issues did not trigger before, boot failure might occur. Be extra careful with **IgnoreInvalidFlexRatio** or **HashServices**.
- (e) Operating systems released before Apple Secure Boot landed (e.g. macOS 10.12 or earlier) will still boot until UEFI Secure Boot is enabled. This is so, because from Apple Secure Boot point they are treated as incompatible and are assumed to be handled by the firmware as Microsoft Windows is.
- (f) On older CPUs (e.g. before Sandy Bridge) enabling Apple Secure Boot might cause slightly slower loading by up to 1 second.
- (g) Since **Default** value will increase with time to support the latest major release operating system, it is not recommended to use **ApECID** and **Default** value together.
- (h) Installing macOS with Apple Secure Boot enabled is not possible while using HFS+ target volume. This may include HFS+ formatted drives when no spare APFS drive is available.

Sometimes the already installed operating system may have outdated Apple Secure Boot manifests on the **Preboot** partition causing boot failure. If there is “OCB: Apple Secure Boot prohibits this boot entry, enforcing!” message, it is likely the case. When this happens, either reinstall the operating system or copy the manifests (files with **.im4m** extension, such as **boot.efi.j137.im4m**) from **/usr/standalone/i386** to **/Volumes/Preboot/<UUID>/System/Library/CoreServices**. Here **<UUID>** is the system volume identifier. On HFS+ installations the manifests should be copied to **/System/Library/CoreServices** on the system volume.

For more details on how to configure Apple Secure Boot with UEFI Secure Boot refer to UEFI Secure Boot section.

8.6 Entry Properties

1. Arguments

Type: plist string

Failsafe: Emptystring

Description: Arbitrary ASCII string used as boot arguments (load options) of the specified entry.

2. Auxiliary

Type: plist boolean

Failsafe: false

Description: This entry will not be listed by default when HideAuxiliary is set to true.

3. Comment

Type: plist string

Failsafe: Emptystring

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

4. Enabled

Type: plist boolean

Failsafe: false

Description: This entry will not be listed unless set to true.

5. Name

Type: plist string

Failsafe: Emptystring

Description: Human readable entry name displayed in boot picker.

6. Path

Type: plist string

Failsafe: Emptystring

Description: Entry location depending on entry type.

- **Entries** specify external boot options, and therefore take device paths in Path key. These values are not checked, thus be extremely careful. Example: PciRoot(0x0)/Pci(0x1,0x1)/.../EFI/COOL.EFI
- **Tools** specify internal boot options, which are part of bootloader vault, and therefore take file paths relative to OC/Tools directory. Example: OpenShell.efi.

7. RealPath

Type: plist boolean

Failsafe: false

Description: Pass full path to the tool when launching.

Passing tool directory may be unsafe for tool accidentally trying to access files without checking their integrity and thus should generally be disabled. Reason to enable this property may include cases where tools cannot work without external files or may need them for better function (e.g. memtest86 for logging and configuration or Shell for automatic script execution).

Note: This property is only valid for Tools. For Entries this property cannot be specified and is always true.

8. TextMode

Type: plist boolean

Failsafe: false

Description: Run the entry in text mode instead of graphics mode.

This setting may be beneficial to some older tools that require text output. By default all the tools are launched in graphics mode. Read more about text modes in Output Properties section below.

10 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 `AppleModels`, 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 all the values are specified (the default), and semi-automatic, where (`Automatic`) only select values are specified, and later used for system configuration.

To inspect SMBIOS contents `dmidecode` utility can be used. Version with macOS specific enhancements can be downloaded from `Acidanthera/dmidecode`.

10.1 Properties

1. `Automatic`

Type: plist boolean

Failsafe: 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.
- When disabled `Generic` section is unused.

Warning: It is strongly discouraged set this option to `false` when intending to update platform information. The only reason to do that is when doing minor correction of the SMBIOS present and similar. In all other cases not using `Automatic` may lead to hard to debug errors.

2. `CustomMemory`

Type: plist boolean

Failsafe: false

Description: Use custom memory configuration defined in the `Memory` section. This completely replaces any existing memory configuration in SMBIOS, and is only active when `UpdateSMBIOS` is set to `true`.

3. `UpdateDataHub`

Type: plist boolean

Failsafe: false

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

[Note: The implementation of the Data Hub protocol in EFI firmware on essentially all systems, including Apple hardware, means that existing Data Hub entries cannot be overridden, while new entries are added to the end with macOS ignoring them. You can work around this by reinstalling the Data Hub protocol using the ProtocolOverrides section. Refer to the DataHub protocol override description for details.](#)

4. `UpdateNVRAM`

Type: plist boolean

Failsafe: 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.

Failsafe: 0 (Automatic)
Description: Refer to SMBIOS ProcessorType.

6. SystemProductName
Type: plist string
Failsafe: [Empty](#) (OEM specified or not installed)
Description: Refer to SMBIOS SystemProductName.

7. SystemSerialNumber
Type: plist string
Failsafe: [Empty](#) (OEM specified or not installed)
Description: Refer to SMBIOS SystemSerialNumber.

Specify OEM value to extract current value from SMBIOS and use it throughout the sections. This feature can only be used on Mac-compatible firmwares.

8. SystemUUID
Type: plist string, GUID
Failsafe: [Empty](#) (OEM specified or not installed)
Description: Refer to SMBIOS SystemUUID.

Specify OEM value to extract current value from SMBIOS and use it throughout the sections. Since not all firmwares have valid (and unique) values, this feature is not applicable to some setups, and may provide unexpected results. It is highly recommended to specify the UUID explicitly. Refer to [UseRawUuidEncoding](#) to determine how SMBIOS value is parsed.

9. MLB
Type: plist string
Failsafe: [Empty](#) (OEM specified or not installed)
Description: Refer to SMBIOS BoardSerialNumber.

Specify OEM value to extract current value from SMBIOS and use it throughout the sections. This feature can only be used on Mac-compatible firmwares.

10. ROM
Type: plist data, 6 bytes
Failsafe: [Empty](#) (OEM specified or not installed)
Description: Refer to 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ROM.

10.3 DataHub Properties

1. PlatformName
Type: plist string
Failsafe: ~~Not installed~~[Empty](#) (Not installed)
Description: Sets name in gEfiMiscSubClassGuid. Value found on Macs is platform in ASCII.
2. SystemProductName
Type: plist string
Failsafe: ~~Not installed~~[Empty](#) (Not installed)
Description: Sets Model in gEfiMiscSubClassGuid. Value found on Macs is equal to SMBIOS SystemProductName in Unicode.
3. SystemSerialNumber
Type: plist string
Failsafe: ~~Not installed~~[Empty](#) (Not installed)
Description: Sets SystemSerialNumber in gEfiMiscSubClassGuid. Value found on Macs is equal to SMBIOS SystemSerialNumber in Unicode.
4. SystemUUID
Type: plist string, GUID
Failsafe: ~~Not installed~~[Empty](#) (Not installed)
Description: Sets system-id in gEfiMiscSubClassGuid. Value found on Macs is equal to SMBIOS SystemUUID (with swapped byte order).

5. **BoardProduct**
Type: plist string
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
Description: Sets board-id in gEfiMiscSubClassGuid. Value found on Macs is equal to SMBIOS BoardProduct in ASCII.
6. **BoardRevision**
Type: plist data, 1 byte
Failsafe: 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
Failsafe: 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_PMCN_2 bit 0)
 - 0x00000002 — Shutdown cause was a SYS_PWROK event (Same as GEN_PMCN_2 bit 1)
 - 0x00000004 — Shutdown cause was a THRMTRIP# event (Same as GEN_PMCN_2 bit 3)
 - 0x00000008 — Rebooted due to a SYS_RESET# event (Same as GEN_PMCN_2 bit 4)
 - 0x00000010 — Power Failure (Same as GEN_PMCN_3 bit 1 PWR_FLR)
 - 0x00000020 — Loss of RTC Well Power (Same as GEN_PMCN_3 bit 2 RTC_PWR_STS)
 - 0x00000040 — General Reset Status (Same as GEN_PMCN_3 bit 9 GEN_RST_STS)
 - 0xffffffff80 — SUS Well Power Loss (Same as GEN_PMCN_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 Watchdog Timer event (Same as PRSTS bit 6)
 - 0x00200000 — Global reset PowerManagement Watchdog Timer event (Same as PRSTS bit 15)
8. **InitialTSC**
Type: plist integer, 64-bit
Failsafe: 0
Description: Sets InitialTSC in gEfiProcessorSubClassGuid. Sets initial TSC value, normally 0.
9. **FSBFrequency**
Type: plist integer, 64-bit
Failsafe: 0 (Automatic)
Description: Sets FSBFrequency in gEfiProcessorSubClassGuid.

Sets CPU FSB frequency. This value equals to CPU nominal frequency divided by CPU maximum bus ratio and is specified in Hz. Refer to MSR_NEHALEM_PLATFORM_INFO (CEh) MSR value to determine maximum bus ratio on modern Intel CPUs.

Note: This value is not used on Skylake and newer but is still provided to follow suit.
10. **ARTFrequency**
Type: plist integer, 64-bit
Failsafe: 0 (Automatic)
Description: Sets ARTFrequency in gEfiProcessorSubClassGuid.

This value contains CPU ART frequency, also known as crystal clock frequency. Its existence is exclusive to the Skylake generation and newer. The value is specified in Hz, and is normally 24 MHz for client Intel segment, 25 MHz for server Intel segment, and 19.2 MHz for Intel Atom CPUs. macOS till 10.15 inclusive assumes 24 MHz by default.

Note: On Intel Skylake X ART frequency may be a little less (approx. 0.25%) than 24 or 25 MHz due to special EMI-reduction circuit as described in Acidanthera Bugtracker.

11. DevicePathsSupported
Type: plist integer, 32-bit
Failsafe: ~~Not installed~~0 ([Not installed](#))
Description: Sets DevicePathsSupported in gEfiMiscSubClassGuid. Must be set to 1 for AppleACPIPlatform.kext to append SATA device paths to Boot#### and efi-boot-device-data variables. Set to 1 on all modern Macs.
12. SmcRevision
Type: plist data, 6 bytes
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
Description: Sets REV in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC REV key.
13. SmcBranch
Type: plist data, 8 bytes
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
Description: Sets RBr in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC RBr key.
14. SmcPlatform
Type: plist data, 8 bytes
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
Description: Sets RPlt in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC RPlt key.

10.4 Memory Properties

1. DataWidth
Type: plist integer, 16-bit
Failsafe: 0xFFFF (unknown)
SMBIOS: Memory Device (Type 17) — Data Width
Description: Specifies the data width, in bits, of the memory. A DataWidth of 0 and a TotalWidth of 8 indicates that the device is being used solely to provide 8 error-correction bits.
2. Devices
Type: plist array
Failsafe: Empty
Description: Specifies the custom memory devices to be added.

Designed to be filled with **plist dictionary** values, describing each memory device. See Memory Devices Properties section below. This should include all memory slots, even if unpopulated.
3. ErrorCorrection
Type: plist integer, 8-bit
Failsafe: 0x03
SMBIOS: Physical Memory Array (Type 16) — Memory Error Correction
Description: Specifies the primary hardware error correction or detection method supported by the memory.
 - 0x01 — Other
 - 0x02 — Unknown
 - 0x03 — None
 - 0x04 — Parity
 - 0x05 — Single-bit ECC
 - 0x06 — Multi-bit ECC
 - 0x07 — CRC
4. FormFactor
Type: plist integer, 8-bit
Failsafe: 0x02
SMBIOS: Memory Device (Type 17) — Form Factor
Description: Specifies the form factor of the memory. On Macs this should usually be DIMM or SODIMM. Commonly used form factors are listed below.

2. BankLocator
Type: plist string
Failsafe: Unknown
SMBIOS: Memory Device (Type 17) — Bank Locator
Description: Specifies the physically labeled bank where the memory device is located.
3. DeviceLocator
Type: plist string
Failsafe: Unknown
SMBIOS: Memory Device (Type 17) — Device Locator
Description: Specifies the physically-labeled socket or board position where the memory device is located.
4. Manufacturer
Type: plist string
Failsafe: Unknown
SMBIOS: Memory Device (Type 17) — Manufacturer
Description: Specifies the manufacturer of this memory device.
5. PartNumber
Type: plist string
Failsafe: Unknown
SMBIOS: Memory Device (Type 17) — Part Number
Description: Specifies the part number of this memory device.
6. SerialNumber
Type: plist string
Failsafe: Unknown
SMBIOS: Memory Device (Type 17) — Serial Number
Description: Specifies the serial number of this memory device.
7. Size
Type: plist integer, 32-bit
Failsafe: 0
SMBIOS: Memory Device (Type 17) — Size
Description: Specifies the size of the memory device, in megabytes. 0 indicates this slot is not populated.
8. Speed
Type: plist integer, 16-bit
Failsafe: 0
SMBIOS: Memory Device (Type 17) — Speed
Description: Specifies the maximum capable speed of the device, in megatransfers per second (MT/s). 0 indicates an unknown speed.

10.5 PlatformNVRAM Properties

1. BID
Type: plist string
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
Description: Specifies the value of NVRAM variable 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:HW_BID.
2. ROM
Type: plist data, 6 bytes
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
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
Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)
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

Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)

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

Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)

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
6. SystemUUID

Type: plist string

Failsafe: ~~Not installed~~[Empty \(Not installed\)](#)

Description: Specifies the value of NVRAM variable 4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:system-id for boot services only. Value found on Macs is equal to SMBIOS SystemUUID.

10.6 SMBIOS Properties

1. BIOSVendor

Type: plist string

Failsafe: ~~OEM-specified~~[Empty \(OEM specified\)](#)

SMBIOS: BIOS Information (Type 0) — Vendor

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

Type: plist string

Failsafe: ~~OEM-specified~~[Empty \(OEM specified\)](#)

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 firmware and is described in BiosId.h. In newer firmware, 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

Failsafe: ~~OEM-specified~~[Empty \(OEM specified\)](#)

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

Failsafe: ~~OEM-specified~~[Empty \(OEM specified\)](#)

SMBIOS: System Information (Type 1) — Manufacturer

Description: OEM manufacturer of the particular board. ~~Shall not be specified~~ Use failsafe unless strictly required. ~~Should not~~ Do not override to contain Apple Inc. on non-Apple hardware, as this confuses numerous services present in the operating system, such as firmware updates, efichk, as well as kernel extensions developed in Acidanthera, such as Lilu and its plugins. In addition it will also make some operating systems such as Linux unbootable.

5. SystemProductName

Type: plist string

Failsafe: ~~OEM-specified~~ Empty (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 AppleModels.

6. SystemVersion

Type: plist string

Failsafe: ~~OEM-specified~~ Empty (OEM specified)

SMBIOS: System Information (Type 1) — Version

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

7. SystemSerialNumber

Type: plist string

Failsafe: ~~OEM-specified~~ Empty (OEM specified)

SMBIOS: System Information (Type 1) — Serial Number

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

8. SystemUUID

Type: plist string, GUID

Failsafe: ~~OEM-specified~~ Empty (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

Failsafe: ~~OEM-specified~~ Empty (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

Failsafe: ~~OEM-specified~~ Empty (OEM specified)

SMBIOS: System Information (Type 1) — Family

Description: Family name. May look like iMac Pro.

11. BoardManufacturer

Type: plist string

Failsafe: ~~OEM-specified~~ Empty (OEM specified)

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

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

12. BoardProduct

Type: plist string

Failsafe: ~~OEM-specified~~ Empty (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

Failsafe: ~~OEM-specified~~Empty (OEM specified)

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

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

14. BoardSerialNumber

Type: plist string

Failsafe: ~~OEM-specified~~Empty (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. BoardAssetTag

Type: plist string

Failsafe: ~~OEM-specified~~Empty (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

Failsafe: ~~OEM-specified~~0 (OEM specified)

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

Description: Either 0xA (Motherboard (includes processor, memory, and I/O) or 0xB (Processor/Memory Module), refer to Table 15 – Baseboard: Board Type for more details.

17. BoardLocationInChassis

Type: plist string

Failsafe: ~~OEM-specified~~Empty (OEM specified)

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

Description: Varies, may be empty or Part Component.

18. ChassisManufacturer

Type: plist string

Failsafe: ~~OEM-specified~~Empty (OEM specified)

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

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

19. ChassisType

Type: plist integer

Failsafe: ~~OEM-specified~~0 (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

Failsafe: ~~OEM-specified~~Empty (OEM specified)

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

Description: Should match BoardProduct.

21. ChassisSerialNumber

Type: plist string

Failsafe: ~~OEM-specified~~Empty (OEM specified)

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

Description: Should match SystemSerialNumber.

22. ChassisAssetTag

Type: plist string

Failsafe: ~~OEM-specified~~Empty (OEM specified)

- 0 — require the default supported version of APFS in OpenCore. The default version will increase with time and thus this setting is recommended. Currently set to the latest point release from High Sierra from App Store (748077008000000).
- -1 — permit any version to load (strongly discouraged).
- Other — use custom minimal APFS version, e.g. 1412101001000000 from macOS Catalina 10.15.4. APFS versions can be found in OpenCore boot log and `OcAptsLib`.

11.8 Audio Properties

1. AudioCodec

Type: plist integer

Failsafe: 0

Description: Codec address on the specified audio controller for audio support.

Normally this contains first audio codec address on the builtin analog audio controller (HDEF). Audio codec addresses, e.g. 2, can be found in the debug log (marked in bold-italic):

```
OCAU: 1/3 PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x1)/VenMsg(<redacted>,00000000) (4 outputs)
OCAU: 2/3 PciRoot(0x0)/Pci(0x3,0x0)/VenMsg(<redacted>,00000000) (1 outputs)
OCAU: 3/3 PciRoot(0x0)/Pci(0x1B,0x0)/VenMsg(<redacted>,02000000) (7 outputs)
```

As an alternative this value can be obtained from `IOHDACodecDevice` class in I/O Registry containing it in `IOHDACodecAddress` field.

2. AudioDevice

Type: plist string

Failsafe: ~~empty string~~ `Empty`

Description: Device path of the specified audio controller for audio support.

Normally this contains builtin analog audio controller (HDEF) device path, e.g. `PciRoot(0x0)/Pci(0x1b,0x0)`. The list of recognised audio controllers can be found in the debug log (marked in bold-italic):

```
OCAU: 1/3 PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x1)/VenMsg(<redacted>,00000000) (4 outputs)
OCAU: 2/3 PciRoot(0x0)/Pci(0x3,0x0)/VenMsg(<redacted>,00000000) (1 outputs)
OCAU: 3/3 PciRoot(0x0)/Pci(0x1B,0x0)/VenMsg(<redacted>,02000000) (7 outputs)
```

As an alternative `gfxutil -f HDEF` command can be used in macOS. Specifying empty device path will result in the first available audio controller to be used.

3. AudioOut

Type: plist integer

Failsafe: 0

Description: Index of the output port of the specified codec starting from 0.

Normally this contains the index of the green out of the builtin analog audio controller (HDEF). The number of output nodes (N) in the debug log (marked in bold-italic):

```
OCAU: 1/3 PciRoot(0x0)/Pci(0x1,0x0)/Pci(0x0,0x1)/VenMsg(<redacted>,00000000) (4 outputs)
OCAU: 2/3 PciRoot(0x0)/Pci(0x3,0x0)/VenMsg(<redacted>,00000000) (1 outputs)
OCAU: 3/3 PciRoot(0x0)/Pci(0x1B,0x0)/VenMsg(<redacted>,02000000) (7 outputs)
```

The quickest way to find the right port is to bruteforce the values from 0 to N - 1.

4. AudioSupport

Type: plist boolean

Failsafe: false

Description: Activate audio support by connecting to a backend driver.

Enabling this setting routes audio playback from builtin protocols to a dedicated audio port (`AudioOut`) of the specified codec (`AudioCodec`) located on the audio controller (`AudioDevice`).

5. MinimumVolume

Type: plist integer

Failsafe: 0

Description: Minimal heard volume level from 0 to 100.

Note: Some platforms may require different values, higher or lower. For example, when detecting key misses in OpenCanopy try increasing this value (e.g. to 10), and when detecting key stall, try decreasing this value. Since every platform is different it may be reasonable to check every value from 1 to 25.

3. KeyMergeThreshold

Type: plist integer

Failsafe: 0

Description: Assume simultaneous combination for keys submitted within this timeout in milliseconds.

Similarly to `KeyForgetThreshold`, this option works around the sequential nature of key submission. To be able to recognise simultaneously pressed keys in the situation when all keys arrive sequentially, we are required to set a timeout within which we assume the keys were pressed together.

Holding multiple keys results in reports every 2 and 1 milliseconds for VMware and APTIO V respectively. Pressing keys one after the other results in delays of at least 6 and 10 milliseconds for the same platforms. The recommended value for this option is 2 milliseconds, but it may be decreased for faster platforms and increased for slower.

4. KeySupport

Type: plist boolean

Failsafe: false

Description: Enable internal keyboard input translation to `AppleKeyMapAggregator` protocol.

This option activates the internal keyboard interceptor driver, based on `AppleGenericInput` aka (`AptioInputFix`), to fill `AppleKeyMapAggregator` database for input functioning. In case a separate driver is used, such as `OpenUsbKbDxe`, this option should never be enabled.

5. KeySupportMode

Type: plist string

Failsafe: Auto

Description: Set internal keyboard input translation to `AppleKeyMapAggregator` protocol mode.

- `Auto` — Performs automatic choice as available with the following preference: `AMI`, `V2`, `V1`.
- `V1` — Uses UEFI standard legacy input protocol `EFI_SIMPLE_TEXT_INPUT_PROTOCOL`.
- `V2` — Uses UEFI standard modern input protocol `EFI_SIMPLE_TEXT_INPUT_EX_PROTOCOL`.
- `AMI` — Uses APTIO input protocol `AMI_EFIKEYCODE_PROTOCOL`.

Note: Currently `V1`, `V2`, and `AMI` unlike `Auto` only do filtering of the particular specified protocol. This may change in the future versions.

6. KeySwap

Type: plist boolean

Failsafe: false

Description: Swap `Command` and `Option` keys during submission.

This option may be useful for keyboard layouts with `Option` key situated to the right of `Command` key.

7. PointerSupport

Type: plist boolean

Failsafe: false

Description: Enable internal pointer driver.

This option implements standard UEFI pointer protocol (`EFI_SIMPLE_POINTER_PROTOCOL`) through select OEM protocols. The option may be useful on Z87 ASUS boards, where `EFI_SIMPLE_POINTER_PROTOCOL` is broken.

8. PointerSupportMode

Type: plist string

Failsafe: ~~empty-string~~ `Empty`

Description: Set OEM protocol used for internal pointer driver.

Currently the only supported variant is `ASUS`, using specialised protocol available on select Z87 and Z97 ASUS boards. More details can be found in `LongSoft/UefiTool#116`. The value of this property cannot be empty if `PointerSupport` is enabled.

9. TimerResolution

Type: plist integer

Failsafe: 0

Description: Set architecture timer resolution.

This option allows to update firmware architecture timer period with the specified value in 100 nanosecond units. Setting a lower value generally improves performance and responsiveness of the interface and input handling.

The recommended value is 50000 (5 milliseconds) or slightly higher. Select ASUS Z87 boards use 60000 for the interface. Apple boards use 100000. In case of issues, this option can be left as 0.

11.10 Output Properties

1. TextRenderer

Type: plist string

Failsafe: BuiltinGraphics

Description: Chooses renderer for text going through standard console output.

Currently two renderers are supported: **Builtin** and **System**. **System** renderer uses firmware services for text rendering. **Builtin** bypassing firmware services and performs text rendering on its own. Different renderers support a different set of options. It is recommended to use **Builtin** renderer, as it supports HiDPI mode and uses full screen resolution.

UEFI firmware generally supports **ConsoleControl** with two rendering modes: **Graphics** and **Text**. Some types of firmware do not support **ConsoleControl** and rendering modes. OpenCore and macOS expect text to only be shown in **Graphics** mode and graphics to be drawn in any mode. Since this is not required by UEFI specification, exact behaviour varies.

Valid values are combinations of text renderer and rendering mode:

- **BuiltinGraphics** — Switch to **Graphics** mode and use **Builtin** renderer with custom **ConsoleControl**.
- **BuiltinText** — Switch to **Text** mode and use **Builtin** renderer with custom **ConsoleControl**.
- **SystemGraphics** — Switch to **Graphics** mode and use **System** renderer with custom **ConsoleControl**.
- **SystemText** — Switch to **Text** mode and use **System** renderer with custom **ConsoleControl**.
- **SystemGeneric** — Use **System** renderer with system **ConsoleControl** assuming it behaves correctly.

The use of **BuiltinGraphics** is generally straightforward. For most platforms it is necessary to enable **ProvideConsoleGop**, set **Resolution** to **Max**. **BuiltinText** variant is an alternative **BuiltinGraphics** for some very old and buggy laptop firmware, which can only draw in **Text** mode.

The use of **System** protocols is more complicated. In general the preferred setting is **SystemGraphics** or **SystemText**. Enabling **ProvideConsoleGop**, setting **Resolution** to **Max**, enabling **ReplaceTabWithSpace** is useful on almost all platforms. **SanitiseClearScreen**, **IgnoreTextInGraphics**, and **ClearScreenOnModeSwitch** are more specific, and their use depends on the firmware.

Note: Some Macs, namely **MacPro5,1**, may have broken console output with newer GPUs, and thus only **BuiltinGraphics** may work for them.

2. ConsoleMode

Type: plist string

Failsafe: Empty ~~string~~ (Maintain current console mode)

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~~ attempt using the largest available console mode. ~~Currently This option is currently ignored as the Builtin text renderer supports only one console mode, so this option is ignored.~~

Note: This field is best left empty on most types of firmware.

3. Resolution

Type: plist string

Failsafe: Empty ~~string~~ (Maintain current screen resolution)

Description: Sets console output screen resolution.

- Set to WxH@Bpp (e.g. 1920x1080@32) or WxH (e.g. 1920x1080) formatted string to request custom resolution from GOP if available.
- Set to ~~empty string not to change screen resolution.~~
- ~~Set to~~ Max to ~~try to use~~ attempt using the largest available screen resolution.

On HiDPI screens APPLE_VENDOR_VARIABLE_GUID UIScale NVRAM variable may need to be set to 02 to enable HiDPI scaling in Builtin text renderer, FileVault 2 UEFI password interface, and boot screen logo. Refer to Recommended Variables section for more details.

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

4. ForceResolution

Type: plist boolean

Failsafe: false

Description: Forces Resolution to be set in cases where the desired resolution is not available by default, such as on legacy Intel GMA and first generation Intel HD Graphics (Ironlake/Arrandale). Setting Resolution to Max will try to pull the largest available resolution from the connected display's EDID.

Note: This option depends on the OC_FORCE_RESOLUTION_PROTOCOL protocol being present. This protocol is currently only supported by OpenDuetPkg. The OpenDuetPkg implementation currently only supports Intel iGPUs.

5. ClearScreenOnModeSwitch

Type: plist boolean

Failsafe: false

Description: Some types of firmware only clear part of the screen when switching from graphics to text mode, leaving a fragment of previously drawn images visible. This option fills the entire graphics screen with black colour before switching to text mode.

Note: This option only applies to System renderer.

6. DirectGopRendering

Type: plist boolean

Failsafe: false

Description: Use builtin graphics output protocol renderer for console.

On some types of firmware, such as on the MacPro5,1, this may provide better performance or fix rendering issues. However, this option is not recommended unless there is an obvious benefit as it may result in issues such as slower scrolling.

7. IgnoreTextInGraphics

Type: plist boolean

Failsafe: false

Description: Some types of firmware output text onscreen in both graphics and text mode. This is typically unexpected as 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 a different mode from Text.

Note: This option only applies to the System renderer.

8. ReplaceTabWithSpace

Type: plist boolean

Failsafe: false

Description: Some types of firmware do not print tab characters or everything that follows them, causing difficulties in using the UEFI Shell's builtin text editor to edit property lists and other documents. This option makes the console output spaces instead of tabs.

Note: This option only applies to System renderer.

9. ProvideConsoleGop

Type: plist boolean

Failsafe: false

Description: Ensure GOP (Graphics Output Protocol) on console handle.

macOS bootloader requires GOP or UGA (for 10.4 EfiBoot) to be present on console handle, yet the exact location of the graphics protocol is not covered by the UEFI specification. This option will ensure GOP and UGA, if present, are available on the console handle.

Note: This option will also replace broken GOP protocol on console handle, which may be the case on MacPro5,1 with newer GPUs.

10. ReconnectOnResChange

Type: plist boolean

Failsafe: false

Description: Reconnect console controllers after changing screen resolution.

On some types of firmware, the controllers that produce the console protocols (simple text out) must be reconnected when the screen resolution is changed via GOP. Otherwise they will not produce text based on the new resolution.

Note: On several boards this logic may result in black screen when launching OpenCore from Shell and thus it is optional. In versions prior to 0.5.2 this option was mandatory and not configurable. Please do not use this unless required.

11. SanitiseClearScreen

Type: plist boolean

Failsafe: false

Description: Some types of firmware reset screen resolutions to a failsafe value (such as 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: This option only applies to [the System](#) renderer. On all known affected systems, `ConsoleMode` ~~had to~~ [must](#) be set to [an](#) empty string for this [option](#) to work.

12. UgaPassThrough

Type: plist boolean

Failsafe: false

Description: Provide UGA protocol instances on top of GOP protocol [instances](#).

Some types of firmware do not implement the legacy UGA protocol but this may be required for screen output by older EFI applications such as EfiBoot from 10.4.

11.11 ProtocolOverrides Properties

1. AppleAudio

Type: plist boolean

Failsafe: false

Description: ~~Reinstalls~~ [Replaces](#) Apple audio protocols with builtin versions.

Apple audio protocols allow macOS bootloader and OpenCore to play sounds and signals for screen reading or audible error reporting. Supported protocols are beep generation and VoiceOver. VoiceOver protocol is specific to Gibraltar machines (T2) and is not supported before macOS High Sierra (10.13). Instead older macOS versions use AppleHDA protocol, which is currently not implemented.

Only one set of audio protocols can be available at a time, so in order to get audio playback in OpenCore user interface on Mac system implementing some of these protocols this setting should be enabled.

Note: Backend audio driver needs to be configured in UEFI **Audio** section for these protocols to be able to stream audio.

2. AppleBootPolicy

Type: plist boolean

Failsafe: false

Description: ~~Reinstalls~~ [Replaces the](#) Apple Boot Policy protocol with a builtin version. This may be used to ensure APFS compatibility on VMs or legacy Macs.

Note: Some Macs, namely MacPro5,1, do have APFS compatibility, but their Apple Boot Policy protocol contains recovery detection issues, thus using this option is advised on them as well.

3. AppleDebugLog
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple Debug Log protocol with a builtin version.
4. AppleEvent
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple Event protocol with a builtin version. This may be used to ensure ~~FileVault~~ FileVault 2 compatibility on VMs or legacy Macs.
5. AppleFramebufferInfo
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple Framebuffer Info protocol with a builtin version. This may be used to override framebuffer information on VMs or legacy Macs to improve compatibility with legacy EfiBoot such as the one in macOS 10.4.
6. AppleImageConversion
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple Image Conversion protocol with a builtin version.
7. AppleImg4Verification
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple IMG4 Verification protocol with a builtin version. This protocol is used to verify im4m manifest files used by Apple Secure Boot.
8. AppleKeyMap
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces Apple Key Map protocols with builtin versions.
9. AppleRtcRam
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple RTC RAM protocol with a builtin version.

Note: Builtin version of Apple RTC RAM protocol may filter out I/O attempts to select RTC memory addresses. The list of addresses can be specified in 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:rtc-blacklist variable as a data array.
10. AppleSecureBoot
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple Secure Boot protocol with a builtin version.
11. AppleSmcIo
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple SMC I/O protocol with a builtin version.

This protocol replaces legacy VirtualSmc EFI driver, and is compatible with any SMC kernel extension. However, in case FakeSMC kernel extension is used, manual NVRAM key variable addition may be needed.
12. AppleUserInterfaceTheme
Type: plist boolean
Failsafe: false
Description: ~~Reinstalls~~ Replaces the Apple User Interface Theme protocol with a builtin version.
13. DataHub
Type: plist boolean

Failsafe: false

Description: ~~Reinstalls~~ Replaces the Data Hub protocol with a builtin version. ~~This will delete all previous properties~~

Note: This will discard all previous entries if the protocol was already installed, so all properties required for safe operation of the system must be specified in your configuration.

14. DeviceProperties

Type: plist boolean

Failsafe: false

Description: ~~Reinstalls~~ Replaces the Device Property protocol with a builtin version. This ~~will delete all previous properties if it was already installed.~~ This may be used to ensure full compatibility on VMs or legacy Macs.

Note: This will discard all previous entries if the protocol was already installed, so all properties required for safe operation of the system must be specified in your configuration.

15. FirmwareVolume

Type: plist boolean

Failsafe: false

Description: ~~Forceibly wraps~~ Wraps Firmware Volume protocols or installs ~~new~~ a new version to support custom cursor images for ~~File Vault~~ FileVault 2. ~~Should be set~~ Set to true to ensure ~~File Vault~~ FileVault 2 compatibility on ~~everything but anything other than~~ VMs and legacy Macs.

Note: Several virtual machines including VMware may have corrupted cursor ~~image~~ images in HiDPI mode and thus, may also require ~~this setting to be enabled~~ enabling this setting.

16. HashServices

Type: plist boolean

Failsafe: false

Description: ~~Forceibly reinstalls~~ Replaces Hash Services protocols with builtin versions. ~~Should be set~~ Set to true to ensure ~~File Vault~~ FileVault 2 compatibility on platforms ~~providing broken~~ with flawed SHA-1 ~~hashing.~~ Can be diagnosed by hash implementations. This can be determined by an invalid cursor size ~~with when~~ UIScale is set to 02, ~~in general platforms prior to.~~ Platforms earlier than APTIO V (Haswell and older) are typically affected.

17. OSInfo

Type: plist boolean

Failsafe: false

Description: ~~Forceibly reinstalls~~ Replaces the OS Info protocol with ~~builtin versions~~ a builtin version. This protocol is ~~generally used~~ typically used by the firmware and other applications to receive notifications from ~~macOS bootloader, by the firmware or by other applications~~ the macOS bootloader.

18. UnicodeCollation

Type: plist boolean

Failsafe: false

Description: ~~Forceibly reinstalls~~ Replaces unicode collation services with builtin ~~version.~~ versions. Set to true to ensure UEFI Shell compatibility on platforms ~~providing broken unicode collation.~~ In general legacy with flawed unicode collation implementations. Legacy Insyde and APTIO platforms on Ivy Bridge ~~and earlier are,~~ and earlier, are typically affected.

11.12 Quirks Properties

1. DisableSecurityPolicy

Type: plist boolean

Failsafe: false

Description: Disable platform security policy.

Note: This setting disables various security features of the firmware, defeating the purpose of any kind of Secure Boot. Do NOT enable if you use UEFI Secure Boot.

2. ExitBootServicesDelay

Type: plist integer

Failsafe: 0

Description: Adds delay in microseconds after EXIT_BOOT_SERVICES event.

This is a very rough workaround to circumvent the `Still waiting for root device` message on some APTIO IV firmware (ASUS Z87-Pro) particularly when using FileVault 2. It appears that for some reason, they execute code in parallel to EXIT_BOOT_SERVICES, which results in the SATA controller being inaccessible from macOS. A better approach ~~should be found in some future~~ is required and Acidanthera is open to suggestions. Expect 3 to 5 seconds to be adequate when this quirk is needed.

3. IgnoreInvalidFlexRatio

Type: plist boolean

Failsafe: false

Description: Some types of firmware (such as APTIO IV) may contain invalid values in the MSR_FLEX_RATIO (0x194) MSR register. These values may cause macOS boot failures on Intel platforms.

Note: While the option is not expected to harm unaffected firmware, its use is ~~only recommended when it is recommended only when~~ specifically required.

4. ReleaseUsbOwnership

Type: plist boolean

Failsafe: false

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

5. RequestBootVarRouting

Type: plist boolean

Failsafe: false

Description: Request redirect of all Boot prefixed variables from EFI_GLOBAL_VARIABLE_GUID to OC_VENDOR_VARIABLE_GUID.

This quirk requires OC_FIRMWARE_RUNTIME protocol implemented in `OpenRuntime.efi`. The quirk lets default boot entry preservation at times when the firmware deletes incompatible boot entries. In summary, this quirk is required to reliably use the Startup Disk preference pane in firmware that is not compatible with macOS boot entries by design.

By redirecting Boot prefixed variables to a separate GUID namespace with the help of `RequestBootVarRouting` quirk we achieve multiple goals:

- Operating systems are jailed and only controlled by OpenCore boot environment to enhance security.
- Operating systems do not mess with OpenCore boot priority, and guarantee fluent updates and hibernation wakes for cases that require reboots with OpenCore in the middle.
- Potentially incompatible boot entries, such as macOS entries, are not deleted or ~~anyhow corrupted~~ corrupted in any way.

6. TscSyncTimeout

Type: plist integer

Failsafe: 0

Description: Attempts to perform TSC synchronisation with a specified timeout.

The primary purpose of this quirk is to enable early bootstrap TSC synchronisation on some server and laptop models when running a debug XNU kernel. For the debug kernel the TSC needs to be kept in sync across the cores before any kext could kick in rendering all other solutions problematic. The timeout is specified in microseconds and depends on the amount of cores present on the platform, the recommended starting value is 500000.

This is an experimental quirk, which should only be used for the aforementioned problem. In all other cases, the quirk may render the operating system unstable and is not recommended. The recommended solution in the other cases is to install a kernel driver such as `VoodooTSCSync`, `TSCAdjustReset`, or `CpuTscSync` (a more specialised variant of `VoodooTSCSync` for newer laptops).

Note: ~~The reason this~~ This quirk cannot replace the kernel driver ~~is~~ because it cannot operate in ACPI S3 ~~mode~~ mode (sleep wake) mode and because the UEFI firmware only provides very limited multicore support ~~preventing the precise update which prevents precise updates~~ of the MSR registers.

7. UnblockFsConnect

Type: plist boolean

Failsafe: false

Description: Some types of firmware block partition handles by opening them in By Driver mode, resulting in ~~being-unable~~ an inability to install File System protocols.

Note: ~~The quirk is mostly relevant for select HP laptops with no drives listed~~ This quirk is useful in cases where unsuccessful drive detection results in an absence of boot entries.

11.13 ReservedMemory Properties

1. Address

Type: plist integer

Failsafe: 0

Description: Start address of the reserved memory region, which should be allocated as reserved effectively marking the memory of this type inaccessible to the operating system.

The addresses written here must be part of the memory map, have [a](#) EfiConventionalMemory type, and [be](#) page-aligned (4 KBs).

Note: Some types of firmware may not allocate memory areas used by S3 (sleep) and S4 (hibernation) code unless CSM is enabled causing wake failures. After comparing the memory maps with CSM disabled and enabled, these areas can be found in the lower memory and can be fixed up by doing the reservation. See `Sample.plist` for more details.

2. Comment

Type: plist string

Failsafe: Empty ~~string~~

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

3. Size

Type: plist integer

Failsafe: 0

Description: Size of the reserved memory region, must be page-aligned (4 KBs).

4. Type

Type: plist string

Failsafe: Reserved

Description: Memory region type matching the UEFI specification memory descriptor types. Mapping:

- Reserved — EfiReservedMemoryType
- LoaderCode — EfiLoaderCode
- LoaderData — EfiLoaderData
- BootServiceCode — EfiBootServicesCode
- BootServiceData — EfiBootServicesData
- RuntimeCode — EfiRuntimeServicesCode
- RuntimeData — EfiRuntimeServicesData
- Available — EfiConventionalMemory
- Persistent — EfiPersistentMemory
- UnusableMemory — EfiUnusableMemory
- ACPIReclaimMemory — EfiACPIReclaimMemory
- ACPIMemoryNVS — EfiACPIMemoryNVS
- MemoryMappedIO — EfiMemoryMappedIO
- MemoryMappedIOPortSpace — EfiMemoryMappedIOPortSpace
- PalCode — EfiPalCode

5. Enabled

Type: plist boolean

Failsafe: false

Description: This region will not be reserved unless set to `true`.

12 Troubleshooting

12.1 Legacy Apple OS

Older operating systems may be more complicated to install, but sometimes can be necessary to use for all kinds of reasons. While a compatible board identifier and CPUID are the obvious requirements for proper functioning of an older operating system, there are many other less obvious things to consider. This section tries to cover a common set of issues relevant to installing older macOS operating systems.

While newer operating systems can be downloaded over the internet, older operating systems did not have installation media for every minor release, ~~so to get a compatible distribution one may have to~~. For compatible distributions of such, download a device-specific image and ~~mod-modify~~ it if necessary. ~~To get the~~ Visit this archived Apple Support article for a list of the bundled device-specific builds for legacy operating systems~~one can visit this archived Apple Support~~. ~~Since it is not always~~. However, as this may not always be accurate, the latest versions are listed below.

12.1.1 macOS 10.8 and 10.9

- Disk images on these systems use Apple Partitioning Scheme and require `OpenPartitionDxe` driver to run DMG recovery and installation (included in `OpenDuet`). It is possible to set `DmgLoading` to `Disabled` to run the recovery without DMG loading avoiding the need for `OpenPartitionDxe`.
- Cached kernel images often do not contain family drivers for networking (`IONetworkingFamily`) or audio (`IOAudioFamily`) requiring the use of `Force` loading in order to inject networking or audio drivers.

12.1.2 macOS 10.7

- All previous issues apply.
- SSSE3 support (not to be confused with SSE3 support) is a hard requirement for macOS 10.7 kernel.
- Many kexts, including Lilu when 32-bit kernel is used and a lot of Lilu plugins, are unsupported on macOS 10.7 and older as they require newer kernel APIs, which are not part of the macOS 10.7 SDK.
- Prior to macOS 10.8 KASLR sliding is not supported, which will result in memory allocation failures on firmware that utilise lower memory for their own purposes. Refer to [acidanthera/bugtracker#1125](#) for tracking.

12.1.3 macOS 10.6

- All previous issues apply.
- SSSE3 support is a requirement for macOS 10.6 kernel with 64-bit userspace enabled. This limitation can mostly be lifted by enabling the `LegacyCommpage` quirk.
- Last released installer images for macOS 10.6 are macOS 10.6.7 builds 10J3250 (for `MacBookPro8,x`) and 10J4139 (for `iMac12,x`), without Xcode). These images are limited to their target model identifiers and have no `-no_compat_check` boot argument support. Modified images (with `ACDT` suffix) without model restrictions can be found here (MEGA Mirror), assuming macOS 10.6 is legally owned. Read `DIGEST.txt` for more details. Note that these are the earliest tested versions of macOS 10.6 with OpenCore.

Model checking may also be erased by editing `OSInstall.mpkg` with e.g. `Flat Package Editor` by making `Distribution` script to always return `true` in `hwbeModelCheck` function. Since updating the only file in the image and not corrupting other files can be difficult and may cause slow booting due to kernel cache date changes, it is recommended to script image rebuilding as shown below:

```
#!/bin/bash
# Original.dmg is original image, OSInstall.mpkg is patched package
mkdir R0
hdiutil mount Original.dmg -noverify -noautoopen -noautoopenrw -noautofsck -mountpoint R0
cp R0/.DS_Store DS_STORE
hdiutil detach R0 -force
rm -rf R0
hdiutil convert Original.dmg -format UDRW -o ReadWrite.dmg
mkdir RW
```

7. Can I use this on Apple hardware or virtual machines?

Sure, most relatively modern Mac models including MacPro5,1 and virtual machines are fully supported. Even though there are little to none specific details relevant to Mac hardware, some ongoing instructions can be found on MacRumors.com.

8. Why ~~do~~must Find&Replace patches ~~must~~be equal in ~~length~~size?

For machine code (x86 code) it is not possible to do differently sized replacements due to relative addressing. For ACPI code this is risky, and is technically equivalent to ACPI table replacement, thus not implemented. More detailed explanation can be found on AppleLife.ru or in the ACPI section of this document.

9. How can I decide which Booter quirks to use?

These quirks originate from AptioMemoryFix driver but provide a wider set of changes specific to modern systems. Note, that OpenRuntime driver is required for most configurations. To get a configuration similar to AptioMemoryFix the following set of quirks should be enabled:

- ProvideConsoleGop (UEFI quirk)
- AvoidRuntimeDefrag
- DiscardHibernateMap
- EnableSafeModeSlide
- EnableWriteUnprotector
- ForceExitBootServices
- ProtectMemoryRegions
- ProvideCustomSlide
- RebuildAppleMemoryMap
- SetupVirtualMap

However, as of today, such set is strongly discouraged as some of these quirks are not necessary to be enabled or need additional quirks. For example, DevirtualiseMmio and ProtectUefiServices are often required, while DiscardHibernateMap and ForceExitBootServices are rarely necessary.

Unfortunately for some quirks such as RebuildAppleMemoryMap, EnableWriteUnprotector, ProtectMemoryRegions, SetupVirtualMap, and SyncRuntimePermissions there is no definite approach even on similar systems, so trying all their combinations may be required for optimal setup. Refer to individual quirk descriptions in this document for more details.