



OpenCore

Reference Manual (~~0.0.4~~0.5.0)

[2019.08.29]

1 Introduction

This document provides information on OpenCore user configuration file format used to setup the correct functioning of macOS operating system. It is to be read as the official clarification of expected OpenCore behaviour. All deviations, if found in published OpenCore releases, shall be considered documentation or implementation bugs, and are requested to be reported through Acidanthera Bugtracker. All other sources or translations of this document are unofficial and may contain errors.

1.1 Known defects

~~For OpenCore issues please refer to~~ This document is structured as a specification, and is not meant to provide a step by step algorithm for configuring end-user board support package (BSP). Any third-party articles, tools, books, etc., providing such material are prone to their authors' preferences, tastes, this document misinterpretation, and essential obsolescence. In case you still use these sources, for example, OpenCore Vanilla Desktop Guide, please ensure following this document for every made decision and judging its consequences. Regardless of the sources used you are required to fully understand every dedicated OpenCore configuration option and concept prior to reporting any issues in Acidanthera Bugtracker.

1.1 Generic Terms

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

5 Booter

5.1 Introduction

This section allows to apply different kinds of UEFI modifications on Apple bootloader (`boot.efi`). The modifications currently provide various patches and environment alterations for different firmwares. Some of these features were originally implemented as a part of `AptioMemoryFix.efi`, which is no longer maintained. See Tips and Tricks section for migration steps.

If you are using this for the first time on a customised firmware, there is a list of checks to do first. Prior to starting please ensure that you have:

- Most up-to-date UEFI firmware (check your motherboard vendor website).
- **Fast Boot** and **Hardware Fast Boot** disabled in firmware settings if present.
- **Above 4G Decoding** or similar enabled in firmware settings if present. Note, that on some motherboards (notably ASUS WS-X299-PRO) this option causes adverse effects, and must be disabled. While no other motherboards with the same issue are known, consider this option to be first to check if you have erratic boot failures.
- **DisableIoMapper** quirk enabled, or **VT-d** disabled in firmware settings if present, or ACPI DMAR table dropped.
- **No ‘slide’ boot argument** present in NVRAM or anywhere else. It is not necessary unless you cannot boot at all or see **No slide values are usable! Use custom slide!** message in the log.
- **CFG Lock** (MSR 0xE2 write protection) disabled in firmware settings if present. Consider patching it if you have enough skills and no option is available. See `VerifyMsrE2` notes for more details.
- **CSM (Compatibility Support Module)** disabled in firmware settings if present. You may need to flash GOP ROM on NVIDIA 6xx/AMD 2xx or older. Use `GopUpdate` or `AMD UEFI GOP MAKER` in case you are not sure how.
- **EHCI/XHCI Hand-off** enabled in firmware settings **only** if boot stalls unless USB devices are disconnected.
- **VT-x, Hyper Threading, Execute Disable Bit** enabled in firmware settings if present.
- While it may not be required, sometimes you have to disable **Thunderbolt support**, **Intel SGX**, and **Intel Platform Trust** in firmware settings present.

When debugging sleep issues you may want to (temporarily) disable Power Nap and automatic power off, which appear to sometimes cause wake to black screen or boot loop issues on older platforms. The particular issues may vary, but in general you should check ACPI tables first. Here is an example of a bug found in some Z68 motherboards. To turn Power Nap and the others off run the following commands in Terminal:

```
sudo pmset autopoweroff 0
sudo pmset powernap 0
sudo pmset standby 0
```

Note: these settings may reset at hardware change and in certain other circumstances. To view their current state use `pmset -g` command in Terminal.

5.2 Properties

1. Quirks

Type: plist dict

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

5.3 Quirks Properties

1. 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 many firmwares using SMM backing for select services like variable storage. SMM may try to access physical addresses, but they get moved by boot.efi.

Note: Most but Apple and VMware firmwares need this quirk.

2. 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 the target board.

3. DisableVariableWrite

Type: plist boolean

Failsafe: false

Description: Protect from macOS NVRAM write access.

This is a security option allowing one to restrict NVRAM access in macOS. This quirk requires OC_FIRMWARE_RUNTIME protocol implemented in `FwRuntimeServices.efi`.

Note: This quirk can also be used as an ugly workaround to buggy UEFI runtime services implementations that fail to write variables to NVRAM and break the rest of the operating system.

4. DiscardHibernateMap

Type: plist boolean

Failsafe: false

Description: Reuse original hibernate memory map.

This option forces XNU kernel to ignore newly supplied memory map and assume that it did not change after waking from hibernation. This behaviour is required to work by Windows, which mandates to preserve runtime memory size and location after S4 wake.

Note: This may be used to workaround buggy memory maps on older hardware, and is now considered rare legacy. Do not use this unless you fully understand the consequences.

5. EnableSafeModeSlide

Type: plist boolean

Failsafe: false

Description: Patch bootloader to have KASLR enabled in safe mode.

This option is relevant to the users that have issues booting to safe mode (e.g. by holding `shift` or using `-x` boot argument). By default safe mode forces 0 slide as if the system was launched with `slide=0` boot argument. This quirk tries to patch `boot.efi` to lift that limitation and let some other value (from 1 to 255) be used. This quirk requires `ProvideCustomSlide` to be enabled.

Note: The necessity of this quirk is determined by safe mode availability. If booting to safe mode fails, this option can be tried to be enabled.

6. EnableWriteUnprotector

Type: plist boolean

Failsafe: false

Description: Permit write access to UEFI runtime services code.

This option bypasses RX permissions in code pages of UEFI runtime services by removing write protection (WP) bit from CRO register during their execution. This quirk requires OC_FIRMWARE_RUNTIME protocol implemented in `FwRuntimeServices.efi`.

Note: The necessity of this quirk is determined by early boot crashes of the firmware.

7. ForceExitBootServices

Type: plist boolean

Failsafe: false

Description: Retry `ExitBootServices` with new memory map on failure.

Try to ensure that `ExitBootServices` call succeeds even with outdated `MemoryMap` key argument by obtaining current memory map and retrying `ExitBootServices` call.

Failsafe: Empty string

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

5. MatchKernel

Type: plist string

Failsafe: Empty string

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

6. PlistPath

Type: plist string

Failsafe: Empty string

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

7.4 Block 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 this value is used.

2. Enabled

Type: plist boolean

Failsafe: `false`

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

3. Identifier

Type: plist string

Failsafe: Empty string

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

4. MatchKernel

Type: plist string

Failsafe: Empty string

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

7.5 Emulate Properties

1. Cpuid1Data

Type: plist data, 16 bytes

Failsafe: All zero

Description: Sequence of EAX, EBX, ECX, EDX values in Little Endian order to replace CPUID (1) call in XNU kernel. Normally it is only the value of EAX that needs to be taken care of, which represents the exact CPUID. And the remainders are to be left as zeroes. For instance, A9 06 03 00 stands for CPUID 0x0306A9 (Ivy Bridge). A good example can be found at [acidanthera/bugtracker#365](#). (See Special NOTES for Haswell+ low-end)

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.

7.6 Patch Properties

1. Base

Type: plist string

Failsafe: Empty string

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

10.3 DataHub Properties

1. PlatformName

Type: plist string

Failsafe: Not installed

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

2. SystemProductName

Type: plist string

Failsafe: 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

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

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

5. BoardProduct

Type: plist string

Failsafe: 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_PMCON_2 bit 0)
- 0x00000002 — Shutdown cause was a SYS_PWROK event (Same as GEN_PMCON_2 bit 1)
- 0x00000004 — Shutdown cause was a THRMTRIP# event (Same as GEN_PMCON_2 bit 3)
- 0x00000008 — Rebooted due to a SYS_RESET# event (Same as GEN_PMCON_2 bit 4)
- 0x00000010 — Power Failure (Same as GEN_PMCON_3 bit 1 PWR_FLR)
- 0x00000020 — Loss of RTC Well Power (Same as GEN_PMCON_3 bit 2 RTC_PWR_STS)
- 0x00000040 — General Reset Status (Same as GEN_PMCON_3 bit 9 GEN_RST_STS)
- 0xfffffff80 — SUS Well Power Loss (Same as GEN_PMCON_3 bit 14)
- 0x00010000 — Wake cause was a ME Wake event (Same as PRSTS bit 0, ME_WAKE_STS)
- 0x00020000 — Cold Reboot was ME Induced event (Same as PRSTS bit 1 ME_HRST_COLD_STS)
- 0x00040000 — Warm Reboot was ME Induced event (Same as PRSTS bit 2 ME_HRST_WARM_STS)
- 0x00080000 — Shutdown was ME Induced event (Same as PRSTS bit 3 ME_HOST_PWRDN)
- 0x00100000 — Global reset ME 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: 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: ~~Not installed~~Automatic

Description: Sets ARTFrequency in gEfiProcessorSubClassGuid. ~~Sets-~~

This value contains CPU ART frequency, Skylake also known as crystal clock frequency. Its existence is exclusive to 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.

11. DevicePathsSupported

Type: plist integer, 32-bit

Failsafe: 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

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

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

Description: Sets RP1t in gEfiMiscSubClassGuid. Custom property read by VirtualSMC or FakeSMC to generate SMC RP1t key.

10.4 PlatformNVRAM Properties

1. BID

Type: plist string

Failsafe: 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

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

This is a workaround for select board firmwares, namely GA-Z77P-D3 (rev. 1.1), failing to properly access higher memory in UEFI Boot Services. On these boards this quirk is required for booting entries that need to allocate large memory chunks, such as macOS DMG recovery entries. On unaffected boards it may cause boot failures, and thus strongly not recommended. For known issues refer to [acidanthera/bugtracker#449](https://github.com/acidanthera/bugtracker/issues/449).

2. `ExitBootServicesDelay`

Type: plist integer

Failsafe: 0

Description: Adds delay in microseconds after `EXIT_BOOT_SERVICES` event.

This is a very ugly quirk to circumvent "Still waiting for root device" message on select APTIO IV firmwares, namely ASUS Z87-Pro, when using FileVault 2 in particular. It seems that for some reason they execute code in parallel to `EXIT_BOOT_SERVICES`, which results in SATA controller being inaccessible from macOS. A better approach should be found in some future. Expect 3-5 seconds to be enough in case the quirk is needed.

3. `IgnoreInvalidFlexRatio`

Type: plist boolean

Failsafe: false

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

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

4. `IgnoreTextInGraphics`

Type: plist boolean

Failsafe: false

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

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

5. `ReplaceTabWithSpace`

Type: plist boolean

Failsafe: false

Description: Some firmwares do not print tab characters or even everything that follows them, causing difficulties or inability to use the UEFI Shell builtin text editor to edit property lists and other documents. This option makes the console output spaces instead of tabs.

Note: `ConsoleControl` may need to be set to `true` for this to work.

6. `ProvideConsoleGop`

Type: plist boolean

Failsafe: false

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

7. `ReleaseUsbOwnership`

Type: plist boolean

Failsafe: false

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

8. `RequestBootVarRouting`

Type: plist boolean

Failsafe: false

Description: Request redirectBoot prefixed variables from `EFI_GLOBAL_VARIABLE_GUID` to `OC_VENDOR_VARIABLE_GUID`.

This quirk requires `OC_FIRMWARE_RUNTIME` protocol implemented in `FwRuntimeServices.efi`. The quirk lets

default boot entry preservation at times when firmwares delete incompatible boot entries. Simply said, you are required to enable this quirk to be able to reliably use Startup Disk preference pane in a firmware that is not compatible with macOS boot entries by design.

9. SanitiseClearScreen

Type: plist boolean

Failsafe: false

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

Note: `ConsoleControl` may need to be set to `true` for this to work. On all known affected systems `ConsoleMode` had to be set to empty string for this to work.

10. ClearScreenOnModeSwitch

Type: plist boolean

Failsafe: false

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

Note: `ConsoleControl` should be set to `true` for this to work.

- Watch Dog is disabled to prevent automatic reboot: `Misc → Debug → DisableWatchDog = true`.
- Boot Picker (entry selector) is enabled: `Misc → Boot → ShowPicker = true`.

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

2. How to customise boot entries?

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

3. How to choose the default boot entry?

OpenCore uses the primary UEFI boot option to select the default entry. This choice can be altered from UEFI Setup, with the macOS Startup Disk preference, or the Windows Boot Camp Control Panel. Since choosing OpenCore's `BOOTx64.EFI` as a primary boot option limits this functionality in addition to several firmwares deleting incompatible boot options, potentially including those created by macOS, you are strongly encouraged to use the `RequestBootVarRouting` quirk, which will preserve your selection made in the operating system within the OpenCore variable space. Note, that `RequestBootVarRouting` requires a separate driver for functioning.

4. What is the simplest way to install macOS?

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

To download recovery online you may use [tool from macrecovery.py](#) [tool from MacInfoPkg](#).

[For offline installation refer to](#) How to create a bootable installer for macOS [article](#).

5. Why do online recovery images (`*.dmg`) fail to load?

This may be caused by missing HFS+ driver, as all presently known recovery volumes have HFS+ filesystem. Another cause may be buggy firmware allocator, which can be worked around with `AvoidHighAlloc` UEFI quirk.

6. 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 in [acidanthera/bugtracker#377](#).

7. Why do Find&Replace patches must equal in length?

For machine code (x86 code) it is not possible to do such 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](#).

8. How can I migrate from `AptioMemoryFix`?

Behaviour similar to that of `AptioMemoryFix` can be obtained by installing `FwRuntimeServices` driver and enabling the quirks listed below. Please note, that most of these are not necessary to be enabled. Refer to their individual descriptions in this document for more details.

- `ProvideConsoleGop` (UEFI quirk)
- `AvoidRuntimeDefrag`
- `DiscardHibernateMap`
- `EnableSafeModeSlide`
- `EnableWriteUnprotector`
- `ForceExitBootServices`
- `ProtectCsmRegion`
- `ProvideCustomSlide`
- `SetupVirtualMap`
- `ShrinkMemoryMap`