



# OpenCore

Reference Manual (~~0.5.9~~0.6.0)

[2020.07.29]

# 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. [Errata sheet is available in](#) OpenCorePkg repository.

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). The intended audience of the document are programmers and engineers with basic understanding of macOS internals and UEFI functioning. For these reasons this document is available exclusively in English, and all other sources or translations of this document are unofficial and may contain errors.

Third-party articles, utilities, books, and alike may be more useful for a wider audience as they could provide guide-like material. However, they are prone to their authors' preferences, tastes, this document misinterpretation, and essential obsolescence. In case you use these sources, for example, Dortania's OpenCore Install Guide and related material, please ensure to follow this document for every made decision and judge its consequences.

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

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

## 2.3 Configuration Structure

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

- `Add` provides support for data addition. Existing data will not be overridden, and needs to be handled separately with `Delete` if necessary.
- `Delete` provides support for data removal.
- `Patch` provides support for data modification.
- `Quirks` provides support for specific hacks.

Root configuration entries consist of the following:

- `ACPI`
- `Booter`
- `DeviceProperties`
- `Kernel`
- `Misc`
- `NVRAM`
- `PlatformInfo`
- `UEFI`

It is possible to perform basic validation of the configuration by using `ConfigValidityocvalidate` utility. Please note, that `ConfigValidityocvalidate` must match the used OpenCore release and may not be able to detect all configuration flaws present in the file.

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

### 3.3 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 supported EDK II release is hosted in acidanthera/audk. The required patches for the package are present in `Patches` directory.

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

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

---

```
git clone https://github.com/acidanthera/audk UDK
git clone --recursive --depth=1 https://github.com/acidanthera/audk UDK
cd UDK
git clone https://github.com/acidanthera/OpenCorePkg
source edksetup.sh
make -C BaseTools
build -a X64 -b RELEASE -t XCODE5 -p OpenCorePkg/OpenCorePkg.dsc
```

---

Listing 1: Compilation Commands

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

---

```
-I/UefiPackages/MdePkg
-I/UefiPackages/MdePkg/Include
-I/UefiPackages/MdePkg/Include/X64
-I/UefiPackages/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
-IIinclude
-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

**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.
- Avoid patching \_OSI to support a higher level of feature sets unless absolutely required. Commonly this enables a number of hacks on APTIO firmwares, which result in the need to add more patches. Modern firmwares generally do not need it at all, and those that do are fine with much smaller patches.
- Try to avoid hacky changes like renaming \_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 report functional key presses on a laptop, the original method can be replaced with a dummy name by patching \_Q11 with XQ11.

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

*Note:* Patches of different Find and Replace lengths are unsupported as they may corrupt ACPI tables and make you system unstable due to area relocation. If you need such changes you may ~~utilities~~utilise “proxy” patching or NOP the remaining area.

## 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.

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

5. `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. Examples of such hardware are Ivy Bridge laptops with Insyde firmware, like Acer V3-571G. Do not use this unless you fully understand the consequences.

6. `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.

7. `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 CR0 register during their execution. This quirk requires `OC_FIRMWARE_RUNTIME` protocol implemented in `OpenRuntime.efi`.

*Note:* This quirk may potentially weaken firmware security, please use `RebuildAppleMemoryMap` if your firmware supports memory attributes table (MAT). [Refer to OCABC: MAT support is 1/0 log entry to determine whether MAT is supported.](#)

8. `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.

*Note:* The necessity of this quirk is determined by early boot crashes of the firmware. Do not use this unless you fully understand the consequences.

9. `ProtectMemoryRegions`

**Type:** plist boolean

**Failsafe:** false

**Description:** Protect memory regions from incorrect access.

Some firmwares incorrectly map select memory regions:

- CSM region can be marked as boot services code or data, which leaves it as free memory for XNU kernel.
- MMIO regions can be marked as reserved memory and stay unmapped, but may be required to be accessible at runtime for NVRAM support.

This quirk attempts to fix types of these regions, e.g. ACPI NVS for CSM or MMIO for MMIO.

*Note:* The necessity of this quirk is determined by artifacts, sleep wake issues, and boot failures. In general only very old firmwares need this quirk.

10. `ProtectSecureBoot`

**Type:** plist boolean

**Failsafe:** false

**Description:** Protect UEFI Secure Boot variables from being written.

Reports security violation during attempts to write to `db`, `dbx`, `PK`, and `KEK` variables from the operating system.

*Note:* This quirk mainly attempts to avoid issues with NVRAM implementations with problematic defragmentation, such as select Insyde or MacPro5,1.

11. `ProtectUefiServices`

**Type:** plist boolean

**Failsafe:** false

**Description:** Protect UEFI services from being overridden by the firmware.

Some modern firmwares including both hardware and virtual machines, like VMware, may update pointers to UEFI services during driver loading and related actions. Consequentially this directly breaks other quirks that affect memory management, like `DevirtualiseMmio`, `ProtectMemoryRegions`, or `RebuildAppleMemoryMap`, and may also break other quirks depending on the effects of these.

*Note:* On VMware the need for this quirk may be diagnosed by “Your Mac OS guest might run unreliably with more than one virtual core.” message.

12. `ProvideCustomSlide`

**Type:** plist boolean

**Failsafe:** false

**Description:** Provide custom KASLR slide on low memory.

This option performs memory map analysis of your firmware and checks whether all slides (from 1 to 255) can be used. As `boot.efi` generates this value randomly with `rdrand` or pseudo randomly `rdtsc`, there is a chance of boot failure when it chooses a conflicting slide. In case potential conflicts exist, this option forces macOS to use a pseudo random value among the available ones. This also ensures that `slide=` argument is never passed to the operating system for security reasons.

*Note:* The necessity of this quirk is determined by `OCABC: Only N/256 slide values are usable!` message in the debug log. If the message is present, this option is to be enabled.

13. `ProvideMaxSlide`

**Type:** plist integer

**Failsafe:** 0

**Description:** Provide maximum KASLR slide when higher ones are unavailable.

This option overrides the maximum slide of 255 by a user specified value between 1 and 254 inclusive when `ProvideCustomSlide` is enabled. It is believed that modern firmwares allocate pool memory from top to bottom, effectively resulting in free memory at the time of slide scanning being later used as temporary memory during kernel loading. In case those memory are unavailable, this option can stop evaluating higher slides.

*Note:* The necessity of this quirk is determined by random boot failure when `ProvideCustomSlide` is enabled and the randomized slide fall into the unavailable range. When `AppleDebug` is enabled, usually the debug log may contain messages like `AAPL: [EB] 'LD:LKC' } Err(0x9)`. To find the optimal value, manually append `slide=X` to `boot-args` and log the largest one that won't cause boot failure.

14. `RebuildAppleMemoryMap`

**Type:** plist boolean

**Failsafe:** false

**Description:** Generate Memory Map compatible with macOS.

Apple kernel has several limitations in parsing UEFI memory map:

- Memory map size must not exceed 4096 bytes as Apple kernel maps it as a single 4K page. Since some firmwares have very large memory maps (approximately over 100 entries) Apple kernel will crash at boot.
- Memory attributes table is ignored. `EfiRuntimeServicesCode` memory statically gets `RX` permissions, and all other memory types get `RW` permissions. Since some firmware drivers may write to global variables

at runtime, Apple kernel will crash at calling UEFI runtime services, unless driver `.data` section has `EfiRuntimeServicesData` type.

To workaround these limitations this quirk applies memory attributes table permissions to memory map passed to Apple kernel and optionally attempts to unify contiguous slots of similar types if the resulting memory map exceeds 4 KB.

*Note 1:* Since many firmwares come with incorrect memory protection table this quirk often comes in pair with `SyncRuntimePermissions`.

*Note 2:* The necessity of this quirk is determined by early boot failures. This quirk replaces `EnableWriteUnprotector` on firmwares supporting memory attributes table (MAT). [This quirk is generally unnecessary when using OpenDuetPkg, but may be required to boot macOS 10.6 and earlier for unclear reasons.](#)

#### 15. `SetupVirtualMap`

**Type:** plist boolean

**Failsafe:** false

**Description:** Setup virtual memory at `SetVirtualAddresses`.

Select firmwares access memory by virtual addresses after `SetVirtualAddresses` call, which results in early boot crashes. This quirk workarounds the problem by performing early boot identity mapping of assigned virtual addresses to physical memory.

*Note:* The necessity of this quirk is determined by early boot failures. Currently new firmwares with memory protection support (like OVMF) do not support this quirk due to acidanthera/bugtracker#719.

#### 16. `SignalAppleOS`

**Type:** plist boolean

**Failsafe:** false

**Description:** Report macOS being loaded through OS Info for any OS.

This quirk is useful on Mac firmwares, which behave differently in different OS. For example, it is supposed to enable Intel GPU in Windows and Linux in some dual-GPU MacBook models.

#### 17. `SyncRuntimePermissions`

**Type:** plist boolean

**Failsafe:** false

**Description:** Update memory permissions for runtime environment.

Some firmwares either fail to properly handle runtime permissions:

- They incorrectly mark `OpenRuntime` as not executable in the memory map.
- They incorrectly mark `OpenRuntime` as not executable in the memory attributes table.
- They lose entries from the memory attributes table after `OpenRuntime` is loaded.
- They mark items in the memory attributes table as read-write-execute.

This quirk tries to update memory map and memory attributes table to correct this.

*Note:* The necessity of this quirk is determined by early boot failures either in macOS or in Linux/Windows. In general only firmwares released in 2018 or later are affected.



## 6 DeviceProperties

### 6.1 Introduction

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

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

---

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

---

Device properties are part of the IODeviceTree (gIODT) plane of macOS I/O Registry. This plane has several construction stages relevant for the platform initialisation. While the early construction stage is performed by the XNU kernel in the IODeviceTreeAlloc method, the majority of the construction is performed by the platform expert, implemented in AppleACPIPlatformExpert.kext.

AppleACPIPlatformExpert incorporates two stages of IODeviceTree construction implemented by calling AppleACPIPlatformExpert::mergeDeviceProperties:

1. During ACPI table initialisation through the recursive ACPI namespace scanning by the calls to AppleACPIPlatformExpert::createDTNubs.
2. During IOService registration (IOServices::registerService) callbacks implemented as a part of AppleACPIPlatformExpert::platformAdjustService function and its private worker method AppleACPIPlatformExpert::platformAdjustPCIDevice specific to the PCI devices.

The application of the stages depends on the device presence in ACPI tables. The first stage applies very early but exclusively to the devices present in ACPI tables. The second stage applies to all devices much later after the PCI configuration and may repeat the first stage if the device was not present in ACPI.

For all kernel drivers, which may inspect the IODeviceTree plane without probing (e.g. Lilu and its plugins like WhateverGreen) it is particularly important to ensure device presence in the ACPI tables. Failing to do so may result in all kinds of erratic behaviour caused by ignoring the injected device properties as they were not constructed at the first stage. See SSDT-IMEI.dsl and SSDT-BRGO.dsl for an example.

### 6.2 Properties

1. Add

**Type:** `plist dict`

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

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

2. Delete

**Type:** `plist dict`

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

### 6.3 Common Properties

Some known properties include:

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

## 7 Kernel

### 7.1 Introduction

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

### 7.2 Properties

1. Add

**Type:** plist array

**Failsafe:** Empty

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

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

To track the dependency order one can inspect the `OSBundleLibraries` key in the `Info.plist` of the kext. Any kext mentioned in the `OSBundleLibraries` of the other kext must be precede this kext.

*Note:* Kexts may have inner kexts (Plug-Ins) in their bundle. Each inner kext must be added separately.

2. Block

**Type:** plist array

**Failsafe:** Empty

**Description:** Remove selected kernel drivers from prelinked kernel.

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

3. Emulate

**Type:** plist dict

**Description:** Emulate select hardware in kernelspace via parameters described in Emulate Properties section below.

4. Patch

**Type:** plist array

**Failsafe:** Empty

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

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

5. Quirks

**Type:** plist dict

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

### 7.3 Add Properties

1. BundlePath

**Type:** plist string

**Failsafe:** Empty string

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

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 this value is used.

3. Enabled

**Type:** plist boolean

## 8 Misc

### 8.1 Introduction

This section contains miscellaneous configuration affecting OpenCore operating system loading behaviour as well as other entries, which do not go to any other section.

OpenCore tries to follow “bless” model also known as “Apple Boot Policy”. The primary specialty of “bless” model is to allow embedding boot options within the file system (and be accessible through a specialised driver) as well as supporting a broader range of predefined boot paths compared to the removable media list found in the UEFI specification.

Each partition will only be used for booting when it corresponds to “Scan policy”: a set of restrictions to only use partitions with specific file systems and from specific device types. Scan policy behaviour is discussed in `ScanPolicy` property description.

Scan process starts with obtaining all the partitions filtered with “Scan policy”. Each partition may produce multiple primary and alternate options. Primary options describe operating systems installed on this media. Alternate options describe recovery options for the operating systems on the media. It is possible for alternate options to exist without primary options and vice versa. Be warned that the options may not necessarily describe the operating systems on the same partition. Each primary and alternate option can be an auxiliary option or not, refer to `HideAuxiliary` for more details. Algorithm to determine boot options behaves as follows:

1. Obtain all available partition handles filtered by “Scan policy” (and driver availability).
2. Obtain all available boot options from `BootOrder` UEFI variable.
3. For each found boot option:
  - Retrieve device path of the boot option.
  - Perform fixups (e.g. NVMe subtype correction) and expansion (e.g. for Boot Camp) of the device path.
  - Obtain device handle by locating device path of the resulting device path (ignore it on failure).
  - Find device handle in the list of partition handles (ignore it if missing).
  - For disk device paths (not specifying a bootloader) execute “bless” (may return > 1 entry).
  - For file device paths check presence on the file system directly.
  - ~~Exclude options with blacklisted filenames (refer to `BlackListAppleUpdate` option).~~
  - On OpenCore boot partition exclude all OpenCore bootstrap files by header checks.
  - Mark device handle as *used* in the list of partition handles if any.
  - Register the resulting entries as primary options and determine their types.  
The option will become auxiliary for some types (e.g. Apple HFS recovery).
4. For each partition handle:
  - If partition handle is marked as *unused* execute “bless” primary option list retrieval.  
In case `BlessOverride` list is set, not only standard “bless” paths will be found but also custom ones.
  - ~~Exclude options with blacklisted filenames (refer to `BlackListAppleUpdate` option).~~
  - On OpenCore boot partition exclude all OpenCore bootstrap files by header checks.
  - Register the resulting entries as primary options and determine their types if found.  
The option will become auxiliary for some types (e.g. Apple HFS recovery).
  - If partition already has primary options of “Apple Recovery” type proceed to next handle.
  - Lookup alternate entries by “bless” recovery option list retrieval and predefined paths.
  - Register the resulting entries as alternate auxiliary options and determine their types if found.
5. Custom entries and tools are added as primary options without any checks with respect to `Auxiliary`.
6. System entries (e.g. `Reset NVRAM`) are added as primary auxiliary options.

The display order of the boot options in the picker and the boot process are determined separately from the scanning algorithm. The display order as follows:

- Alternate options follow corresponding primary options, i.e. Apple recovery will be following the relevant macOS option whenever possible.
- Options will be listed in file system handle firmware order to maintain an established order across the reboots regardless of the chosen operating system for loading.
- Custom entries, tools, and system entries will be added after all other options.
- Auxiliary options will only show upon entering “Advanced Mode” in the picker (usually by pressing “Space”).

The boot process is as follows:

- Try looking up first valid primary option through `BootNext` UEFI variable.
- On failure looking up first valid primary option through `BootOrder` UEFI variable.
- Mark the option as the default option to boot.
- Boot option through the picker or without it depending on the `ShowPicker` option.
- Show picker on failure otherwise.

*Note 1:* This process is meant to work reliably only when `RequestBootVarRouting` option is enabled or the firmware does not control UEFI boot options (`OpenDuetPkg` or custom BDS). Without `BootProtect` it also is possible that other operating systems overwrite `OpenCore`, make sure to enable it if you plan to use them.

*Note 2:* UEFI variable boot options' boot arguments will be removed if present as they may contain arguments compromising the operating system, which is undesired once secure boot is enabled.

*Note 3:* Some operating systems, namely Windows, will create their boot option and mark it as top most upon first boot or after NVRAM Reset. When this happens default boot entry choice will update till next manual reconfiguration.

## 8.2 Properties

### 1. Boot

**Type:** `plist dict`

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

### 2. BlessOverride

**Type:** `plist array`

**Description:** Add custom scanning paths through bless model.

Designed to be filled with `plist string` entries containing absolute UEFI paths to customised bootloaders, for example, `\EFI\debian\grubx64.efi` for Debian bootloader. This allows unusual boot paths to be automatically discovered by the boot picker. Designwise they are equivalent to predefined blessed path, such as `\System\Library\CoreServices\boot.efi` or `\EFI\Microsoft\Boot\bootmgfw.efi`, but unlike predefined bless paths they have highest priority.

### 3. Debug

**Type:** `plist dict`

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

### 4. Entries

**Type:** `plist array`

**Description:** Add boot entries to boot picker.

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

### 5. Security

**Type:** `plist dict`

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

### 6. Tools

**Type:** `plist array`

**Description:** Add tool entries to boot picker.

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

*Note:* Select tools, for example, UEFI Shell, are very dangerous and **MUST NOT** appear in production configurations, especially in vaulted ones and protected with secure boot, as they may be used to easily bypass secure boot chain.

## 8.3 Boot Properties

### 1. ConsoleAttributes

**Type:** `plist integer`

**Failsafe:** 0

**Description:** Sets specific attributes for console.

Text renderer supports colour arguments as a sum of foreground and background ~~colors~~colours according to UEFI specification. The value of black background and black foreground (0) is reserved. List of colour names:

- 0x00 — EFI\_BLACK
- 0x01 — EFI\_BLUE
- 0x02 — EFI\_GREEN
- 0x03 — EFI\_CYAN
- 0x04 — EFI\_RED
- 0x05 — EFI\_MAGENTA
- 0x06 — EFI\_BROWN
- 0x07 — EFI\_LIGHTGRAY
- 0x08 — EFI\_DARKGRAY
- 0x09 — EFI\_LIGHTBLUE
- 0x0A — EFI\_LIGHTGREEN
- 0x0B — EFI\_LIGHTCYAN
- 0x0C — EFI\_LIGHTRED
- 0x0D — EFI\_LIGHTMAGENTA
- 0x0E — EFI\_YELLOW
- 0x0F — EFI\_WHITE
- 0x10 — EFI\_BACKGROUND\_BLACK
- 0x11 — EFI\_BACKGROUND\_BLUE
- 0x12 — EFI\_BACKGROUND\_GREEN
- 0x13 — EFI\_BACKGROUND\_CYAN
- 0x14 — EFI\_BACKGROUND\_RED
- 0x15 — EFI\_BACKGROUND\_MAGENTA
- 0x16 — EFI\_BACKGROUND\_BROWN
- 0x17 — EFI\_BACKGROUND\_LIGHTGRAY

*Note:* This option may not work well with **System** text renderer. Setting a background different from black could help testing proper GOP functioning.

## 2. HibernateMode

**Type:** plist string

**Failsafe:** None

**Description:** Hibernation detection mode. The following modes are supported:

- None — Avoid hibernation for your own good.
- Auto — Use RTC and NVRAM detection.
- RTC — Use RTC detection.
- NVRAM — Use NVRAM detection.

## 3. HideAuxiliary

**Type:** plist boolean

**Failsafe:** false

**Description:** Hides auxiliary entries from picker menu by default.

An entry is considered auxiliary when at least one of the following applies:

- Entry is macOS recovery.
- Entry is macOS Time Machine.
- Entry is explicitly marked as **Auxiliary**.
- Entry is system (e.g. ~~Clean~~Reset NVRAM).

To see all entries picker menu needs to be reloaded in extended mode by pressing **Spacebar** key. Hiding auxiliary entries may increase boot performance for multidisk systems.

## 4. 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 fallback to the default icon:
  - .VolumeIcon.icns file at Preboot root for APFS.
  - .VolumeIcon.icns file at volume root for other filesystems.
  - ~~<TOOL\_NAME>.icns file for Tools.~~

Volume icons can be set in Finder. Note, that enabling this may result in external and internal icons to be indistinguishable.

- 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.
  - <TOOL\_NAME>.l1l (<TOOL\_NAME>.l2x) file near tool for Tools.

Prerendered labels can be generated via disklabel utility or bless command. When disabled or missing text labels (.contentDetails or .disk\_label.contentDetails) are to be rendered instead.
- 0x0004 — OC\_ATTR\_USE\_GENERIC\_LABEL\_IMAGE, provides predefined label images for boot entries without custom entries. May give less detail for the actual boot entry.
- 0x0008 — OC\_ATTR\_USE\_ALTERNATE\_ICONS, changes used icon set to an alternate one if it is supported. For example, this could make a use of old-style icons with a custom background colour.

#### 5. PickerAudioAssist

**Type:** plist boolean

**Failsafe:** false

**Description:** Enable screen reader by default in boot picker.

For macOS bootloader screen reader preference is set in `preferences.efires` archive in `isV0Enabled.int32` file and is controlled by the operating system. For OpenCore screen reader support this option is an independent equivalent. Toggling screen reader support in both OpenCore boot picker and macOS bootloader FileVault 2 login window can also be done with `Command + F5` key combination.

*Note:* screen reader requires working audio support, see `UEFI Audio Properties` section for more details.

#### 6. PollAppleHotKeys

**Type:** plist boolean

**Failsafe:** false

**Description:** Enable modifier hotkey handling in boot picker.

In addition to `action hotkeys`, which are partially described in `PickerMode` section and are normally handled by Apple BDS, there exist modifier keys, which are handled by operating system bootloader, namely `boot.efi`. These keys allow to change operating system behaviour by providing different boot modes.

On some firmwares it may be problematic to use modifier keys due to driver incompatibilities. To workaround this problem this option allows registering select hotkeys in a more permissive manner from within boot picker. Such extensions include the support of tapping on keys in addition to holding and pressing `Shift` along with other keys instead of just `Shift` alone, which is not detectible on many PS/2 keyboards. This list of known modifier hotkeys includes:

- `CMD+C+MINUS` — disable board compatibility checking.
- `CMD+K` — boot release kernel, similar to `kcsuffix=release`.
- `CMD+S` — single user mode.
- `CMD+S+MINUS` — disable KASLR slide, requires disabled SIP.
- `CMD+V` — verbose mode.
- `Shift` — safe mode.

## 8.4 Debug Properties

### 1. AppleDebug

**Type:** plist boolean

**Failsafe:** false

**Description:** Enable `boot.efi` debug log saving to OpenCore log.

*Note:* This option only applies to 10.15.4 and newer.

### 2. ApplePanic

**Type:** plist boolean

**Failsafe:** false

**Description:** Save macOS kernel panic to OpenCore root partition.

The file is saved as `panic-YYYY-MM-DD-HHMMSS.txt`. It is strongly recommended to have `keepsyms=1` boot argument to see debug symbols in the panic log. In case it was not present `kpdescribe.sh` utility (bundled with OpenCore) may be used to partially recover the stacktrace.

Development and debug kernels produce more helpful kernel panics. Consider downloading and installing `KernelDebugKit` from [developer.apple.com](https://developer.apple.com) when debugging a problem. To activate a development kernel you will need to add a `kcsuffix=development` boot argument. Use `uname -a` command to ensure that your current loaded kernel is a development (or a debug) kernel.

In case OpenCore kernel panic saving mechanism was not used, kernel panics may still be found in `/Library/Logs/DiagnosticReports` directory. Starting with macOS Catalina kernel panics are stored in JSON format, so they need to be preprocessed before passing to `kpdescribe.sh`:

---

```
cat Kernel.panic | grep macOSProcessedStackshotData |  
python -c 'import json,sys;print(json.load(sys.stdin)["macOSPanicString"]'
```

---

### 3. DisableWatchDog

**Type:** plist boolean

**Failsafe:** false

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

### 4. DisplayDelay

**Type:** plist integer

**Failsafe:** 0

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

### 5. DisplayLevel

**Type:** plist integer, 64 bit

**Failsafe:** 0

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

- 0x00000002 (bit 1) — `DEBUG_WARN` in `DEBUG`, `NOOPT`, `RELEASE`.
- 0x00000040 (bit 6) — `DEBUG_INFO` in `DEBUG`, `NOOPT`.
- 0x00400000 (bit 22) — `DEBUG_VERBOSE` in custom builds.
- 0x80000000 (bit 31) — `DEBUG_ERROR` in `DEBUG`, `NOOPT`, `RELEASE`.

### 6. SerialInit

**Type:** plist boolean

**Failsafe:** false

**Description:** Perform serial port initialisation.

This option will perform serial port initialisation within OpenCore prior to enabling (any) debug logging. Serial port configuration is defined via PCDs at compile time in `gEfiMdeModulePkgTokenSpaceGuid` GUID. Default values as found in `MdeModulePkg.dec` are as follows:

- `PcdSerialBaudRate` — Baud rate: 115200.
- `PcdSerialLineControl` — Line control: no parity, 8 data bits, 1 stop bit.

[See more details in Debugging section.](#)

## 7. SysReport

**Type:** plist boolean

**Failsafe:** false

**Description:** Produce system report on ESP folder.

This option will create a **SysReport** directory on ESP partition unless it is already present. The directory will contain ACPI and SMBIOS dumps.

*Note:* For security reasons **SysReport** option is **not** available in **RELEASE** builds. Use a **DEBUG** build if you need this option.

## 8. Target

**Type:** plist integer

**Failsafe:** 0

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

The following logging targets are supported:

- 0x01 (bit 0) — Enable logging, otherwise all log is discarded.
- 0x02 (bit 1) — Enable basic console (onscreen) logging.
- 0x04 (bit 2) — Enable logging to Data Hub.
- 0x08 (bit 3) — Enable serial port logging.
- 0x10 (bit 4) — Enable UEFI variable logging.
- 0x20 (bit 5) — Enable non-volatile UEFI variable logging.
- 0x40 (bit 6) — Enable logging to file.

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

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

---

```
ioreg -lw0 -p IODeviceTree | grep boot-log | sort | sed 's/.*<\(.*\)>.*\1/' | xxd -r -p
```

---

UEFI variable log does not include some messages and has no performance data. For safety reasons log size is limited to 32 kilobytes. Some firmwares may truncate it much earlier or drop completely if they have no memory. Using non-volatile flag will write the log to NVRAM flash after every printed line. To obtain UEFI variable log use the following command in macOS:

---

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

---

*Warning:* Some firmwares are reported to have broken NVRAM garbage collection. This means that they may not be able to always free space after variable deletion. Do not use non-volatile NVRAM logging without extra need on such devices.

While OpenCore boot log already contains basic version information with build type and date, this data may also be found in NVRAM in **opencore-version** variable even with boot log disabled.

File logging will create a file named **opencore-YYYY-MM-DD-HHMMSS.txt** at EFI volume root with log contents (the upper case letter sequence is replaced with date and time from the firmware). Please be warned that some file system drivers present in firmwares are not reliable, and may corrupt data when writing files through UEFI. Log is attempted to be written in the safest manner, and thus is very slow. Ensure that **DisableWatchDog** is set to **true** when you use a slow drive. [Try to avoid frequent use of this option when dealing with flash drives as large I/O amounts may speedup memory wear and render this flash drive unusable in shorter time.](#)

When interpreting the log, note that the lines are prefixed with a tag describing the relevant location (module) of the log line allowing one to better attribute the line to the functionality. The list of currently used tags is provided below.

### Drivers and tools:

- BMF — OpenCanopy, bitmap font



- BS — Bootstrap
- GSTT — GoptStop
- HDA — AudioDxe
- KKT — KeyTester
- MMDD — MmapDump
- OCPAVP — PavpProvision
- OCRST — ResetSystem
- OCUI — OpenCanopy
- OC — OpenCore main
- VMOPT — VerifyMemOpt

#### Libraries:

- AAPL — OcDebugLogLib, Apple EfiBoot logging
- OCABC — OcAfterBootCompatLib
- OCAE — OcAppleEventLib
- OCAK — OcAppleKernelLib
- OCAU — OcAudioLib
- OCAV — OcAppleImageVerificationLib
- OCA — OcAcpiLib
- OCBP — OcAppleBootPolicyLib
- OCB — OcBootManagementLib
- OCCL — OcAppleChunkListLib
- OCCPU — OcCpuLib
- OCC — OcConsoleLib
- OCDH — OcDataHubLib
- OCDI — OcAppleDiskImageLib
- OCFSQ — OcFileLib, UnblockFs quirk
- OCFS — OcFileLib
- OCFV — OcFirmwareVolumeLib
- OCHS — OcHashServicesLib
- OCIC — OcImageConversionLib
- OCII — OcInputLib
- OCJS — OcApfsLib
- OCKM — OcAppleKeyMapLib
- OCL — OcDebugLogLib
- OCMCO — OcMachoLib
- OCME — OcHeciLib
- OCMM — OcMemoryLib
- OCPI — OcFileLib, partition info
- OCPNG — OcPngLib
- OCRAM — OcAppleRamDiskLib
- OCRTC — OcRtcLib
- OCSB — OcAppleSecureBootLib
- OCSMB — OcSmbiosLib
- OCSMC — OcSmcLib
- OCST — OcStorageLib
- OCS — OcSerializedLib
- OCTPL — OcTemplateLib
- OCUC — OcUnicodeCollationLib
- OCUT — OcAppleUserInterfaceThemeLib
- OCXML — OcXmlLib

## 8.5 Security Properties

### 1. AllowNvramReset

**Type:** plist boolean

**Failsafe:** false

**Description:** Allow CMD+OPT+P+R handling and enable showing NVRAM `Reset` entry in boot picker.

*Note 1:* It is known that some Lenovo laptops have a firmware bug, which makes them unbootable after performing NVRAM reset. See [acidanthera/bugtracker#995](#) for more details.

*Note 2:* Resetting NVRAM will also erase all the boot options otherwise not backed up with bless (e.g. Linux).

2. AllowSetDefault

**Type:** plist boolean

**Failsafe:** false

**Description:** Allow CTRL+Enter and CTRL+Index handling to set the default boot option in boot picker.

3. AuthRestart

**Type:** plist boolean

**Failsafe:** false

**Description:** Enable VirtualSMC-compatible authenticated restart.

Authenticated restart is a way to reboot FileVault 2 enabled macOS without entering the password. To perform authenticated restart one can use a dedicated terminal command: `sudo fdsetup authrestart`. It is also used when installing operating system updates.

VirtualSMC performs authenticated restart by saving disk encryption key split in NVRAM and RTC, which despite being removed as soon as OpenCore starts, may be considered a security risk and thus is optional.

4. ~~BlacklistAppleUpdate~~**Type:** ~~plist boolean~~**Failsafe:** ~~false~~**Description:** ~~Ignore boot options trying to update Apple peripheral firmware (e.g. MultiUpdater.efi).~~

5. BootProtect

**Type:** plist string

**Failsafe:** None

**Description:** Attempt to provide bootloader persistence.

Valid values:

- None — do nothing.
- Bootstrap — create or update top-priority \EFI\OC\Bootstrap\Bootstrap.efi boot option (Boot9696) in UEFI variable storage at bootloader startup. For this option to work RequestBootVarRouting is required to be enabled.

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 Bootstrap mode this file path becomes no longer used for bootstrapping OpenCore.

*Note 1:* Some firmwares may have broken NVRAM, no boot option support, or various other incompatibilities of any kind. While unlikely, the use of this option may even cause boot failure. Use at your own risk on boards known to be compatible.

*Note 2:* Be warned 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.

6. ExposeSensitiveData

**Type:** plist integer

**Failsafe:** 0x6

**Description:** Sensitive data exposure bitmask (sum) to operating system.

- 0x01 — Expose printable booter path as an UEFI variable.
- 0x02 — Expose OpenCore version as an UEFI variable.
- 0x04 — Expose OpenCore version in boot picker menu title.
- 0x08 — Expose OEM information as a set of UEFI variables.

Exposed booter path points to OpenCore.efi or its booter depending on the load order. To obtain booter path use the following command in macOS:

---

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

---

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

- \* 1 — enables print something to BOOTER.LOG (stripped code implies there may be a crash)
- \* 2 — enables perf logging to /efi/debug-log in the device three
- \* 4 — enables timestamp printing for styled printf calls
- `level=VALUE` — deprecated starting from 10.15. Verbosity level of DEBUG output. Everything but 0x80000000 is stripped from the binary, and this is the default value.

*Note:* To see verbose output from `boot.efi` on modern macOS versions enable `AppleDebug` option. This will save the log to general OpenCore log. For versions before 10.15.4 set `bootercfg` to `log=1`. This will print verbose output onscreen.

- `7C436110-AB2A-4BBB-A880-FE41995C9F82:bootercfg-once`  
Booter arguments override removed after first launch. Otherwise equivalent to `bootercfg`.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:efiboot-perf-record`  
Enable performance log saving in `boot.efi`. Performance log is saved to physical memory and is pointed by `efiboot-perf-record-data` and `efiboot-perf-record-size` variables. Starting from 10.15.4 it can also be saved to OpenCore log by `AppleDebug` option.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:fmm-computer-name`  
Current saved host name. ASCII string.
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:nvda_drv`  
NVIDIA Web Driver control variable. Takes ASCII digit 1 or 0 to enable or disable installed driver.
- [`7C436110-AB2A-4BBB-A880-FE41995C9F82:run-efi-updater`](#)  
[Override EFI firmware updating support in macOS \(MultiUpdater, ThorUtil, and so on\). Setting this to No or alternative boolean-castable value will prevent any firmware updates in macOS starting with 10.10 at least.](#)
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:StartupMute`  
Mute startup chime sound in firmware audio support. 8-bit integer. The value of 0x00 means unmuted. Missing variable or any other value means muted. This variable only affects Gibraltar machines (T2).
- `7C436110-AB2A-4BBB-A880-FE41995C9F82:SystemAudioVolume`  
System audio volume level for firmware audio support. 8-bit integer. The bit of 0x80 means muted. Lower bits are used to encode volume range specific to installed audio codec. The value is capped by `MaximumBootBeepVolume` AppleHDA layout value to avoid too loud audio playback in the firmware.

## 11.3 Tools

Standalone tools may help to debug firmware and hardware. Some of the known tools are listed below. While some tools can be launched from within OpenCore many should be run separately either directly or from `Shell`.

To boot into OpenShell or any other tool directly save `OpenShell.efi` under the name of `EFI\BOOT\BOOTX64.EFI` on a FAT32 partition. In general it is unimportant whether the partition scheme is GPT or MBR.

While the previous approach works both on Macs and other computers, an alternative Mac-only approach to bless the tool on an HFS+ or APFS volume:

---

```
sudo bless --verbose --file /Volumes/VOLNAME/DIR/OpenShell.efi \
--folder /Volumes/VOLNAME/DIR/ --setBoot
```

---

Listing 3: Blessing tool

*Note 1:* You may have to copy `/System/Library/CoreServices/BridgeVersion.bin` to `/Volumes/VOLNAME/DIR`.

*Note 2:* To be able to use `bless` you may have to disable System Integrity Protection.

*Note 3:* To be able to boot you may have to disable Secure Boot if present.

Some of the known tools are listed below (builtin tools are marked with \*):

<code>BootKicker*</code>	Enter Apple BootPicker menu (exclusive for Macs with compatible GPUs).
<code>ChipTune*</code>	Test BeepGen protocol and generate audio signals of different style and length.
<code>CleanNvram*</code>	Reset NVRAM alternative bundled as a standalone tool.
<code>GopStop*</code>	Test GraphicsOutput protocol with a simple scenario.
<code>HdaCodecDump*</code>	Parse and dump High Definition Audio codec information (requires <code>AudioDxe</code> ).
<code>KeyTester*</code>	Test keyboard input in <code>SimpleText</code> mode.
<code>MemTest86</code>	Memory testing utility.
<code>OpenControl*</code>	Unlock and lock back NVRAM protection for other tools to be able to get full NVRAM access when launching from OpenCore.
<code>OpenShell*</code>	OpenCore-configured UEFI <code>Shell</code> for compatibility with a broad range of firmwares.
<code>PavpProvision</code>	Perform EPID provisioning (requires certificate data configuration).
<code>ResetSystem*</code>	Utility to perform system reset. Takes reset type as an argument: <code>ColdReset</code> , <code>WarmResetFirmware</code> , <code>Shutdown</code> , <code>WarmReset</code> . Defaults to <code>ColdReset</code> .
<code>RtcRw*</code>	Utility to read and write RTC (CMOS) memory.
<code>VerifyMsrE2*</code>	Check CFG Lock (MSR 0xE2 write protection) consistency across all cores.

## 11.4 OpenCanopy

OpenCanopy is a graphical OpenCore user interface that runs in `External PickerMode` and relies on `OpenCorePkg OcBootManagementLib` similar to the builtin text interface.

OpenCanopy requires graphical resources located in `Resources` directory to run. Sample resources (fonts and images) can be found in `OcBinaryData` repository. [You can find customised icons over the internet \(e.g. here or there\).](#)

OpenCanopy provides full support for `PickerAttributes` and offers a configurable builtin icon set. The default chosen icon set depends on the `DefaultBackgroundColor` variable value. For `Light Gray Old` icon set will be used, for other colours — the one without a prefix.

Predefined icons are put to `\EFI\OC\Resources\Image` directory. Full list of supported icons (in `.icns` format) is provided below. Missing optional icons will use the closest available icon. External entries will use `Ext`-prefixed icon if available (e.g. `OldExtHardDrive.icns`).

- `Cursor` — Mouse cursor (mandatory).
- `Selected` — Selected item (mandatory).
- `Selector` — Selecting item (mandatory).
- `HardDrive` — Generic OS (mandatory).
- `Apple` — Apple OS.
- `AppleRecv` — Apple Recovery OS.
- `AppleTM` — Apple Time Machine.
- `Windows` — Windows.
- `Other` — Custom entry (see `Entries`).

- Audio type can be `OCEFIAudio` for OpenCore audio files or `AXEFIAudio` for macOS bootloader audio files.
- Audio localisation is a two letter language code (e.g. `en`) with an exception for Chinese, Spanish, and Portuguese. Refer to `APPLE_VOICE_OVER_LANGUAGE_CODE` definition for the list of all supported localisations.
- Audio path is the base filename corresponding to a file identifier. For macOS bootloader audio paths refer to `APPLE_VOICE_OVER_AUDIO_FILE` definition. For OpenCore audio paths refer to `OC_VOICE_OVER_AUDIO_FILE` definition. The only exception is OpenCore boot chime file, which is `OCEFIAudio_VoiceOver_Boot.wav`.

Audio localisation is determined separately for macOS bootloader and OpenCore. For macOS bootloader it is set in `preferences.efi` archive in `systemLanguage.utf8` file and is controlled by the operating system. For OpenCore the value of `prev-lang:kbd` variable is used. When native audio localisation of a particular file is missing, English language (`en`) localisation is used. Sample audio files can be found in OcBinaryData repository.

### 3. ConnectDrivers

**Type:** plist boolean

**Failsafe:** false

**Description:** Perform UEFI controller connection after driver loading.

This option is useful for loading drivers following UEFI driver model as they may not start by themselves. Examples of such drivers are filesystem or audio drivers. While effective, this option may not be necessary for drivers performing automatic connection, and may slightly slowdown the boot.

*Note:* Some firmwares, made by Apple in particular, only connect the boot drive to speedup the boot process. Enable this option to be able to see all the boot options when having multiple drives.

### 4. Drivers

**Type:** plist array

**Failsafe:** None

**Description:** Load selected drivers from `OC/Drivers` directory.

Designed to be filled with string filenames meant to be loaded as UEFI drivers.

### 5. Input

**Type:** plist dict

**Failsafe:** None

**Description:** Apply individual settings designed for input (keyboard and mouse) in Input Properties section below.

### 6. Output

**Type:** plist dict

**Failsafe:** None

**Description:** Apply individual settings designed for output (text and graphics) in Output Properties section below.

### 7. ProtocolOverrides

**Type:** plist dict

**Failsafe:** None

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

*Note:* all protocol instances are installed prior to driver loading.

### 8. Quirks

**Type:** plist dict

**Failsafe:** None

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

### 9. ReservedMemory

**Type:** plist array

**Description:** Designed to be filled with `plist dict` values, describing memory areas exquisite to particular firmware and hardware functioning, which should not be used by the operating system. An example of such memory region could be second 256 MB corrupted by Intel HD 3000 or an area with faulty RAM. See ReservedMemory Properties section below.

## 11.7 APFS Properties

### 1. EnableJumpstart

**Type:** plist boolean

**Failsafe:** false

**Description:** Load embedded APFS drivers from APFS containers.

APFS EFI driver is bundled in all bootable APFS containers. This option performs loading of signed APFS drivers with respect to `ScanPolicy`. See more details in “EFI Jumpstart” section of Apple File System Reference.

### 2. [GlobalConnect](#)

**Type:** [plist boolean](#)

**Failsafe:** [false](#)

**Description:** [Perform full device connection during APFS loading.](#)

[Instead of partition handle connection normally used for APFS driver loading every handle is connected recursively. This may take more time than usual but can be the only way to access APFS partitions on some firmwares like those found on older HP laptops.](#)

### 3. HideVerbose

**Type:** plist boolean

**Failsafe:** false

**Description:** Hide verbose output from APFS driver.

APFS verbose output can be useful for debugging.

### 4. JumpstartHotPlug

**Type:** plist boolean

**Failsafe:** false

**Description:** Load APFS drivers for newly connected devices.

Performs APFS driver loading not only at OpenCore startup but also during boot picker. This permits APFS USB hot plug. Disable if not required.

### 5. MinDate

**Type:** plist integer

**Failsafe:** 0

**Description:** Minimal allowed APFS driver date.

APFS driver date connects APFS driver with the calendar release date. Older versions of APFS drivers may contain unpatched vulnerabilities, which can be used to inflict harm on your computer. This option permits restricting APFS drivers to only recent releases.

- 0 — require the default supported release date of APFS in OpenCore. The default release date will increase with time and thus this setting is recommended. Currently set to 2018/06/21.
- -1 — permit any release date to load (strongly discouraged).
- Other — use custom minimal APFS release date, e.g. 20200401 for 2020/04/01. APFS release dates can be found in OpenCore boot log and `0cApfsLib`.

### 6. MinVersion

**Type:** plist integer

**Failsafe:** 0

**Description:** Minimal allowed APFS driver version.

APFS driver version connects APFS driver with the macOS release. APFS drivers from older macOS releases will become unsupported and thus may contain unpatched vulnerabilities, which can be used to inflict harm on your computer. This option permits restricting APFS drivers to only modern macOS versions.

- 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 `0cApfsLib`.

Enabling this setting plays boot chime through builtin audio support. Volume level is determined by `MinimumVolume` and `VolumeAmplifier` settings and `SystemAudioVolume` NVRAM variable.

*Note:* this setting is separate from `StartupMute` NVRAM variable to avoid conflicts when the firmware is able to play boot chime.

#### 7. `VolumeAmplifier`

**Type:** plist integer

**Failsafe:** 0

**Description:** Multiplication coefficient for system volume to raw volume linear translation from 0 to 1000.

Volume level range read from `SystemAudioVolume` varies depending on the codec. To transform read value in `[0, 127]` range into raw volume range `[0, 100]` the read value is scaled to `VolumeAmplifier` percents:

$$RawVolume = MIN(\frac{SystemAudioVolume * VolumeAmplifier}{100}, 100)$$

*Note:* the transformation used in macOS is not linear, but it is very close and this nuance is thus ignored.

## 11.9 Input Properties

#### 1. `KeyFiltering`

**Type:** plist boolean

**Failsafe:** false

**Description:** Enable keyboard input sanity checking.

Apparently some boards like GA Z77P-D3 may return uninitialised data in `EFI_INPUT_KEY` with all input protocols. This option discards keys that are neither ASCII, nor are defined in the UEFI specification (see tables 107 and 108 in version 2.8).

#### 2. `KeyForgetThreshold`

**Type:** plist integer

**Failsafe:** 0

**Description:** Remove key unless it was submitted during this timeout in milliseconds.

`AppleKeyMapAggregator` protocol is supposed to contain a fixed length buffer of currently pressed keys. However, the majority of the drivers only report key presses as interrupts and pressing and holding the key on the keyboard results in subsequent submissions of this key with some defined time interval. As a result we use a timeout to remove once pressed keys from the buffer once the timeout expires and no new submission of this key happened.

This option allows to set this timeout based on your platform. The recommended value that works on the majority of the platforms is 5 milliseconds. For reference, holding one key on VMware will repeat it roughly every 2 milliseconds and the same value for APTIO V is 3–4 milliseconds. Thus it is possible to set a slightly lower value on faster platforms and slightly higher value on slower platforms for more responsive input.

*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

UEFI firmwares generally support `ConsoleControl` with two rendering modes: `Graphics` and `Text`. Some firmwares 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`.
- `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`.

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

**Description:** Sets console output mode as specified with the `WxH` (e.g. `80x24`) formatted string.

Set to empty string not to change console mode. Set to `Max` to try to use largest available console mode. Currently `Builtin` text renderer supports only one console mode, so this option is ignored.

*Note:* This field is best to be left empty on most firmwares.

## 3. `Resolution`

**Type:** plist string

**Failsafe:** Empty string

**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 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. `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~~ colour before switching to text mode.

*Note:* This option only applies to `System` renderer.

## 5. `DirectGopRendering`

**Type:** plist boolean

**Failsafe:** false

**Description:** Use builtin graphics output protocol renderer for console.



On some firmwares this may provide better performance or even fix rendering issues, like on `MacPro5,1`. However, it is recommended not to use this option unless there is an obvious benefit as it may even result in slower scrolling.

6. `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:* This option only applies to `System` renderer.

7. `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:* This option only applies to `System` renderer.

8. `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 ~~GOP~~the graphics protocol is not covered by the UEFI specification. This option will ensure GOP ~~is installed on console handle if it is present~~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.

9. `ReconnectOnResChange`

**Type:** plist boolean

**Failsafe:** false

**Description:** Reconnect console controllers after changing screen resolution.

On some firmwares when screen resolution is changed via GOP, it is required to reconnect the controllers, which produce the console protocols (simple text out). 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.

10. `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:* This option only applies to `System` renderer. On all known affected systems `ConsoleMode` had to be set to empty string for this to work.

11. `UgaPassThrough`

**Type:** plist boolean

**Failsafe:** false

**Description:** Provide UGA protocol instances on top of GOP protocol.

Some firmwares do not implement legacy UGA protocol, but it may be required for screen output by older EFI applications like EfiBoot from 10.4.

## 11.11 ProtocolOverrides Properties

### 1. AppleAudio

**Type:** plist boolean

**Failsafe:** false

**Description:** Reinstalls 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 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 Apple Debug Log protocol with a builtin version.

### 4. AppleEvent

**Type:** plist boolean

**Failsafe:** false

**Description:** Reinstalls Apple Event protocol with a builtin version. This may be used to ensure File Vault 2 compatibility on VMs or legacy Macs.

### 5. [AppleFramebufferInfo](#)

**Type:** [plist boolean](#)

**Failsafe:** [false](#)

**Description:** [Reinstalls 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 like the one in macOS 10.4.](#)

### 6. AppleImageConversion

**Type:** plist boolean

**Failsafe:** false

**Description:** Reinstalls Apple Image Conversion protocol with a builtin version.

### 7. AppleKeyMap

**Type:** plist boolean

**Failsafe:** false

**Description:** Reinstalls Apple Key Map protocols with builtin versions.

### 8. AppleRtcRam

**Type:** plist boolean

**Failsafe:** false

**Description:** Reinstalls Apple RTC RAM protocol with 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.

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.

However, some firmwares do their own boot option scanning upon startup by checking file presence on the available disks. Quite often this scanning includes non-standard locations, such as Windows Bootloader paths. Normally it is not an issue, but some firmwares, ASUS firmwares on APTIO V in particular, have bugs. For them scanning is implemented improperly, and firmware preferences may get accidentally corrupted due to `BootOrder` entry duplication (each option will be added twice) making it impossible to boot without ~~cleaning~~resetting NVRAM.

To trigger the bug one should have some valid boot options (e.g. OpenCore) and then install Windows with `RequestBootVarRouting` enabled. As Windows bootloader option will not be created by Windows installer, the firmware will attempt to create it itself, and then corrupt its boot option list.

This quirk removes all duplicates in `BootOrder` variable attempting to resolve the consequences of the bugs upon OpenCore loading. It is recommended to use this key along with `BootProtect` option.

## 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. `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.

## 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 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.

## 6. `TscSyncTimeout`

**Type:** plist integer

**Failsafe:** 0

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

First usable sector is 34, last usable sector is 419430366  
Partitions will be aligned on 2048-sector boundaries  
Total free space is 4029 sectors (2.0 MiB)

Number	Start (sector)	End (sector)	Size	Code	Name
1	2048	1023999	499.0 MiB	2700	Basic data partition
2	1024000	1226751	99.0 MiB	EF00	EFI system partition
3	1226752	1259519	16.0 MiB	0C01	Microsoft reserved ...
4	1259520	419428351	199.4 GiB	0700	Basic data partition

Command (? for help): c  
Partition number (1-4): 4  
Enter name: BOOTCAMP

Command (? for help): w

Final checks complete. About to write GPT data. THIS WILL OVERWRITE EXISTING PARTITIONS!!

Do you want to proceed? (Y/N): Y  
OK; writing new GUID partition table (GPT) to \\.\physicaldrive0.  
Disk synchronization succeeded! The computer should now use the new partition table.  
The operation has completed successfully.

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Listing 4: Relabeling Windows volume

## How to choose Windows BOOTCAMP with custom NTFS drivers?

Third-party drivers providing NTFS support, such as NTFS-3G, Paragon NTFS, Tuxera NTFS or Seagate Paragon Driver break certain macOS functionality, including Startup Disk preference pane normally used for operating system selection. While the recommended option remains not to use such drivers as they commonly corrupt the filesystem, and prefer the driver bundled with macOS with optional write support (command or GUI), there still exist vendor-specific workarounds for their products: Tuxera, Paragon, etc.

## 12.2 Debugging

Similar to other projects working with hardware OpenCore supports auditing and debugging. The use of NOOPT or DEBUG build modes instead of RELEASE can produce a lot more debug output. With NOOPT source level debugging with GDB or IDA Pro is also available. For GDB check OpenCore Debug page. For IDA Pro you will need IDA Pro 7.3 or newer, refer to Debugging the XNU Kernel with IDA Pro for more details.

To obtain the log during boot you can make the use of serial port debugging. Serial port debugging is enabled in Target, e.g. 0xB for onscreen with serial. [OpenCore uses To initialise serial within OpenCore use 115200SerialInit baud rate, 8 data bits, no parity, and 1 stop bitconfiguration option.](#) For macOS your best choice are CP2102-based UART devices. Connect motherboard TX to USB UART RX, and motherboard GND to USB UART GND. Use screen utility to get the output, or download GUI software, such as CoolTerm.

*Note:* On several motherboards (and possibly USB UART dongles) PIN naming may be incorrect. It is very common to have GND swapped with RX, thus you have to connect motherboard “TX” to USB UART GND, and motherboard “GND” to USB UART RX.

Remember to enable COM port in firmware settings, and never use USB cables longer than 1 meter to avoid output corruption. To additionally enable XNU kernel serial output you will need debug=0x8 boot argument.

## 12.3 Tips and Tricks

### 1. How to debug boot failure?

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

- You have a DEBUG or NOOPT version of OpenCore.
- Logging is enabled (1) and shown onscreen (2): Misc → Debug → Target = 3.

- 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 like `RebuildAppleMemoryMap`, `EnableWriteUnprotector`, `ProtectMemoryRegions`, `RebuildAppleMemoryMap`, `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.