



OpenCore

Reference Manual (0.6.~~5~~.6)

[2021.01.18]

Codestyle. The codebase follows EDK II codestyle with few changes and clarifications.

- Write inline documentation for the functions and variables only once: in headers, where a header prototype is available, and inline for **static** variables and functions.
- Use line length of 120 characters or less, preferably 100 characters.
- Use spaces after casts, e.g. `(VOID *) (UINTN) Variable`.
- Use [two spaces as indentations as always](#).
- [Use](#) [SPDX](#) license headers as shown in [acidanthera/bugtracker#483](#).

3.5 Debugging

The codebase incorporates EDK II debugging and few custom features to improve the experience.

- Use module prefixes, 2-5 letters followed by a colon (:), for debug messages. For `OpenCorePkg` use `OC:`, for libraries and drivers use their own unique prefixes.
- Do not use dots (.) in the end of debug messages and separate `EFI_STATUS`, printed by `%r`, with a hyphen (e.g. `OCRAM: Allocation of %u bytes failed - %r\n`).
- Use `DEBUG_CODE_BEGIN ()` and `DEBUG_CODE_END ()` constructions to guard debug checks that may potentially reduce the performance of release builds and are otherwise unnecessary.
- Use `DEBUG` macro to print debug messages during normal functioning, and `RUNTIME_DEBUG` for debugging after `EXIT_BOOT_SERVICES`.
- Use `DEBUG_VERBOSE` debug level to leave debug messages for future debugging of the code, which are currently not necessary. By default `DEBUG_VERBOSE` messages are ignored even in `DEBUG` builds.
- Use `DEBUG_INFO` debug level for all non critical messages (including errors) and `DEBUG_BULK_INFO` for extensive messages that should not appear in NVRAM log that is heavily limited in size. These messages are ignored in `RELEASE` builds.
- Use `DEBUG_ERROR` to print critical human visible messages that may potentially halt the boot process, and `DEBUG_WARN` for all other human visible errors, `RELEASE` builds included.

When trying to find the problematic change it is useful to rely on `git-bisect` functionality. There also are some unofficial resources that provide per-commit binary builds of OpenCore, such as Dortania.

Warning: This feature is very dangerous as it passes unprotected data to firmware variable services. Use it only when no hardware NVRAM implementation is provided by the firmware or it is incompatible.

4. LegacyOverwrite

Type: plist boolean

Failsafe: false

Description: Permits overwriting firmware variables from `nvr.plist`.

Note: Only variables accessible from the operating system will be overwritten.

5. LegacySchema

Type: plist dict

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

* value can be used to accept all variables for select GUID.

WARNING: Choose variables very carefully, as `nvr.plist` is not vaulted. For instance, do not put `boot-args` or `csr-active-config`, as this can bypass SIP.

6. WriteFlash

Type: plist boolean

Failsafe: false

Description: Enables writing to flash memory for all added variables.

Note: It is recommended to have this value enabled on most types of firmware but it is left configurable for firmware that may have issues with NVRAM variable storage garbage collection or similar.

To read NVRAM variable value from macOS, `nvr` could be used by concatenating GUID and name variables separated by a `:` symbol. For example, `nvr 7C436110-AB2A-4BBB-A880-FE41995C9F82:boot-args`.

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

9.3 Mandatory Variables

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

The following variables are mandatory for macOS functioning:

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

9.4 Recommended Variables

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

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

- `FW_FEATURE_SUPPORTS_UEFI_WINDOWS_BOOT` (0x20000000) - Without this bit it is not possible to reboot to Windows installed on a drive with EFI partition being the first partition on the disk.

3. `MaxBIOSVersion`

Type: `plist boolean`

Failsafe: `false`

Description: Sets `BIOSVersion` to `9999.999.999.999.999`, recommended for legacy Macs when using Automatic PlatformInfo to avoid BIOS updates in unofficially supported macOS versions.

4. `SystemMemoryStatus`

Type: `plist string`

Failsafe: `Auto`

Description: Indicates whether system memory is upgradable in `PlatformFeature`. This controls the visibility of the Memory tab in About This Mac.

Valid values:

- `Auto` — use the original `PlatformFeature` value.
- `Upgradable` — explicitly unset `PT_FEATURE_HAS_SOLDERED_SYSTEM_MEMORY` (0x2) in `PlatformFeature`.
- `Soldered` — explicitly set `PT_FEATURE_HAS_SOLDERED_SYSTEM_MEMORY` (0x2) in `PlatformFeature`.

Note: On certain Mac models (namely MacBookPro10,x and any MacBookAir), `SPMemoryReporter.spreporter` will ignore `PT_FEATURE_HAS_SOLDERED_SYSTEM_MEMORY` and assume that system memory is non-upgradable.

5. `ProcessorType`

Type: `plist integer`

Failsafe: `0` (Automatic)

Description: Refer to SMBIOS `ProcessorType`.

6. `SystemProductName`

Type: `plist string`

Failsafe: `MacPro6,1`

Description: Refer to SMBIOS `SystemProductName`.

7. `SystemSerialNumber`

Type: `plist string`

Failsafe: `OPENCORE_SN1`

Description: Refer to SMBIOS `SystemSerialNumber`.

8. `SystemUUID`

Type: `plist string, GUID`

Failsafe: `OEM specified`

Description: Refer to SMBIOS `SystemUUID`.

9. `MLB`

Type: `plist string`

Failsafe: `OPENCORE_MLB_SN11`

Description: Refer to SMBIOS `BoardSerialNumber`.

10. `ROM`

Type: `plist data, 6 bytes`

Failsafe: `all zero`

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

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`

11 UEFI

11.1 Introduction

UEFI (Unified Extensible Firmware Interface) is a specification that defines a software interface between an operating system and platform firmware. This section allows to load additional UEFI modules and/or apply tweaks for the onboard firmware. To inspect firmware contents, apply modifications and perform upgrades UEFITool and supplementary utilities can be used.

11.2 Drivers

Depending on the firmware a different set of drivers may be required. Loading an incompatible driver may lead the system to unbootable state or even cause permanent firmware damage. Some of the known drivers are listed below:

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

11.3 Tools and Applications

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, see more details in the Tools subsection of the configuration, most 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: `/System/Library/CoreServices/BridgeVersion.bin` should be copied to `/Volumes/VOLNAME/DIR`.

Note 2: To be able to use `bless` disabling System Integrity Protection is necessary.

Note 3: To be able to boot Secure Boot might be disabled 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 <code>UEFI Shell</code> for compatibility with a broad range of firmware.
<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>Firmware</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. Customised icons can be found 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`).

Note: In the following all dimensions are normative for the 1x scaling level and shall be scaled accordingly for other levels.

- `Cursor` — Mouse cursor (mandatory, [up to 144x144](#)).
- `Selected` — Selected item (mandatory, [144x144](#)).

- **Selector** — Selecting item (mandatory, [up to 144x40](#)).
- **Left** — Scrolling left (mandatory, [40x40](#)).
- **Right** — Scrolling right (mandatory, [40x40](#)).
- **HardDrive** — Generic OS (mandatory, [128x128](#)).
- **Background** — Centred background image.
- **Apple** — Apple OS ([128x128](#)).
- **AppleRecv** — Apple Recovery OS ([128x128](#)).
- **AppleTM** — Apple Time Machine ([128x128](#)).
- **Windows** — Windows ([128x128](#)).
- **Other** — Custom entry (see [Entries](#), [128x128](#)).
- **ResetNVRAM** — Reset NVRAM system action or tool ([128x128](#)).
- **Shell** — Entry with UEFI Shell name (for e.g. [OpenShell](#) ([128x128](#))).
- **Tool** — Any other tool ([128x128](#)).

Predefined labels are put to `\EFI\OC\Resources\Label` directory. Each label has `.1b1` or `.12x` suffix to represent the scaling level. Full list of labels is provided below. All labels are mandatory.

- **EFIBoot** — Generic OS.
- **Apple** — Apple OS.
- **AppleRecv** — Apple Recovery OS.
- **AppleTM** — Apple Time Machine.
- **Windows** — Windows.
- **Other** — Custom entry (see [Entries](#)).
- **ResetNVRAM** — Reset NVRAM system action or tool.
- **Shell** — Entry with UEFI Shell name (e.g. `OpenShell`).
- **Tool** — Any other tool.

[Note: All labels must have a height of exactly 12 px. There is no limit for their width.](#)

Label and icon generation can be performed with bundled utilities: `disklabel` and `icnspack`. ~~Please refer to sample data for the details about the dimensions.~~ Font is Helvetica 12 pt times scale factor.

Font format corresponds to AngelCode binary BMF. While there are many utilities to generate font files, currently it is recommended to use `dpFontBaker` to generate bitmap font (using `CoreText` produces best results) and `fonverter` to export it to binary format.

11.5 OpenRuntime

`OpenRuntime` is an OpenCore plugin implementing `OC_FIRMWARE_RUNTIME` protocol. This protocol implements multiple features required for OpenCore that are otherwise not possible to implement in OpenCore itself as they are needed to work in runtime, i.e. during operating system functioning. Feature highlights:

- NVRAM namespaces, allowing to isolate operating systems from accessing select variables (e.g. `RequestBootVarRouting` or `ProtectSecureBoot`).
- Read-only and write-only NVRAM variables, enhancing the security of OpenCore, Lilu, and Lilu plugins, such as `VirtualSMC`, which implements `AuthRestart` support.
- NVRAM isolation, allowing to protect all variables from being written from an untrusted operating system (e.g. `DisableVariableWrite`).
- UEFI Runtime Services memory protection management to workaround read-only mapping (e.g. `EnableWriteUnprotector`).

11.6 Properties

1. APFS

Type: plist dict

Failsafe: None

Description: Provide APFS support as configured in APFS Properties section below.

2. Audio

Type: plist dict

Failsafe: empty string

Description: Set OEM protocol used for internal pointer driver.

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

9. TimerResolution

Type: plist integer

Failsafe: 0

Description: Set architecture timer resolution.

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

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

11.10 Output Properties

1. TextRenderer

Type: plist string

Failsafe: BuiltinGraphics

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

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

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

Valid values are combinations of text renderer and rendering mode:

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

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

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

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

2. ConsoleMode

Type: plist string

Failsafe: Empty string

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 left empty on most types of firmware.

12 Troubleshooting

12.1 Legacy Apple OS

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

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

12.1.1 macOS 10.8 and 10.9

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

12.1.2 macOS 10.7

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

12.1.3 macOS 10.6

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

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

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

```
hdiutil mount ReadWrite.dmg -noverify -noautoopen -noautoopenrw -noautofsck -mountpoint RW
cp OSInstall.mpkg RW/System/Installation/Packages/OSInstall.mpkg
killall Finder fsevents
rm -rf RW/.fsevents
cp DS_STORE RW/.DS_Store
hdiutil detach RW -force
rm -rf DS_STORE RW
hdiutil convert ReadWrite.dmg -format UDZO -o ReadOnly.dmg
```

12.1.4 macOS 10.5

- All previous issues apply.
- This macOS version does not support x86_64 kernel and requires i386 kernel extensions and patches.
- This macOS version uses the first (V1) version of `prelinkedkernel`, which has kext symbol tables corrupted by the kext tools. This nuance renders `prelinkedkernel` kext injection impossible in OpenCore. `Mkext` kext injection will still work without noticeable performance drain and will be chosen automatically when `KernelCache` is set to `Auto`.
- Last released installer image for macOS 10.5 is macOS 10.5.7 build 9J3050 (for MacBookPro5,3). Unlike the others, this image is not limited to the target model identifiers and can be used as is. The original 9J3050 image can be found here ([MEGA Mirror](#)), assuming macOS 10.5 is legally owned. Read `DIGEST.txt` for more details. Note that this is the earliest tested version of macOS 10.5 with OpenCore.

12.1.5 macOS 10.4

- All previous issues apply.
- This macOS version has a hard requirement to access all the optional packages on the second DVD disk installation media, requiring either two disks or USB media installation.
- Last released installer images for macOS 10.4 are macOS 10.4.10 builds 8R4061a (for MacBookPro3,1) and 8R4088 (for iMac7,1). These images are limited to their target model identifiers as on newer macOS versions. Modified 8R4088 images (with ACDT suffix) without model restrictions can be found here ([MEGA Mirror](#)), assuming macOS 10.4 is legally owned. Read `DIGEST.txt` for more details. Note that these are the earliest tested versions of macOS 10.4 with OpenCore.

12.2 UEFI Secure Boot

OpenCore is designed to provide a secure boot chain between firmware and operating system. On most x86 platforms trusted loading is implemented via UEFI Secure Boot model. Not only OpenCore fully supports this model, but it also extends its capabilities to ensure sealed configuration via vaulting and provide trusted loading to the operating systems using custom verification, such as Apple Secure Boot. Proper secure boot chain requires several steps and careful configuration of select settings as explained below:

1. Enable Apple Secure Boot by setting `SecureBootModel` to run macOS. Note, that not every macOS is compatible with Apple Secure Boot and there are several other restrictions as explained in Apple Secure Boot section.
2. Disable DMG loading by setting `DmgLoading` to `Disabled` if users have concerns of loading old vulnerable DMG recoveries. This is **not** required, but recommended. For the actual tradeoffs see the details in DMG loading section.
3. Make sure that APFS JumpStart functionality restricts the loading of old vulnerable drivers by setting `MinDate` and `MinVersion` to 0. More details are provided in APFS JumpStart section. An alternative is to install `apfs.efi` driver manually.
4. Make sure that `Force` driver loading is not needed and all the operating systems are still bootable.
5. Make sure that `ScanPolicy` restricts loading from undesired devices. It is a good idea to prohibit all removable drivers or unknown filesystems.