OpenCore

Reference Manual (0.6.~~0~~.1)

[2020.08.10]

- 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 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 unnoficial resources that provide per-commit binary builds of OpenCore, like Dortania.

- 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 automaticlly 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. For tool examples check the UEFI section of this document.

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 colours according to UEFI specification. The value of black background and black foreground (`0`) is reserved. List of colour names:

   - `0x00` — `EFI_BLACK`

8. `TakeoffDelay`
   Type: `plist integer`, 32 bit
   Failsafe: `0`
   Description: Delay in microseconds performed before handling picker startup and `action hotkeys`.

   Introducing a delay may give extra time to hold the right `action hotkey` sequence to e.g. boot to recovery mode. On some platforms setting this option to at least `5000-10000` microseconds may be necessary to access `action hotkeys` at all due to the nature of the keyboard driver.

9. `Timeout`
   Type: `plist integer`, 32 bit
   Failsafe: `0`
   Description: Timeout in seconds in boot picker before automatic booting of the default boot entry. Use 0 to disable timer.

10. `PickerMode`
    Type: `plist string`
    Failsafe: `Builtin`
    Description: Choose boot picker used for boot management.

    Picker describes underlying boot management with an optional user interface responsible for handling boot options. The following values are supported:

    - `Builtin` — boot management is handled by OpenCore, a simple text only user interface is used.
    - `External` — an external boot management protocol is used if available. Otherwise `Builtin` mode is used.
    - `Apple` — Apple boot management is used if available. Otherwise `Builtin` mode is used.

    Upon success `External` mode will entirely disable all boot management in OpenCore except policy enforcement. In `Apple` mode it may additionally bypass policy enforcement. See OpenCanopy plugin for an example of a custom user interface.

    OpenCore built-in boot picker contains a set of actions chosen during the boot process. The list of supported actions is similar to Apple BDS and in general can be accessed by holding `action hotkeys` during boot process. Currently the following actions are considered:

    - `Default` — this is the default option, and it lets OpenCore built-in boot picker to loads the default boot option as specified in Startup Disk preference pane.
    - `ShowPicker` — this option forces picker to show. Normally it can be achieved by holding `OPT` key during boot. Setting `ShowPicker` to `true` will make `ShowPicker` the default option.
    - `ResetNvram` — this option performs select UEFI variable erase and is normally achieved by holding `CMD+OPT+P+R` key combination during boot. Another way to erase UEFI variables is to choose `Reset NVRAM` in the picker. This option requires `AllowNvramReset` to be set to `true`.
    - `BootApple` — this options performs booting to the first found Apple operating system unless the default chosen operating system is already made by Apple. Hold `X` key to choose this option.
    - `BootAppleRecovery` — this option performs booting to Apple operating system recovery. Either the one related to the default chosen operating system, or first found in case default chosen operating system is not made by Apple or has no recovery. Hold `CMD+R` key combination to choose this option.

    Note 1: Activated `KeySupport`, `OpenUsbKbDxe`, or similar driver is required for key handling to work. On many firmwares it is not possible to get all the keys function.

    Note 2: In addition to `OPT` OpenCore supports `Escape` key to display picker when `ShowPicker` is disabled. This key exists for `Apple` picker mode and for firmwares with PS/2 keyboards that fail to report held `OPT` key and require continual presses of `Escape` key to enter the boot menu.

    Note 3: On Macs with problematic GOP it may be difficult to access Apple BootPicker. ~~To~~ `BootKicker` utility can be blessed to workaround this problem even without loading OpenCore. On some Macs `BootKicker` ~~utility can be blessed~~will not run from OpenCore.

8.4 Debug Properties

1. `AppleDebug`
   Type: `plist boolean`

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. `ApECID`
   Type: `plist integer`, 64 bit
   Failsafe: `0`
   Description: Apple Enclave Identifier.

   Setting this value to any (random) non-zero 64-bit integer will allow using personalised Apple Secure Boot identifiers. This value set and `SecureBootModel` valid and not `Disabled` is equivalent to to ahieve `Full Security` of Apple Secure Boot.

   Note: You will have to reinstall the operating system or use the recovery after setting this value to non-zero.

4. `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 fdesetup 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.

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 bootstraping OpenCore.

   Note 1: Some firmewares 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. `DmgLoading`
   Type: `plist string`
   Failsafe: `Signed`
   Description: Attempt to provide bootloader persistence.

   Valid values:

   - `Disabled` — loading DMG images will fail.
   - `Signed` — only Apple-signed DMG images will load.
   - `Any` — any DMG images will mount as normal filesystems.

7. 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:

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

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

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

   To obtain OpenCore version use the following command in macOS:

```
nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:opencore-version
```

   To obtain OEM information use the following commands in macOS:

```
nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:oem-product # SMBIOS Type1 ProductName
nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:oem-vendor  # SMBIOS Type2 Manufacturer
nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:oem-board   # SMBIOS Type2 ProductName
```

8. HaltLevel
   Type: plist integer, 64 bit
   Failsafe: 0x80000000 (DEBUG_ERROR)
   Description: EDK II debug level bitmask (sum) causing CPU to halt (stop execution) after obtaining a message of HaltLevel. Possible values match DisplayLevel values.

9. Vault
   Type: plist string
   Failsafe: Secure
   Description: Enables vaulting mechanism in OpenCore.

   Valid values:

   - Optional — require nothing, no vault is enforced, insecure.
   - Basic — require vault.plist file present in OC directory. This provides basic filesystem integrity verification and may protect from unintentional filesystem corruption.
   - Secure — require vault.sig signature file for vault.plist in OC directory. This includes Basic integrity checking but also attempts to build a trusted bootchain.

   vault.plist file should contain SHA-256 hashes for all files used by OpenCore. Presence of this file is highly recommended to ensure that unintentional file modifications (including filesystem corruption) do not happen unnoticed. To create this file automatically use create_vault.sh script. Regardless of the underlying filesystem, path name and case must match between config.plist and vault.plist.

   vault.sig file should contain a raw 256 byte RSA-2048 signature from SHA-256 hash of vault.plist. The signature is verified against the public key embedded into OpenCore.efi. To embed the public key you should do either of the following:

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

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

The complete set of commands to:

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

Can look as follows:

```
cd /Volumes/EFI/EFI/OC
/path/to/create_vault.sh .
/path/to/RsaTool -sign vault.plist vault.sig vault.pub
off=$(($(strings -a -t d OpenCore.efi | grep "=BEGIN OC VAULT=" | cut -f1 -d' ')+16))
dd of=OpenCore.efi if=vault.pub bs=1 seek=$off count=528 conv=notrunc
rm vault.pub
```

Note 1: While it may appear obvious, but you have to use an external method to verify `OpenCore.efi` and `BOOTx64.efi` for secure boot path. For this you are recommended to at least enable UEFI SecureBoot with a custom certificate, and sign `OpenCore.efi` and `BOOTx64.efi` with your custom key. More details on customising secure boot on modern firmwares can be found in Taming UEFI SecureBoot paper (in Russian).

Note 2: `vault.plist` and `vault.sig` are used regardless of this option when `vault.plist` is present or public key is embedded into `OpenCore.efi`. Setting this option will only ensure configuration sanity, and abort the boot process otherwise.

10. `ScanPolicy`
    Type: `plist integer`, 32 bit
    Failsafe: `0x10F0103`
    Description: Define operating system detection policy.

    This value allows to prevent scanning (and booting) from untrusted source based on a bitmask (sum) of select flags. As it is not possible to reliably detect every file system or device type, this feature cannot be fully relied upon in open environments, and the additional measures are to be applied.

    Third party drivers may introduce additional security (and performance) measures following the provided scan policy. Scan policy is exposed in `scan-policy` variable of `4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102` GUID for UEFI Boot Services only.

    - `0x00000001` (bit `0`) — `OC_SCAN_FILE_SYSTEM_LOCK`, restricts scanning to only known file systems defined as a part of this policy. File system drivers may not be aware of this policy, and to avoid mounting of undesired file systems it is best not to load its driver. This bit does not affect dmg mounting, which may have any file system. Known file systems are prefixed with `OC_SCAN_ALLOW_FS_`.
    - `0x00000002` (bit `1`) — `OC_SCAN_DEVICE_LOCK`, restricts scanning to only known device types defined as a part of this policy. This is not always possible to detect protocol tunneling, so be aware that on some systems it may be possible for e.g. USB HDDs to be recognised as SATA. Cases like this must be reported. Known device types are prefixed with `OC_SCAN_ALLOW_DEVICE_`.
    - `0x00000100` (bit `8`) — `OC_SCAN_ALLOW_FS_APFS`, allows scanning of APFS file system.
    - `0x00000200` (bit `9`) — `OC_SCAN_ALLOW_FS_HFS`, allows scanning of HFS file system.
    - `0x00000400` (bit `10`) — `OC_SCAN_ALLOW_FS_ESP`, allows scanning of EFI System Partition file system.
    - `0x00000800` (bit `11`) — `OC_SCAN_ALLOW_FS_NTFS`, allows scanning of NTFS (Msft Basic Data) file system.
    - `0x00001000` (bit `12`) — `OC_SCAN_ALLOW_FS_EXT`, allows scanning of EXT (Linux Root) file system.
    - `0x00010000` (bit `16`) — `OC_SCAN_ALLOW_DEVICE_SATA`, allow scanning SATA devices.
    - `0x00020000` (bit `17`) — `OC_SCAN_ALLOW_DEVICE_SASEX`, allow scanning SAS and Mac NVMe devices.
    - `0x00040000` (bit `18`) — `OC_SCAN_ALLOW_DEVICE_SCSI`, allow scanning SCSI devices.
    - `0x00080000` (bit `19`) — `OC_SCAN_ALLOW_DEVICE_NVME`, allow scanning NVMe devices.
    - `0x00100000` (bit `20`) — `OC_SCAN_ALLOW_DEVICE_ATAPI`, allow scanning CD/DVD devices.
    - `0x00200000` (bit `21`) — `OC_SCAN_ALLOW_DEVICE_USB`, allow scanning USB devices.
    - `0x00400000` (bit `22`) — `OC_SCAN_ALLOW_DEVICE_FIREWIRE`, allow scanning FireWire devices.
    - `0x00800000` (bit `23`) — `OC_SCAN_ALLOW_DEVICE_SDCARD`, allow scanning card reader devices.

- 0x01000000 (bit 24) — OC_SCAN_ALLOW_DEVICE_PCI, allow scanning devices directly connected to PCI bus (e.g. VIRTIO).

Note: Given the above description, 0xF0103 value is expected to allow scanning of SATA, SAS, SCSI, and NVMe devices with APFS file system, and prevent scanning of any devices with HFS or FAT32 file systems in addition to not scanning APFS file systems on USB, CD, and FireWire drives. The combination reads as:

- OC_SCAN_FILE_SYSTEM_LOCK
- OC_SCAN_DEVICE_LOCK
- OC_SCAN_ALLOW_FS_APFS
- OC_SCAN_ALLOW_DEVICE_SATA
- OC_SCAN_ALLOW_DEVICE_SASEX
- OC_SCAN_ALLOW_DEVICE_SCSI
- OC_SCAN_ALLOW_DEVICE_NVME

11. SecureBootModel
Type: plist string
Failsafe: Default
Description: Apple Secure Boot hardware model.

Defines Apple Secure Boot hardware model and policy. Specifying this value defines which operating systems will be bootable. Operating systems shipped before the specified model was released will not boot. Valid values:

- Default — Recent available model, currently set to j215.
- Disabled — No model, Secure Boot will be disabled.
- j137 — iMacPro1,1 (December 2017)
- j680 — MacBookPro15,1 (July 2018)
- j132 — MacBookPro15,2 (July 2018)
- j174 — Macmini8,1 (October 2018)
- j140k — MacBookAir8,1 (October 2018)
- j780 — MacBookPro15,3 (May 2019)
- j213 — MacBookPro15,4 (July 2019)
- j140a — MacBookAir8,2 (July 2019)
- j152f — MacBookPro16,1 (November 2019)
- j160 — MacPro7,1 (December 2019)
- j230k — MacBookAir9,1 (March 2020)
- j214k — MacBookPro16,2 (May 2020)
- j223 — MacBookPro16,3 (May 2020)
- j215 — MacBookPro16,4 (June 2020)
- j185 — iMac20,1 (August 2020)
- j185f — iMac20,2 (August 2020)

PlatformInfo and SecureBootModel are independent, allowing to enabling Apple Secure Boot with any SMBIOS. Setting SecureBootModel to any valid value but Disabled is equivalent to Medium Security of Apple Secure Boot. To achieve Full Security one will need to also specify ApECID value.

Note: Default value will increase with time to support the latest major release operating system. It is not recommended to use ApECID and Default value together.

8.6 Entry Properties

1. Arguments
Type: plist string
Failsafe: Empty string
Description: Arbitrary ASCII string used as boot arguments (load options) of the specified entry.

2. Auxiliary
Type: plist boolean
Failsafe: false
Description: This entry will not be listed by default when HideAuxiliary is set to true.

AudioDxe*	HDA audio support driver in UEFI firmwares for most Intel and some other analog audio controllers. Staging driver, refer to acidanthera/bugtracker#740 for known issues in AudioDxe.
CrScreenshotDxe*	Screenshot making driver saving images to the root of OpenCore partition (ESP) or any available writeable filesystem upon pressing F10. This is a modified version of CrScreenshotDxe driver by Nikolaj Schlej.
ExFatDxe	Proprietary ExFAT file system driver for Bootcamp support commonly found in Apple firmwares. For Sandy Bridge and earlier CPUs ExFatDxeLegacy driver should be used due to the lack of RDRAND instruction support.
HfsPlus	Proprietary HFS file system driver with bless support commonly found in Apple firmwares. For Sandy Bridge and earlier CPUs HfsPlusLegacy driver should be used due to the lack of RDRAND instruction support.
HiiDatabase*	HII services support driver from MdeModulePkg. This driver is included in most firmwares starting with Ivy Bridge generation. Some applications with the GUI like UEFI Shell may need this driver to work properly.
EnhancedFatDxe	FAT filesystem driver from FatPkg. This driver is embedded in all UEFI firmwares, and cannot be used from OpenCore. It is known that multiple firmwares have a bug in their FAT support implementation, which leads to corrupted filesystems on write attempt. Embedding this driver within the firmware may be required in case writing to EFI partition is needed during the boot process.
NvmExpressDxe*	NVMe support driver from MdeModulePkg. This driver is included in most firmwares starting with Broadwell generation. For Haswell and earlier embedding it within the firmware may be more favourable in case a NVMe SSD drive is installed.
OpenCanopy*	OpenCore plugin implementing graphical interface.
OpenRuntime*	OpenCore plugin implementing OC_FIRMWARE_RUNTIME protocol.
OpenUsbKbDxe*	USB keyboard driver adding the support of AppleKeyMapAggregator protocols on top of a custom USB keyboard driver implementation. This is an alternative to builtin KeySupport, which may work better or worse depending on the firmware.
PartitionDxe	Proprietary partition management driver with Apple Partitioning Scheme support commonly found in Apple firmwares. This driver can be used to support loading older DMG recoveries such as macOS 10.9 using Apple Partitioning Scheme. For Sandy Bridge and earlier CPUs PartitionDxeLegacy driver should be used due to the lack of RDRAND instruction support.
Ps2KeyboardDxe*	PS/2 keyboard driver from MdeModulePkg. OpenDuetPkg and some firmwares may not include this driver, but it is necessary for PS/2 keyboard to work. Note, unlike OpenUsbKbDxe this driver has no AppleKeyMapAggregator support and thus requires KeySupport to be enabled.
Ps2MouseDxe*	PS/2 mouse driver from MdeModulePkg. Some very old laptop firmwares may not include this driver, but it is necessary for touchpad to work in UEFI graphical interfaces, such as OpenCanopy.
UsbMouseDxe*	USB mouse driver from MdeModulePkg. Some virtual machine firmwares like OVMF may not include this driver, but it is necessary for mouse to work in UEFI graphical interfaces, such as OpenCanopy.
VBoxHfs	HFS file system driver with bless support. This driver is an alternative to a closed source HfsPlus driver commonly found in Apple firmwares. While it is feature complete, it is approximately 3 times slower and is yet to undergo a security audit.
XhciDxe*	XHCI USB controller support driver from MdeModulePkg. This driver is included in most firmwares starting with Sandy Bridge generation. For earlier firmwares or legacy systems it may be used to support external USB 3.0 PCI cards.

Driver marked with * are bundled with OpenCore. To compile the drivers from UDK (EDK II) use the same command you normally use for OpenCore compilation, but choose a corresponding package:

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

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. `AppleImg4Verification`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Apple IMG4 Verification protocol with a builtin version. This protocol is used to verify `im4m` manifest files used by Apple Secure Boot.

8. `AppleKeyMap`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Apple Key Map protocols with builtin versions.

9. `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.

10. `AppleSecureBoot`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Reinstalls Apple Secure Boot protocol with a builtin version.

11. `AppleSmcIo`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Reinstalls Apple SMC I/O protocol with a builtin version.

    This protocol replaces legacy `VirtualSmc` UEFI driver, and is compatible with any SMC kernel extension. However, in case `FakeSMC` kernel extension is used, manual NVRAM key variable addition may be needed.

12. `AppleUserInterfaceTheme`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Reinstalls Apple User Interface Theme protocol with a builtin version.

13. `DataHub`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Reinstalls Data Hub protocol with a builtin version. This will delete all previous properties if the protocol was already installed.

14. `DeviceProperties`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Reinstalls Device Property protocol with a builtin version. This will delete all previous properties if it was already installed. This may be used to ensure full compatibility on VMs or legacy Macs.

15. `FirmwareVolume`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Forcibly wraps Firmware Volume protocols or installs new to support custom cursor images for File Vault 2. Should be set to `true` to ensure File Vault 2 compatibility on everything but VMs and legacy Macs.

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

16. `HashServices`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Forcibly reinstalls Hash Services protocols with builtin versions. Should be set to `true` to ensure File Vault 2 compatibility on platforms providing broken SHA-1 hashing. Can be diagnosed by invalid cursor size with `UIScale` set to `02`, in general platforms prior to APTIO V (Haswell and older) are affected.

17. `OSInfo`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Forcibly reinstalls OS Info protocol with builtin versions. This protocol is generally used to receive notifications from macOS bootloader, by the firmware or by other applications.

18. `UnicodeCollation`
    Type: `plist boolean`