initramfs

The initramfs contains all the necessary programs and config files needed to bring up the machine, mount the root file system and hand off the rest of the boot process to the installed system. It can be further customized with additional modules, binaries, files and hooks for special use cases and hardware.

Usage

Automated image generation

Every kernel in Arch Linux comes with its own *.preset* file stored in `/etc/mkinitcpio.d/` with configuration presets for `mkinitcpio`. Pacman hooks build a new image after every kernel upgrade or installation of a new kernel.

Manual image generation

To manually generate a Linux kernel image issue the following command:

```
mkinitcpio -p linux
```

This will generate a new kernel image with the settings of the preset file `/etc/mkinitcpio.d/linux.preset`.

To generate kernel images with every preset available, pass the `-P` argument:

```
mkinitcpio -P
```

Configuration

To customize your initramfs, place drop-in configuration files into `/etc/mkinitcpio.conf.d/`. They will override the settings in the main configuration file at `/etc/mkinitcpio.conf`.

An overview of the settings you can customize:

Setting	Type	Description
`MODULES`	Array	Kernel modules to be loaded before any boot hooks are run.
`BINARIES`	Array	Additional binaries you want included in the initramfs image.
`FILES`	Array	Additional files you want included in the initramfs image.
`HOOKS`	Array	Hooks are scripts that execute in the initial ramdisk.
`COMPRESSION`	String	Which tool to use for compressing the image.
`COMPRESSION_OPTIONS`	Array	Extra arguments to pass to the `COMPRESSION` tool.

> **WARNING:** Do not use the `COMPRESSION_OPTIONS` setting, unless you know exactly what you are doing. Misuse can produce unbootable images!

MODULES

The `MODULES` array is used to specify modules to load before anything else is done.

Here you can specify additional kernel modules needed in early userspace, e.g. file system modules (`ext2`, `reiser4`, `btrfs`), keyboard drivers (`usbhid`, `hid_apple`, etc.), USB 3 hubs (`xhci_hcd`) or "out-of-tree" modules which are not part of the Linux kernel (mainly NVIDIA GPU drivers). It is also needed to add modules for hardware devices that are not always connected but you would like to be operational from the very start if they are connected during boot.

> **HINT:** If you don't know the name of the driver of a device, `lshw` can tell you what hardware uses which driver, e.g.:

```
*-usb:2
             description: USB controller
             product: Tiger Lake-LP USB 3.2 Gen 2x1 xHCI Host Controller
             vendor: Intel Corporation
             physical id: 14
             bus info: pci@0000:00:14.0
             version: 20
             width: 64 bits
             clock: 33MHz
             capabilities: xhci bus_master cap_list
```

```
    HERE ->  configuration: driver=xhci_hcd latency=0
             resources: iomemory:600-5ff irq:163 memory:603f260000-603f26ffff
```

The second to last line starting with `configuration` shows the driver being used.

Example of a `MODULES` array that adds two modules to the generated image needed for keyboard input, if the keyboard is connected to a USB 3 hub, e.g. a docking station:

```
MODULES=(xhci_hcd usbhid)
```

CAUTION: Keep in mind that adding to the initramfs increases the size of the resulting image on disk. Unless you have created your boot partition (more specifically the EFI System partition at either `/efi`, `/boot` or `/boot/efi`) with generous space, you should limit yourself to modules strictly needed for your system. The `autodetect` hook tries to detect all currently loaded modules of the running system to determine the needed modules to include by default. Only include additional modules if something doesn't work as expected.

ATTENTION: If you use an NVIDIA graphics card, the following modules are **required** in the `MODULES` array for early KMS:

```
MODULES=(nvidia nvidia_modeset nvidia_uvm nvidia_drm)
```

BINARIES

The `BINARIES` array holds the name of extra executables needed to boot the system. It can also be used to replace binaries provided by `HOOKS`. The executable names are sourced from the `PATH` evironment variable, associated libraries are added as well.

Example of a `BINARIES` array that adds the `kexec` binary:

```
BINARIES=(kexec)
```

This option usually only needs to be set for special use cases, e.g. when there's a binary you need included that is not already part of a member in the `HOOKS` array.

FILES

The `FILES` array holds the full path to arbitrary files for inclusion in the image.

Example of a module configuration file to be included in the image, containting the names of modules to auto-load and optional module parameters:

```
FILES=(/etc/modprobe.d/modprobe.conf)
```

This option usually only needs to be set for special use cases.

HOOKS

The `HOOKS` array is the most important setting in the file. Hooks are small scripts which describe what will be added to the image. Hooks are referred to by their name, and executed in the order they are listed in the `HOOKS` array.

> **HINT:** For a full list of availble hooks run:
>
> ```
> mkinitcpio -L
> ```
>
> See the help text for a hook with:
>
> ```
> mkinitcpio -H hook_name
> ```
>
> Alternatively, refer to Arch Wiki for a complete rundown of all the different hooks and their recommended order.

By default, systemd will bring the whole system up start to finish. In this case bootup will be handled by systemd unit files instead of scripts.

The benefit of this is faster boot times and some additional features like unlocking LUKS encrypted file systems with a TPM or FIDO2 token and automatic detection and mounting of partitions with the appropriate GUID Partition Table (GPT) UUIDs (see: Discoverable Partition Specification).

The default `HOOKS` array should be enough to bring up most systems. However, if you have special use cases, additional hooks will be needed:

Hook	Description
`mdadm_udev`	Needed for assembling RAID arrays via udev (software RAID), needs the `mdadm` package installed
`sd-encrypt`	Needed for booting from an encrypted file system, needs the `cryptsetup` package installed
`lvm2`	Needed for booting a system that is on LVM, needs the `lvm2` package installed

One such special case is encryption, which would result in a `HOOKS` array that looks like this:

> **ATTENTION:** The order of the hooks in the array is important! Any hook placed *after* `autodetect` is stripped down to match only the hardware present during initramfs generation. While this minimizes the image size, it removes the driver redundancy needed for hardware changes. For example, if you build the image using a built-in laptop keyboard, `autodetect` might omit drivers for external USB keyboards, leaving you unable to type a decryption password or boot prompt if you switch inputs later. To ensure device compatibility across changing environments, place critical input and hardware hooks *before* the `autodetect` hook.

```
HOOKS=(base systemd autodetect microcode modconf kms keyboard sd-vconsole block sd-encrypt filesystems fsck)
```

COMPRESSION

The `COMPRESSION` option instructs `mkinitcpio` to compress the resulting images to save on space on the EFI System Partition or `/boot` partition. This can be especially important if you include a lot of modules and hooks and the size of the image grows.

Compressing the initramfs is a tradeoff between:

- time it takes to compress the image
- space saved
- time it takes the kernel to decompress the image during boot

Which one you choose is something you have to decide on the constraints you're working with (slow/fast CPU, available cores, RAM usage, disk space), but generally speaking the default `zstd` compression strikes a good balance.

Algorithm	Description
`cat`	Uncompressed
`zstd`	Best tradeoff between de-/compression time and image size (default)
`gzip`	Balanced between speed and size, acceptable performance
`bzip2`	Rarely used, decent compression, resource conservative
`lzma`	Very small size, slow to compress
`xz`	Smallest size at longer compression time, RAM intensive compression

Algorithm	Description
`lzop`	Slightly better compression than lz4, still fast to decompress
`lz4`	Fast decompression, slow compression, "largest" compressed output

> **NOTE:** See this article for a comprehensive comparison between compression algorithms.

`COMPRESSION_OPTIONS`

> **WARNING:** Misuse of this option may lead to an **unbootable system** if the kernel is unable to unpack the resulting archive. **Do not set** this option unless you're *absolutely* sure that you have to!

The `COMPRESSION_OPTIONS` setting allows you to pass additional parameters for the compression tool. Available parameters depend on the algorithm chosen for the `COMPRESSION` option. Refer to the tool's manual for available options. If left empty `mkinitcpio` will make sure it always produces a working image.

Additionally, `MODULES_DECOMPRESS` instructs `mkinitcpio` to decompress kernel modules prior to inclusion in the initramfs. This can further increase compression efficiency and bring down the initramfs size further. When this option is not set, compressed kernel modules are included as-is.

For example, to use the maximum zstd compression level, using all available CPU cores and show verbose output during compression:

```
COMPRESSION="zstd"
COMPRESSION_OPTIONS=(-T0 -19 --long --auto-threads=logical -v)
MODULES_DECOMPRESS="yes"
```

Unified Kernel Image

A unified kernel image (UKI) combines an EFI stub image, CPU microcode, kernel command line and an initramfs into a single file that can be read and executed by the machine's UEFI firmware, thus making a boot manager potentially redundant.

The main benefit of UKIs is streamlining the signing process for Secure Boot, as there is only a single file to sign. By keeping this executable on a separately mounted EFI System Partition, the standard `/boot` directory can safely reside inside an encrypted LUKS partition, ensuring all

underlying system files are fully encrypted while the boot sequence itself is protected against tampering.

Version 31 of `mkinitcpio` introduced support for building UKIs out of the box. Starting with v39, `systemd-ukify` is the recommended tool by which to generate UKIs. As `systemd-ukify` is *not* part of the `systemd` package, you'll have to install it manually:

```
pacman -S --asdeps systemd-ukify
```

To make `mkinitcpio` generate UKIs, edit the appropriate `*.preset` file for your kernel in `/etc/mkinitcpio.d/`:

- comment out the `default_image` and `fallback_image` lines (as they won't be needed)
- uncomment the `default_uki` and `fallback_uki` lines (prompts `mkinitcpio` to switch to UKI generation)
- point the file path to somewhere on your EFI System Partition (e.g. `/efi`)

> **NOTE:** `mkinitcpio` will automatically source command line parameters from files in `/etc/cmdline.d/*.conf` or a complete single command line from `/etc/kernel/cmdline`. If you need different images to use different kernel command line parameters, the `*_options` line in the `*.preset` allows you to pass additional arguments to `mkinitcpio`, i.e. the `--cmdline` argument to point it to a different file containing a different set of kernel command line parameters.

> **NOTE:** Placing the UKI under `/efi/EFI/Linux/` allows `systemd-boot` to automatically detect images and list them without having to specifically create boot entries for them.

A `*.preset` file edited for UKI generation could look something like this:

```
# mkinitcpio preset file for the 'linux' package

#ALL_config="/etc/mkinitcpio.conf"
ALL_kver="/boot/vmlinuz-linux"
#ALL_kerneldest="/boot/vmlinuz-linux"

#PRESETS=('default')
PRESETS=('default' 'fallback')

#default_config="/etc/mkinitcpio.conf"
#default_image="/boot/initramfs-linux.img"
default_uki="/efi/EFI/Linux/arch-linux.efi"
#default_options="--splash /usr/share/systemd/bootctl/splash-arch.bmp"
```

```
#fallback_config="/etc/mkinitcpio.conf"
#fallback_image="/boot/initramfs-linux-fallback.img"
fallback_uki="/efi/EFI/Linux/arch-linux-fallback.efi"
fallback_options="-S autodetect,plymouth --cmdline /etc/kernel/cmdline_fallback"
```

This `*.preset` file instructs `mkinitcpio` to generate a UKI and enables the fallback initramfs. It skips the `autodetect` and `plymouth` hooks for the fallback initramfs and passes a different set of kernel command line parameters, e.g. displaying boot logs instead of showing a splash screen.

Kernel Command Line Parameters

`mkinitcpio` automatically looks for kernel command line parameters specified in `/etc/cmdline.d/*.conf` as drop-in files or `/etc/kernel/cmdline` as a single file.

> **WARNING:** If `mkinitcpio` does not find command line parameters in either of the above locations, it will fall back to reading the command line of the currently booted system from `/proc/cmdline`. If you're booted into the Arch installation environment, this will most likely leave you with an unbootable system. **Set at least one command line parameter in one of the above locations!**

Create the directory for command line parameter drop-in files and start with specifying parameters for the root file system:

```
mkdir /etc/cmdline.d
nano /etc/cmdline.d/root.conf
```

Continue by specifying the root file system via persistent block device naming and mounting it writable:

```
root=UUID=XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX rw
```

You can add as many `*.conf` files as you need to logically split up kernel parameters. All of the parameters from all files will be included in the UKI.

GPT auto mounting

> **ATTENTION:** This requires that the correct GPT partition types were set during partitioning and that the file systems to be auto mounted are located on the same disk as the EFI system partition. If other important file systems are located on other disks, i.e. the home directory is on another physical storage device, they must still be specified via `/etc/crypttab` and

`/etc/fstab`.

IMPORTANT: Be aware of the specifics of your chosen root file system. For example, when using btrfs, you will still need to specify the subvolume and any other file system options as kernel command line parameters (for example `rootflags=noatime,compress=zstd,subvol=@`), as automatic discovery and mounting will use the default options for mounting file systems.

Since the default initramfs type is systemd-based, it's possible to rely on `systemd-gpt-auto-generator(8)` for automatic discovery and mounting of file systems during boot. It specifically looks for a partition of type "Linux root" (specifically, the pre-determined GPT partition GUID). If it finds an encrypted LUKS container, it will ask for the passphrase for it and subsequently mount the file system within. This eliminates the need for `root` and `rd.luks` kernel command line parameters.

Once autommatically discovered file systems have been mounted, `/etc/crypttab` and `/etc/fstab` are processed and the boot process continues like normal.

Manually

In cases where GPT auto mounting is not possible or undesired, the manual way of specifying encrypted devices remains available.

In a systemd-based initramfs, `rd.luks.name` is used to specify the encrypted partition by its UUID and a mapper name by which the decrypted file system is made available, resulting in a kernel command line that looks like this:

NOTE: By default, dm-crypt does not allow TRIM for SSDs for security reasons (information leak). To override this behavior, either specify `rd.luks.options=discard` as an additional kernel command line parameter or add the `discard` option in `/etc/crypttab` in the options field.

```
rd.luks.name=XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX=root root=/dev/mapper/root rw
```

The UUID of the encrypted file system can easily be determined using `cryptsetup luksUUID`:

NOTE: Pressing `Ctrl + T` inside `nano` allows you to paste the result of a command at the current cursor position.

```
cryptsetup luksUUID /dev/disk/by-label/cryptroot
```

If you prefer a config file approach, or want/need to mount multiple encrypted file systems during boot, add `x-initrd.attach` to the options column in your installed system's `/etc/crypttab` file. This will indicate to the `sd-encrypt` hook that the device is required during early boot and add it to

`/etc/crypttab` in the initramfs. Using persistent block device naming, the file could look like this (see `crypttab(5)` for details on the syntax):

> **NOTE:** Instead of the UUID, you can also pass the assigned `LABEL` of the LUKS container, e.g. `LABEL=cryptroot`.

```
# <name>    <device>                                    <passphrase>    <options>
root        UUID=XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX                  x-initrd.attach
```

This allows for omitting any `rd.luks` parameters entirely:

> **ATTENTION:** Be aware of the specifics of your chosen root file system. For example, when using btrfs, you will still need to specify the subvolume and any other file system options as kernel command line parameters (for example `rootflags=noatime,compress=zstd,subvol=@`), as automatic discovery and mounting will use the default options for mounting file systems.

```
root=/dev/mapper/root rw
```

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