Replicant and bootloaders

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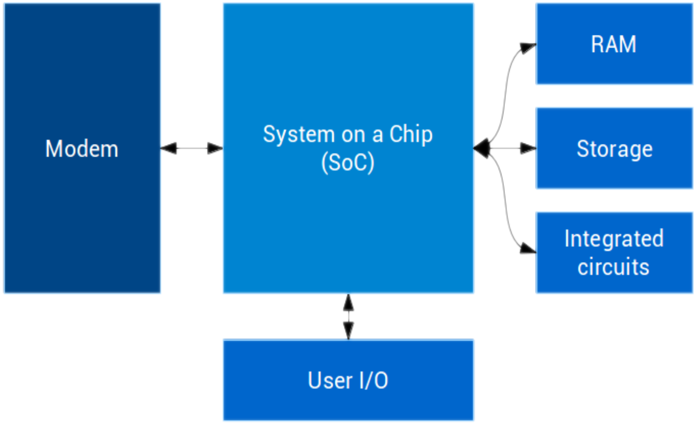
Freedom Privacy and Security:

- The Replicant website has a page (`https://replicant.us/freedom-privacy-security-issues.php`) that has more details on freedom, privacy and security issues commonly found in smartphones.
- That page consists mainly of HTML, its source code is available in `https://git.replicant.us/replicant/website.git`, and patches are reviewed on the Replicant mailing list.
- The README also has some information on a very easy way to deploy the website locally to test changes.



Hardware-side overview

Bootloader?

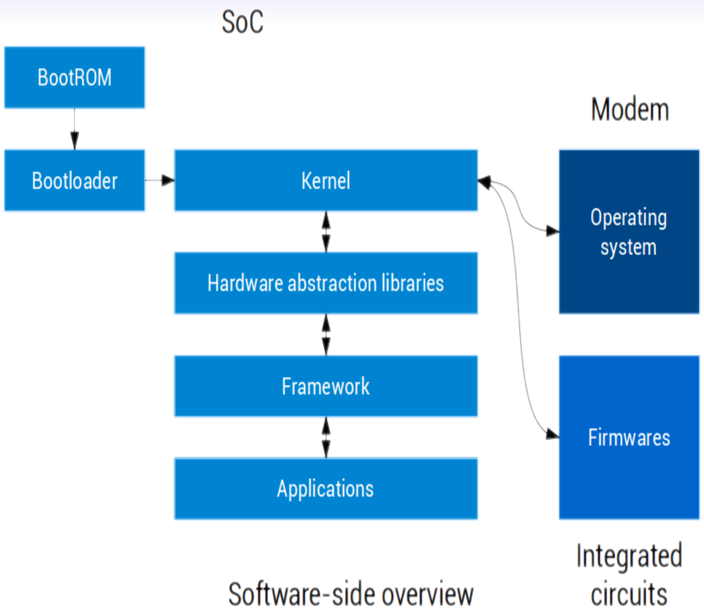
Here it is Equivalent to:

- The BIOS + GRUB
- UEFI: UEFI can load the Linux kernel directly

Why are bootloader needed on smartphones and tablets?

By itself, the hardware is usually capable of loading and running a limited amount of code from the internal storage, however most of the hardware doesn't even work at boot, including:

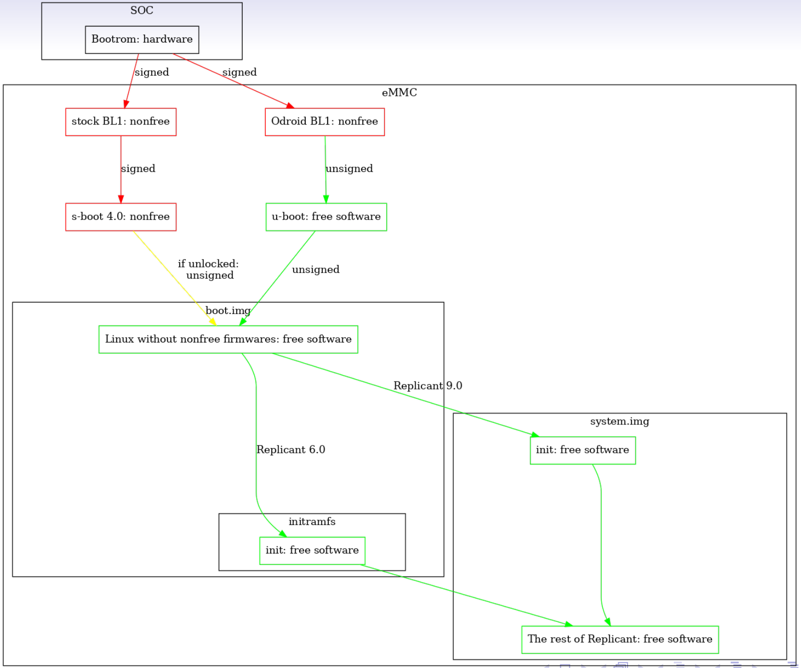
- The Display
- The RAM
- The buttons

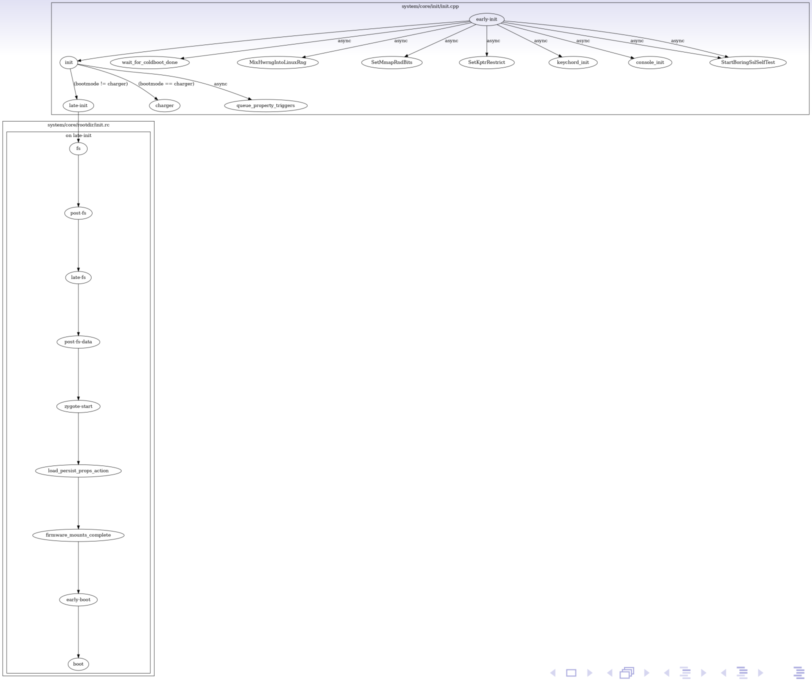

SoC
BootROM
Bootloader
Kernel
Hardware abstraction libraries
Framework
Applications
Modem
Operating system
Firmwares
Integrated circuits
Software-side overview

Bootrom$\rightarrow$Bootloader$\rightarrow$ Replicant

Samsung devices Bootrom$\rightarrow$BL1$\rightarrow$s-boot 4.0$\rightarrow$Replicant
Applies at least to the following devices:

- Galaxy S2 (I9100)
- Galaxy SIII (I9300)
- Galaxy SIII 4G (I9305)
- Galaxy Note II (N7100)
- Galaxy Note II 4G (N7105)


SOC
Bootrom: hardware
signed
signed
eMMC
stock BL1: nonfree
Odroid BL1: nonfree
signed
unsigned
s-boot 4.0: nonfree
u-boot: free software
if unlocked: unsigned
unsigned
boot.img
Linux without nonfree firmwares: free software
Replicant 9.0
Replicant 6.0
system.img
init: free software
initramfs
init: free software
The rest of Replicant: free software


system/core/init/init.cpp
early-init
async
init
wait_for_coldboot_done
MixHwrngIntoLinuxRng
SetMmapRndBits
SetKptrRestrict
keychord_init
console_init
StartBoringSslSelfTest
(bootmode != charger)
(bootmode == charger)
late-init
charger
queue_property_triggers
system/core/rootdir/init.rc
on late-init
fs
post-fs
late-fs
post-fs-data
zygote-start
load_persist_props_action
firmware_mounts_complete
early-boot
boot

General nonfree bootloader issues:

The fact that the bootloader is mostly invisible to the user doesn't magically make its related freedom issues disapear.
As with all software, it is required for it to be free software in order to respect users freedom.

Examples of issues:

- As it is able to modify the operating system it's supposed to load and execute, and that the code is nonfree, we cannot give any guarantees that it doesn't do that. Some BIOS do that with computrace for instance.
- It could refuses to boot if you changed the software or hardware.
  - Apple's ipad and iphones?
  - BIOS/UEFI with the WiFi card.
- Or loads another extra software you don't whish.
- Be able to tinker with boot is also important (ways to boot, security, etc)

Examples of tinkering:

- Adding filesystems (recent ext4).
- Adding dual boot.
- Adding new recovery ways (A/B recovery).
- Having a single bootloader for multiple devices.
- Having a single Android image for multiple devices.
- Fixing hardare security issues when they are found (rowhammer).
- Getting failed boot logs.
- Automatic testing of Replicant (install from the network, boot on it).

"Midas":

- Galaxy SIII (I9300)
- Galaxy SIII 4G (I9305)
- Galaxy Note II (N7100)
- Galaxy Note II 4G (N7105)

Issues found on Midas with BL1$\rightarrow$s-boot 4.0$\rightarrow$Linux:

- Nonfree BL1 and s-boot
- Doesn't take the commandline arguments from the boot.img
- Doesn't support the devicetree
- Initialize the MMU
- Loads and run a second OS (MobiCore) in TrustZone that is nonfree.

TrustZone

- Has more hardware privileges than the Linux kernel
- Implementing a rootkit in TrustZone is possible[3]
- "the TEE has [..] monotonic clock that ticks in suspend[2]"
- SOC specific and lacks SOC documentation.
- Discussions on weather free software in TrustZone is desirable are planned in this conference.

Upstream Linux bootloader requirements
Documentation/arm/Booting:

The MMU must be off.

Instruction cache may be on or off.

Data cache must be off.

MMU on in practice:

- Requires a patch to boot: "ANDROID: arm: decompressor: Flush tlb before swiching domain 0 to client mode"
- I spent between several days and a week bisecting the commit that broke booting between 5.1 and 5.2-rc1 (merges, rebases, non-compiling commits, etc).
- Not substainable: What happens if in the future new maintainers don't have the time or skills to bisect breakages?
- Most of the work on Android 9 is still re-usable on future devices that would have free software bootloaders.

Sharp Zaurus (SA11x0)

```
$ ls arch/arm/boot/compressed/
atags_to_fdt.c debug.S efi-header.S
head-sa1100.S head-xscale.S
ll_char_wr.S misc.c piggy.S
vmlinux.lds.S big-endian.S decompress.c
head.S head-sharpsl.S libfdt_env.h
Makefile misc.h string.c
```

head-sa1100.S

```
   @ Data cache might be active.
   @ Be sure to flush kernel binary out of the cache,
   @ whatever state it is, before it is turned off.
   @ This is done by fetching through currently executed
   @ memory to be sure we hit the same cache.
   bic     r2, pc, #0x1f
   add     r3, r2, #0x4000          @ 16 kb is quite enough...
1: ldr     r0, [r2], #32
   teq     r2, r3
   bne     1b
   mcr     p15, 0, r0, c7, c10, 4   @ drain WB
   mcr     p15, 0, r0, c7, c7, 0    @ flush I & D caches

   @ disabling MMU and caches
   mrc     p15, 0, r0, c1, c0, 0    @ read control reg
   bic     r0, r0, #0x0d            @ clear WB, DC, MMU
   bic     r0, r0, #0x1000          @ clear Icache
   mcr     p15, 0, r0, c1, c0, 0
```

In practice Russel King (ARM maintainer):

SA11x0 pre-dates the booting document, which came about because of the desire to make the kernel less dependent on the host CPU type. So "sa11x0 does it so we can do it" is really not an argument I ever want to see to justify this kind of stuff.

The booting requirements have been known since at least 2002, some SEVENTEEN years ago, and the problem was identified as buggy back in 2012. As far as I can see, nothing has changed.

Entering the kernel with the MMU on and optionally caches on is an inherently unsafe thing to do. The kernel would have been placed into RAM via the data cache, and then we're trying to execute code - unless the caches have been properly cleaned and invalidated, there is no guarantee that we'd even reach any instructions to do our own cache cleaning and invalidation. So, caches on is utter madness.

MMU on presents a problem: the kernel moves itself around during decompression - if it happens to move itself on top of the in-use page tables, then that would be really bad. There's another issue as well - if the page tables are already setup, and we create a different mapping for the virtual address range, the _only_ way to safely switch to that mapping is via a break-make arrangement, which means we need code to disable the MMU, flush it. It is not as simple as "a few extra instructions to flush TLBs" although that may work in the majority of cases. Architecturally, it is wrong.

Things can get even worse - what if the page tables are located where the kernel writes its own page tables - modifying the live tables and changing the type of the entries. Architecturally unpredictable behaviour may result.

What is written in Documentation/arm/Booting is not for our fun, it is there to spell out what the kernel requires to be able to boot reliably on hardware. If it isn't followed, then booting a kernel will be unreliable.

downstream u-boot port

- No MMU enabled at boot
- Gets the commandline arguments from the boot.img
- Support the devicetree. Even supports modifying it on the fly.
- No display support, but leds are supported

Issues found on Midas with BL1$\rightarrow$u-boot$\rightarrow$Linux:

- Nonfree and non-redistributable BL1

- https://replicant.us/freedom-privacy-security-issues.php
- https://source.android.com/security/authentication/gatekeeper
- https://hackinparis.com/data/slides/2013/Slidesthomasroth.pdf