Kernel initialization

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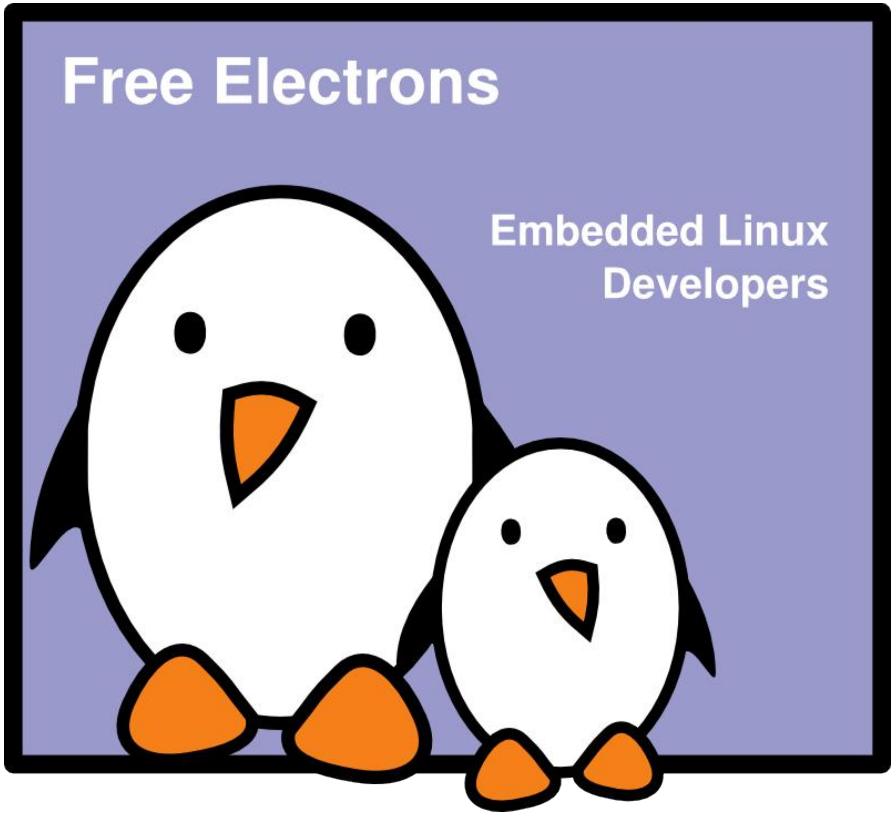
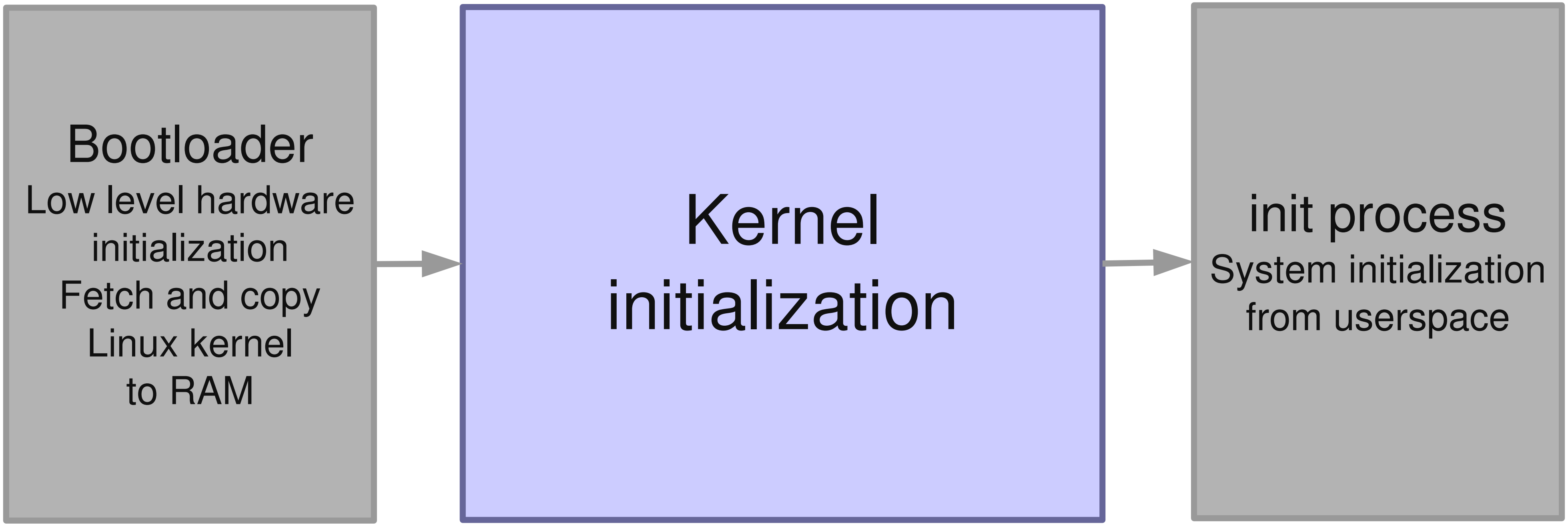


Latest update: Dec 20, 2010,
Document sources, updates and translations:
http://free-electrons.com/docs/kernel-init
Corrections, suggestions, contributions and translations are welcome!

From bootloader to userspace



Bootloader

Low level hardware initialization

Fetch and copy Linux kernel to RAM

Kernel initialization

init process

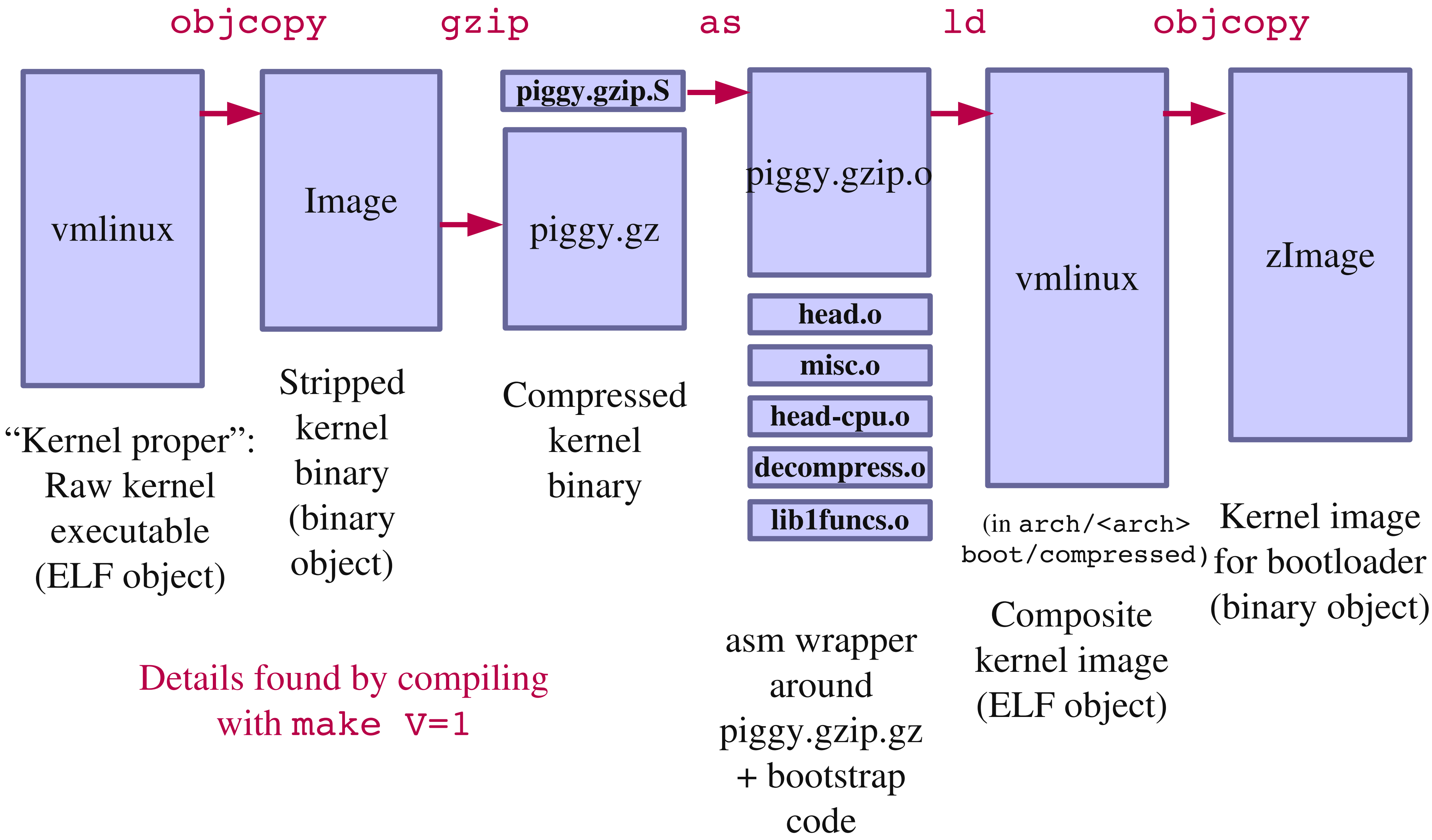
System initialization from userspace

Kernel bootstrap (1)

How the kernel bootstraps itself appears in kernel building. Example on ARM (pxa cpu) in Linux 2.6.36:

```
...
LD      vmlinux
SYSMAP  System.map
SYSMAP  .tmp_System.map
OBJCOPY arch/arm/boot/Image
Kernel: arch/arm/boot/Image is ready
AS      arch/arm/boot/compressed/head.o
GZIP    arch/arm/boot/compressed/piggy.gzip
AS      arch/arm/boot/compressed/piggy.gzip.o
CC      arch/arm/boot/compressed/misc.o
CC      arch/arm/boot/compressed/decompress.o
AS      arch/arm/boot/compressed/head-xscale.o
SHIPPED arch/arm/boot/compressed/lib1funcs.S
AS      arch/arm/boot/compressed/lib1funcs.o
LD      arch/arm/boot/compressed/vmlinux
OBJCOPY arch/arm/boot/zImage
Kernel: arch/arm/boot/zImage is ready
...
```

Kernel bootstrap (2)



`objcopy` `gzip` `as` `ld` `objcopy`

vmlinux

"Kernel proper": Raw kernel executable (ELF object)

Image

Stripped kernel binary (binary object)

piggy.gzip.S

piggy.gz

Compressed kernel binary

piggy.gzip.o

head.o

misc.o

head-cpu.o

decompress.o

lib1funcs.o

asm wrapper around piggy.gzip.gz + bootstrap code

vmlinux

(in `arch/<arch> boot/compressed`)

Composite kernel image (ELF object)

zImage

Kernel image for bootloader (binary object)

Details found by compiling with `make V=1`

Bootstrap code

- `head.o`:
  Architecture specific initialization code.
  This is what is executed by the bootloader
- `head-cpu.o` (here `head-xscale.o`):
  CPU specific initialization code
- `decompress.o`, `misc.o:`
  Decompression code
- `lib1funcs.o`:
  Optimized ARM division routines (ARM only)

Bootstrap code tasks

Main work done by `head.o`:

- Check the architecture, processor and machine type.
- Configure the MMU, create page table entries and enable virtual memory.
- Calls the `start_kernel` function in `init/main.c`.
  Same code for all architectures.
  Anybody interesting in kernel startup should study this file!

start_kernel main actions

- Calls `setup_arch(&command_line)` (function defined in `arch/<arch>/kernel/setup.c`), copying the command line from where the bootloader left it.
  - On `arm`, this function calls `setup_processor` (in which CPU information is displayed) and `setup_machine` (locating the machine in the list of supported machines).
- Initializes the console as early as possible (to get error messages)
- Initializes many subsystems (see the code)
- Eventually calls `rest_init`.

rest_init: starting the init process

Starting a new kernel thread which will later become the init process

```
static noinline void __init_refok rest_init(void)
        __releases(kernel_lock)
{
        int pid;

        rcu_scheduler_starting();
        /*
         * We need to spawn init first so that it obtains pid 1, however
         * the init task will end up wanting to create kthreads, which, if
         * we schedule it before we create kthreadd, will OOPS.
         */
        kernel_thread(kernel_init, NULL, CLONE_FS | CLONE_SIGHAND);
        numa_default_policy();
        pid = kernel_thread(kthreadd, NULL, CLONE_FS | CLONE_FILES);
        rcu_read_lock();
        kthreadd_task = find_task_by_pid_ns(pid, &init_pid_ns);
        rcu_read_unlock();
        complete(&kthreadd_done);

        /*
         * The boot idle thread must execute schedule()
         * at least once to get things moving:
         */
        init_idle_bootup_task(current);
        preempt_enable_no_resched();
        schedule();
        preempt_disable();

        /* Call into cpu_idle with preempt disabled */
        cpu_idle();
}
```

Source: Linux 2.6.36

kernel_init

kernel_init does two main things:

- Call do_basic_setup
  Now that kernel services are ready, start device initialization:
  (Linux 2.6.36 code excerpt):

```
static void __init do_basic_setup(void)
{
        cpuset_init_smp();
        usermodehelper_init();
        init_tmpfs();
        driver_init();
        init_irq_proc();
        do_ctors();
        do_initcalls();
}
```

- Call init_post

do_initcalls

Calls pluggable hooks registered with the macros below.

Advantage: the generic code doesn't have to know about them.

```
/*
 * A "pure" initcall has no dependencies on anything else, and purely
 * initializes variables that couldn't be statically initialized.
 *
 * This only exists for built-in code, not for modules.
 */
#define pure_initcall(fn)               __define_initcall("0",fn,1)

#define core_initcall(fn)               __define_initcall("1",fn,1)
#define core_initcall_sync(fn)          __define_initcall("1s",fn,1s)
#define postcore_initcall(fn)           __define_initcall("2",fn,2)
#define postcore_initcall_sync(fn)      __define_initcall("2s",fn,2s)
#define arch_initcall(fn)               __define_initcall("3",fn,3)
#define arch_initcall_sync(fn)          __define_initcall("3s",fn,3s)
#define subsys_initcall(fn)             __define_initcall("4",fn,4)
#define subsys_initcall_sync(fn)        __define_initcall("4s",fn,4s)
#define fs_initcall(fn)                 __define_initcall("5",fn,5)
#define fs_initcall_sync(fn)            __define_initcall("5s",fn,5s)
#define rootfs_initcall(fn)             __define_initcall("rootfs",fn,rootfs)
#define device_initcall(fn)             __define_initcall("6",fn,6)
#define device_initcall_sync(fn)        __define_initcall("6s",fn,6s)
#define late_initcall(fn)               __define_initcall("7",fn,7)
#define late_initcall_sync(fn)          __define_initcall("7s",fn,7s)
```

Defined in `include/linux/init.h`

initcall example

From `arch/arm/mach-pxa/lpd270.c` (Linux 2.6.36)

```
static int __init lpd270_irq_device_init(void)
{
        int ret = -ENODEV;
        if (machine_is_logicpd_pxa270()) {
                ret = sysdev_class_register(&lpd270_irq_sysclass);
                if (ret == 0)
                        ret = sysdev_register(&lpd270_irq_device);
        }
        return ret;
}

device_initcall(lpd270_irq_device_init);
```

init_post

The last step of Linux booting

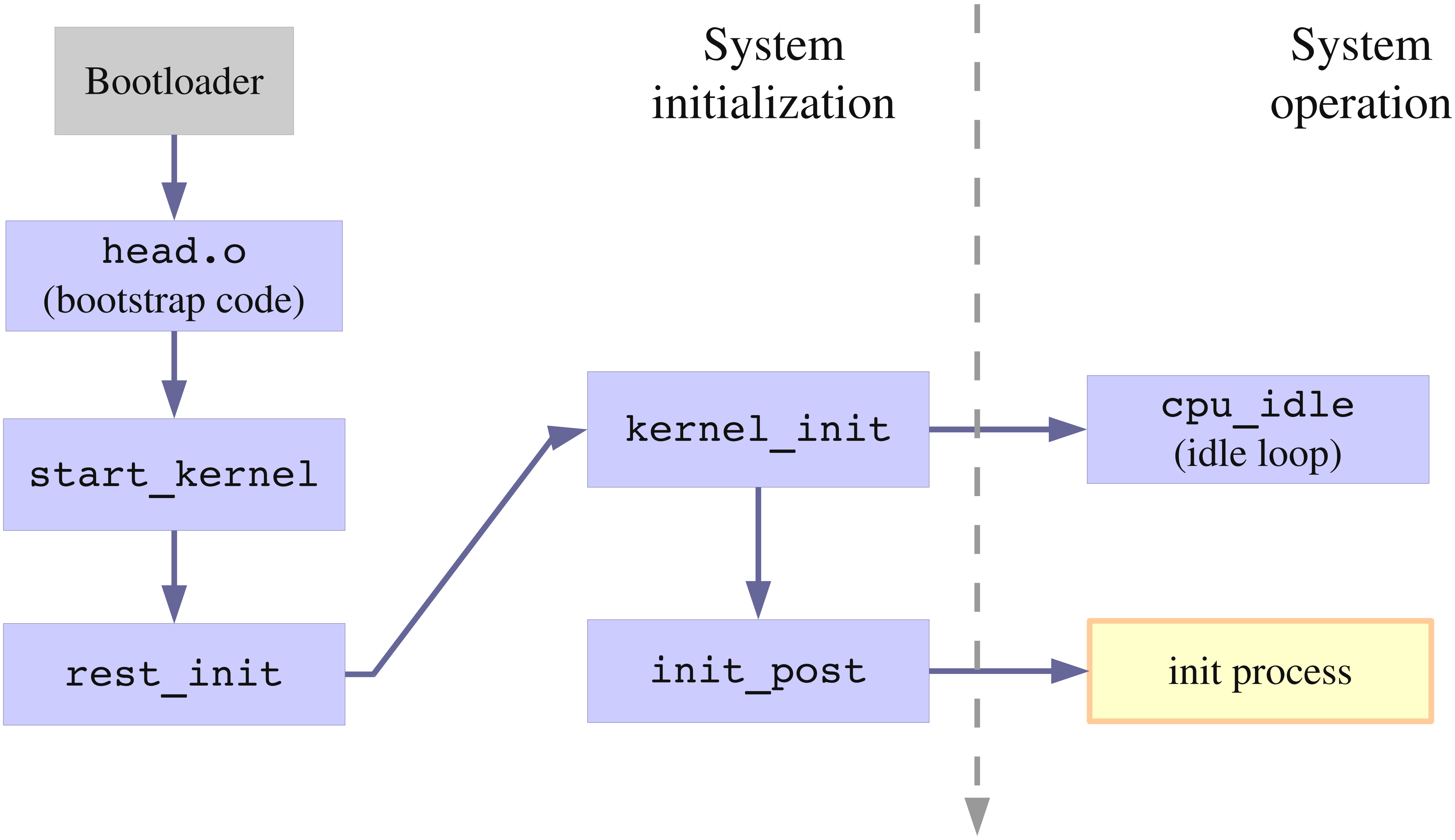
- First tries to open a console
- Then tries to run the init process, effectively turning the current kernel thread into the userspace init process.

init_post code

```
static noinline int init_post(void)
        __releases(kernel_lock)
{
        /* need to finish all async __init code before freeing the memory */
        async_synchronize_full();
        free_initmem();
        mark_rodata_ro();
        system_state = SYSTEM_RUNNING;
        numa_default_policy();


        current->signal->flags |= SIGNAL_UNKILLABLE;

        if (ramdisk_execute_command) {
                run_init_process(ramdisk_execute_command);
                printk(KERN_WARNING "Failed to execute %s\n",
                                ramdisk_execute_command);
        }

        /*
         * We try each of these until one succeeds.
         *
         * The Bourne shell can be used instead of init if we are
         * trying to recover a really broken machine.
         */
        if (execute_command) {
                run_init_process(execute_command);
                printk(KERN_WARNING "Failed to execute %s.  Attempting "
                                        "defaults...\n", execute_command);
        }
        run_init_process("/sbin/init");
        run_init_process("/etc/init");
        run_init_process("/bin/init");
        run_init_process("/bin/sh");

        panic("No init found.  Try passing init= option to kernel. "
              "See Linux Documentation/init.txt for guidance.");
}
```

Source:
`init/main.c`
in Linux 2.6.36

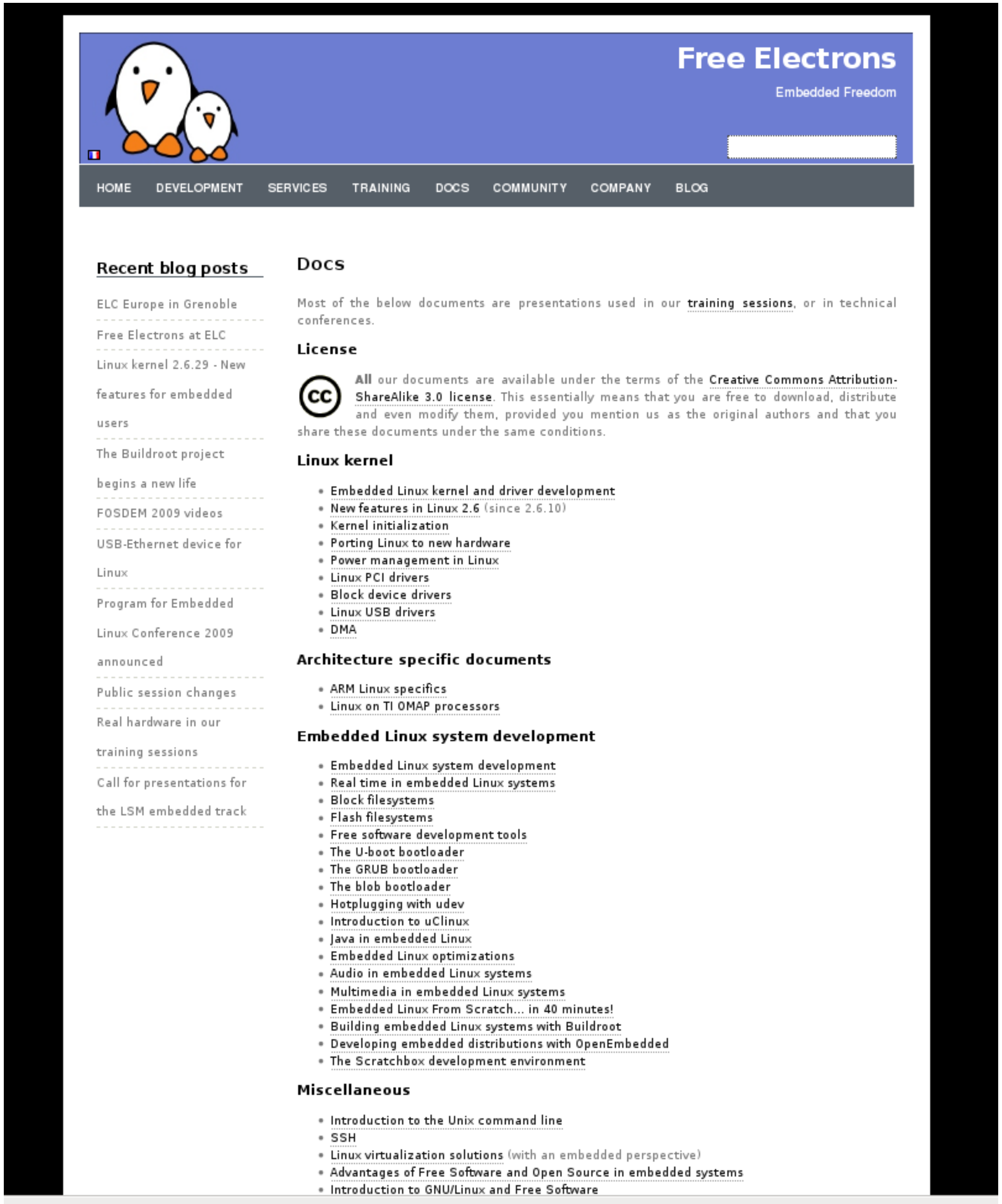
Kernel initialization graph



Kernel initialization - What to remember

- The bootloader executes bootstrap code.
- Bootstrap code initializes the processor and board, and uncompresses the kernel code to RAM, and calls the kernel's `start_kernel` function.
- Copies the command line from the bootloader.
- Identifies the processor and machine.
- Initializes the console.
- Initializes kernel services (memory allocation, scheduling, file cache...)
- Creates a new kernel thread (future init process) and continues in the idle loop.
- Initializes devices and execute initcalls.

Related documents



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