Kexec

Ready for Embedded Linux

Magnus Damm

magnus.damm@gmail.com

Renesas Electronics Corp.

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Outline

Bootloader Basics

Overview & Use Cases

Inside the Bootloader

Four Examples

Kexec-based Bootloaders

Introduction & Motivation

Hardware Setup Code

Kernel Configuration & Tuning

Optimizing User Space

Real World Examples

SH-Based Boards

ARM-Based Boards

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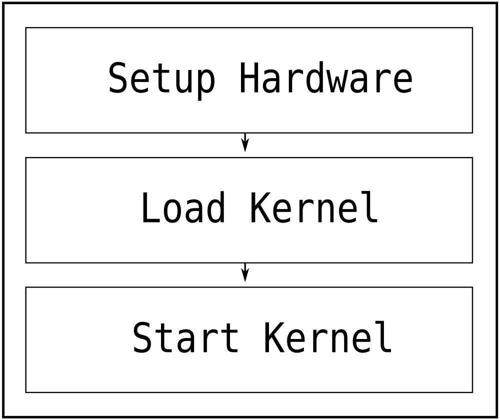
Overview



Setup Hardware

Load Kernel

Start Kernel

Use Cases

Development:

- Load Kernel Over Ethernet/USB

Standalone:

- Load Kernel From NAND/NOR/MMC/USB

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Inside the Bootloader

Hardware Setup (Assembly + C):

- Setup CS Memory Windows
- Initialize Caches & MMU
- Configure Clocks & GPIOs
- Setup System RAM
- Configure I/O Devices

Inside the Bootloader

Load Kernel (C only):

- "Driver Model"
- Network Stack / Filesystem
- Kernel File Format Parser

Start Kernel (C + Assembly):

- Prepare Kernel Parameters
- Execute Kernel

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Example 1: Good Old PC

BIOS:

- Located in ROM / NOR Flash
- Performs Hardware Setup
- Loads Bootloader from HDD

Bootloader:

- Executes from RAM
- Loads Kernel from HDD

Example 2: Embedded NOR Flash

```
[SoC + RAM + NOR Flash + I/O]
```

Bootloader:

- Located in NOR Flash
- Performs Hardware Setup
- Loads Kernel from NOR Flash

Example 3: Embedded NOR Flash + NAND / MMC

```
[SoC + RAM + NOR Flash + NAND Flash / MMC + I/O]
```

Bootloader:

- Located in NOR Flash
- Performs Hardware Setup
- Loads Kernel from NAND Flash / MMC

Example 4: Embedded NAND Flash / MMC

```
[SoC + RAM + NAND Flash / MMC + I/O]
```

Mask ROM:

- Located inside SoC
- Loads Bootloader from NAND Flash / MMC

Bootloader:

- Executes from On-chip RAM
- Performs Hardware Setup
- Loads Kernel from NAND Flash / MMC

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What is Kexec?

> "kexec is a system call that implements the ability to shutdown your current kernel, and to start another kernel. It is like a reboot but it is indepedent of the system firmware..."

Configuration help text in Linux-2.6.17

What is Kexec?

Kexec is a combination of kernel code and user space code:

- Linux kernel support available through CONFIG_KEXEC.
- kexec-tools provides the user space tool kexec.

Simple Kexec example to reboot into “zImage”:

```
# kexec -l zImage -append="console=ttySC0"
# kexec -e
```

Many thanks to:

- Eric W. Biederman - Kexec and kexec-tools author.
- Simon Horman - kexec-tools maintainer.
- Tony Lindgren - Kexec fixes for ARM.

So what is a Kexec-based Bootloader?

A Kexec-based bootloader is a combination of:

- Hardware setup code (not mandatory).
- A Linux kernel configured with `CONFIG_KEXEC=y`.
- User space with `kexec-tools`.

Motivation

SH-Mobile board - sh7724-based "`kfr2r09`"

- Handset prototype
- USB Gadget-only hardware design
- Micro-SD slot
- Upstream kernel driver for USB-Gadget
- No U-boot port, no U-boot drivers

Motivation - U-boot vs the Kernel

Question: Add U-boot support or extend the kernel?

U-boot and Barebox:

- Established
- Low barrier of entry
- Small

The Linux Kernel:

- Good hardware support
- Release management

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Hardware Setup Code for SH - Overview

“romImage” for SH:

- Includes all setup code needed to boot the system
- Supported by the boards `kfr2r09` and `ecovec24`
- Use “`make romImage`” to build image
- Burn to the NOR flash at the reset vector
- Merged in linux-2.6.31

Hardware Setup Code for SH - Files

“romImage” files:

- arch/sh/include/mach-xxx/mach/partner-jet-setup.txt - debug script
- arch/sh/include/mach-xxx/mach/romimage.h - board setup code
- arch/sh/boot/romimage/ - romImage wrapper for zImage
- arch/sh/boot/compressed/ - standard zImage
- arch/sh/configs/ - romImage configurations

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Kernel Configuration & Tuning - Iteration 1 - L-size

Start with an unoptimized kernel:

- Use the defconfig for your board, compile-in drivers
- Compile-in the kernel cmdline using CONFIG_CMDLINE_OVERWRITE=y
- Pass “quiet” on the kernel cmdline to silence the kernel
- Point out user space with CONFIG_INITRAMFS_SOURCE
- Set CONFIG_INITRAMFS_COMPRESSION_NONE=y
- Play around with CONFIG_KERNEL_GZIP/BZIP2/LZMA/LZO

Kernel Configuration & Tuning - Iteration 2 - M-size

Base on top of Iteration 1 and...

- Tune the kernel configuration for your use case
  - Remove unused subsystems, filesystems and drivers
  - Only one timer driver is needed
- CONFIG_SLOB=y, CONFIG_TINY_RCU=y
- Remember to keep CONFIG_KEXEC=y

Kernel Configuration & Tuning - Iteration 3 - S-size

Base on top of Iteration 2 and...

- Disable module support
- Disable even more kernel features (warning!)
  - CONFIG_EMBEDDED, CONFIG_BUG, CONFIG_PRINTK

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Optimizing User Space - Iteration 1

Start with an unoptimized initramfs:

- Use an existing cross toolchain (perhaps glibc to keep it simple)
- Build static `busybox` binary using allyesconfig
- Build a static `kexec` binary from `kexec-tools`
- Hack up configuration files and scripts
- Combine with the kernel using CONFIG_INITRAMFS_SOURCE

Uncompressed initramfs size: ~2.6 MiB (~300 Apps, sh4)

With L-size romImage, compressed with LZMA: ~2.9 MiB (~2s)

With L-size romImage, compressed with LZO: ~3.7 MiB (~1.5s)

Optimizing User Space - Iteration 2

Base on top of Iteration 1 and...

- Trim the `busybox` configuration to save space
- Remember to keep `udhcpc` and `tftp` if you netboot
- For speedup, replace `mdev` with kernel option `CONFIG_DEVTMPFS=y`

Uncompressed initramfs size: ~1.6 MiB (~60 Apps, sh4)

With M-size romImage, compressed with LZMA: ~2.0 MiB (~1.5s)

With M-size romImage, compressed with LZO: ~2.6 MiB (~1s)

Optimizing User Space - Iteration 3

Base on top of Iteration 2 and...

- Disable further `busybox` applets
- Hack `busybox` and `kexec-tools` into a single static binary

Uncompressed initramfs size: ~1 MiB (~30 Apps, sh4)

With S-size romImage, compressed with LZMA: ~1.0 MiB (~1s)

With S-size romImage, compressed with LZO: ~1.4 MiB (~0.5s)

Optimizing User Space

Keep on interating...

- Switch to a smaller libc
- Remove dead code

For quicker turn around time, use zImage to test user space

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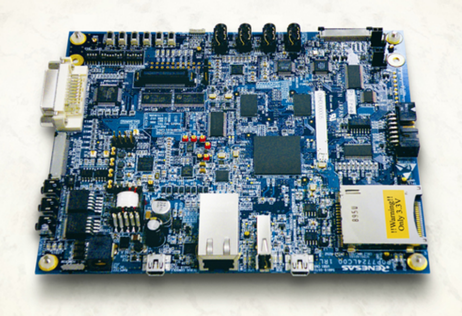
SH-Based Board MS7724



SH-Mobile board "MS7724" aka "Ecovec24":

- romImage burned to reset vector in NOR Flash
- Loads kernel over Ethernet using CONFIG_SH_ETH=y
- USB Storage support with CONFIG_USB_R8A66597_HCD=y
- LCD splash screen using CONFIG_FB_SH_MOBILE_LCDC=y

SH-Based Board kfr2r09

SH-Mobile board - sh7724-based "`kfr2r09`":

- romImage burned to reset vector in NOR Flash
- Loads kernel over USB Gadget using CONFIG_USB_CDC_COMPOSITE=y
- Loads kernel from Micro-SD using CONFIG_MFD_SH_MOBILE_SDHI=y

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ARM-Based Boards G3EVM & G4EVM

SH-Mobile ARM Boards `G3EVM` & `G4EVM`:

- U-boot burned to reset vector in NOR Flash
- U-boot starts uImage kernel from NOR Flash
- uImage has USB Host using CONFIG_USB_R8A66597_HCD=y
- uImage supports boot over USB Ethernet adapter

Summary

- From power-on to shell prompt in about a second.
- Unoptimized romImage needs ~4 MiB Flash
- Optimized romImage needs ~1 MiB Flash
- Size not an issue with NAND Flash / MMC Boot.