



D3 - Linux Drivers

Writing Linux Drivers

Objectives

- Mastering kernel development and debug tools
- Discovering multi-core programming in the Linux kernel
- Programming IOs, interrupts, timers and DMA
- Installing and integrating drivers inside Linux kernel
- Managing synchronous and asynchronous IOs and ioctl
- Writing a complete character driver
- Understanding specificities of 2.6 and 3.x versions
- Mastering kernel debugging technics with Lauterbach JTAG probes.

Labs are conducted on target boards, that can be:

Dual Cortex/A7-based "STM32MP15-DISCO" boards from STMicroelectronics.

Quad Cortex/A9-based "SabreLite" boards from NXP.

Quad Cortex/A53-based "imx8q-evk" boards from NXP.

We use a recent (4.x) linux kernel, as supported by the chip supplier.

Target audience

- This course is for engineers that install Linux on a custom platform and have to create specific device drivers.

Course environment

- Printed course material (in English)
- One Linux PC for two trainees.
- One target platform for two trainees

Prerequisite

- Good C programming skills
- Preferably knowledge of Linux user programming (see our [D0 - Linux user mode programming](#) course or [oD0 - Linux User Mode Programming](#) course)

Course Outline

FIRST DAY

Linux kernel programming

- Development in the Linux kernel
- Memory allocation
- Linked lists

Exercise: Writing the "hello world" kernel module

Exercise: Adding a driver to kernel sources and configuration menu

Exercise: Using module parameters

Exercise: Writing interdependent modules using memory allocations, reference counting and linked lists

Linux kernel debugging

- The /proc and debugfs filesystems
- Traces
- The kernel Dynamic Debugging interface
- The Kernel Address Sanitizer
- Debugging memory problems with kmemleak
- Using the Undefined Behavior Sanitizer
- Code coverage using gcov
- Debugging with kgdb
- Debugging with a JTAG probe

Exercise: Display dynamic traces on the running kernel

Exercise: Debug a module initialization using kgdb

Kernel multi-tasking

- Task handling
- Concurrent programming
- Timers
- Kernel threads

Exercise: Fixing race conditions in the previous lab with mutexes

SECOND DAY

Introduction to Linux drivers

- Accessing the device driver from user space
- Driver registration

Exercise: Step by step implementation of a character driver:

- driver registration (major/minor reservation) and device special file creation (/dev)

Driver I/O functions

- Kernel structures used by drivers
- Opening and closing devices
- Data transfers
- Controlling the device
- Mapping device memory

Exercise: Step by step implementation of a character driver:

- Implementing open and release
- Implementing read and write
- Implementing ioctl
- Implementing mmap

THIRD DAY

Synchronous and asynchronous requests

- Task synchronization
- Synchronous request
- Asynchronous requests

Exercise: implementation of a pipe-like driver:

- implementing waiting and waking
- adding non-blocking, asynchronous and multiplexed operations (O_NONBLOCK, SIGIO, poll/select)

Input/Output and interrupts

- Memory-mapped registers
- Interrupts
- Gpios
- User-level access through /sys or the GPIO character driver

Exercise: Polling gpio driver with raw register access

Exercise: Interrupt-based gpio driver with raw register access

Exercise: gpio driver using the gpiolib

Busses

- Plug-and-Play management
- Static devices declaration
 - in the BSP code
 - in the device tree
- Platform bus
- PCI
- SPI
- Power management
 - System sleep
 - Implementing power management in drivers
 - Remote wakeup

Exercise: Implementing a platform driver and customizing the device tree to associate it to its device (a serial port)

Exercise: Implementing power management in the previous driver

Exercise: Implementing remote wakeup in the previous driver

FOURTH DAY

Linux Driver Model

- Linux Driver Model Architecture
 - Overview
 - Classes
 - Busses
- Hot plug management
 - Plugging devices
 - Removing devices
- Writing udev rules

Exercise: Writing a custom class driver

Exercise: Writing a misc driver

DMA

- Direct Memory Access
 - DMA scenarios
 - Buffer access
- DMA programming
 - Bus master DMA
 - Slave DMA
- Memory barriers

Exercise: Implementing slave DMA in a serial port driver

ANNEXES

USB Drivers

- The USB bus
- USB devices
- User-space USB interface
- USB descriptors
- USB requests
- USB device drivers

Exercise: Writing a USB host driver

Network drivers

- structures
 - network interface representation (struct net_device)
 - network packet (struct sk_buff)
- scatter/gather
- interface
 - receiving packets
 - sending packets
 - lost packets management
 - network interface statistics
- New network API (NAPI)
 - "interrupt mitigation" (suppression of unneeded IRQs)
 - "packet throttling" (suppression of packets in the driver itself when system is overwhelmed)

Memory management

- Virtual Memory
- Memory Allocation
 - Free page management
 - Normal memory allocation
 - Virtual memory allocation
 - Huge allocations