



Understanding the Linux Graphics Stack training

On-line seminar, 4 sessions of 4 hours

Latest update: July 12, 2024

Title	Understanding the Linux Graphics Stack training
Training objectives	<ul style="list-style-type: none">• Be able to understand the basics of graphics display: image and color representation, pixel drawing, pixel operations.• Be able to understand graphics hardware: display pipeline components, display and rendering hardware.• Have a solid understanding of the Linux kernel graphics stack components and role: TTY, framebuffer and DRM subsystems.• Have a solid understanding of the Linux user-space graphics stack components and role: DRM from user-space, X.org, Wayland, OpenGL.
Duration	Four half days - 16 hours (4 hours per half day)
Pedagogics	<ul style="list-style-type: none">• Lectures delivered by the trainer, over video-conference. Participants can ask questions at any time.• Practical demonstrations done by the trainer, over video-conference. Participants can ask questions at any time.• Instant messaging for questions between sessions (replies under 24h, outside of week-ends and bank holidays).• Electronic copies of presentations, lab instructions and data files. They are freely available at https://bootlin.com/doc/training/graphics.
Trainer	One of the engineers listed on: https://bootlin.com/training/trainers/
Language	Oral lectures: English, French. Materials: English.
Audience	People developing multimedia devices using the Linux kernel



Prerequisites	<ul style="list-style-type: none">• Solid experience with the C programming language: participants must be familiar with the usage of complex data types and structures, pointers, function pointers, and the C pre-processor.• Experience with low-level development in Linux and hardware interfaces: participants should have a minimal understanding of memory management, interaction with common hardware interfaces (registers, interrupts), the interaction between Linux user-space applications and the Linux kernel (system calls). Following Bootlin's <i>Linux kernel driver development</i> course at bootlin.com/training/kernel/ allows to fulfill this pre-requisite.• Minimal English language level: B1, according to the <i>Common European Framework of References for Languages</i>, for our sessions in English. See bootlin.com/pub/training/cefr-grid.pdf for self-evaluation.
Required equipment	<ul style="list-style-type: none">• Computer with the operating system of your choice, with the Google Chrome or Chromium browser for videoconferencing.• Webcam and microphone (preferably from an audio headset)• High speed access to the Internet
Certificate	Only the participants who have attended all training sessions, and who have scored over 50% of correct answers at the final evaluation will receive a training certificate from Bootlin.
Disabilities	Participants with disabilities who have special needs are invited to contact us at training@bootlin.com to discuss adaptations to the training course.



Half day 1

Lecture - Image and Color Representation

- Light, pixels and pictures
- Sampling, frequency domain, aliasing
- Color quantization and representation
- Colorspaces and channels, alpha
- YUV and chroma sub-sampling
- Pixel data planes, scan order
- Pixel formats, FourCC codes, modifiers

Introducing the basic notions used for representing color images in graphics.

Lecture - Pixel Drawing

- Accessing and iterating over pixel data
- Concepts about rasterization
- Rectangle drawing
- Linear gradient drawing
- Disk drawing
- Circular gradient drawing
- Line drawing
- Line and shape aliasing, sub-pixel drawing
- Circles and polar coordinates
- Parametric curves

Presenting how to access pixel data in memory and draw basic shapes.

Lecture - Pixel Operations

- Region copy
- Alpha blending
- Color-keying
- Scaling and interpolation
- Linear filtering and convolution
- Blur filters
- Dithering

Providing basic notions about filtering, with very common examples of how it's used.

Demo - Drawing and operations

- Examples of various shapes and region drawing
- Examples of basic pixel operations

Illustrating the concepts presented along the way.



Half day 2

Lecture - Pipeline Components Overview and Generalities

- Types of graphics hardware implementations
- Graphics memory and buffers
- Graphics pipelines
- Display, render and video hardware overview

Presenting the hardware involved in graphics pipelines.

Lecture - Display hardware

- Visual display technologies: CRT, plasma, LCD, OLED, EPD
- Display timings, modes and EDID
- Display interfaces: VGA, DVI, HDMI, DP, LVDS, DSI, DP
- Bridges and transcoders

Presenting the inner workings of display hardware.

Lecture - Rendering Hardware Specifics

- Digital Signal Processors (DSPs)
- Dedicated hardware accelerators
- Graphics Processing Unit (GPUs)

Describing the architecture of processing and rendering hardware.

Lecture - System Integration, Memory and Performance

- Graphics integration and memory
- Shared graphics memory access
- Graphics memory constraints and performance
- Offloading graphics to hardware
- Graphics performance tips

Topics related to graphics integration, memory management and performance aspects.



Half day 3

Lecture - Display Stack Overview

- System-agnostic overview: kernel, user-space display and rendering
- Linux kernel overview
- Linux-compatible low-level userspace overview
- X Window and Wayland overview
- High-level graphics libraries and desktop environments overview

Presenting what software components are required for modern computer graphics and how they are divided between kernel and userspace.

Lecture - TTY Kernel Aspects, Framebuffer Device Kernel Aspects

- Linux TTY subsystem introduction
- Virtual terminals and graphics
- Virtual terminals switching and graphics
- Fbdev overview
- Fbdev basic operations
- Fbdev limitations

How TTYs interact with graphics in Linux along with a short presentation of fbdev and why it's deprecated.

Lecture - DRM Kernel Aspects

- DRM devices
- DRM driver identification and capabilities
- DRM master, magic and authentication
- DRM memory management
- DRM KMS dumb buffer API
- DRM FourCCs and modifiers
- DRM KMS resources probing
- DRM KMS modes
- DRM KMS framebuffer management
- DRM KMS legacy configuration and page flipping
- DRM event notification
- DRM KMS object properties
- DRM KMS atomic
- DRM render
- DRM Prime zero-copy memory sharing (dma-buf)
- DRM sync object fencing
- DRM debug and documentation

An exhaustive presentation of the DRM interface.

Demo - Kernel Aspects

- Linux TTY and virtual terminals
- DRM KMS mode-setting
- DRM KMS driver walkthrough
- DRM render driver walkthrough

Illustrating how kernel aspects work.



Half day 4

Lecture - X Window Userspace Aspects

- X11 protocol and architecture
- X11 protocol extensions
- Xorg architecture and acceleration
- Xorg drivers overview
- X11 and OpenGL acceleration: GLX and DRI2
- Xorg usage, integration and configuration
- Major issues with X11
- Xorg debug and documentation

Presenting all things related to X11 and Xorg.

Lecture - Wayland Userspace Aspects

- Wayland overview and paradigm
- Wayland protocol and architecture
- Wayland core protocol detail
- Wayland extra protocols
- Wayland asynchronous interface
- Wayland OpenGL integration
- Wayland status and adoption
- Wayland debug and documentation

An in-depth presentation of Wayland.

Lecture - Mesa 3D Userspace Aspects

- Standardized 3D rendering APIs: OpenGL, OpenGL ES, EGL and Vulkan
- Mesa 3D overview
- Mesa 3D implementation highlights
- Mesa 3D internals: Gallium 3D
- Mesa 3D internals: intermediate representations
- Mesa 3D Generic Buffer Management (GBM)
- Mesa 3D hardware support status
- Mesa 3D versus proprietary implementations
- Mesa 3D hardware support: debug and documentation

Presenting 3D APIs and the Mesa 3D implementation.

Demo - Userspace Aspects

- Xorg code walkthrough
- Wayland compositor core walkthrough
- Wayland client examples
- Mesa code walk-through
- OpenGL and EGL examples

Illustrating userspace aspects, client and server implementations.



Questions and Answers

- Questions and answers with the audience about the course topics
- Extra presentations if time is left, according what most participants are interested in.