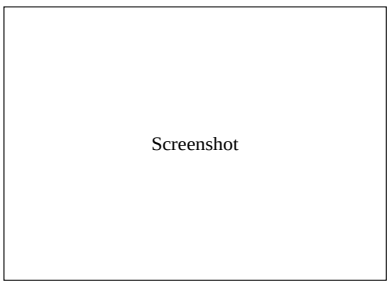
The Linux Frame Buffer Device Subsystem



Geert Uytterhoeven
geert@linux-m68k.org

Overview

◇ Introduction to Frame Buffer Devices

◇ The Abstract Console Driver

◇ The Frame Buffer Console Driver

◇ Frame Buffer Device Programming

◇ Applications using the Frame Buffer Device

◇ Conclusions and Future Development

Introduction

What? The frame buffer device

◇ provides an abstraction for the graphics hardware

◇ represents the frame buffer of the graphics hardware

◇ provides a well-defined interface to the hardware for application software

Exception: hardware acceleration is hardware specific

Why?

→ Need for **graphical text consoles**

Why Graphical Text Consoles?

- Non-PC hardware doesn't always support (VGA) text mode
- Firmware may program the hardware in graphics mode
- VGA legacy support will be removed eventually

Other features:

+ More flexible: arbitrary resolutions, color depths, refresh rates, font sizes
+ No limit for the number of characters in a font
+ Fancy features like anti-aliased fonts, . . .
- Inherently slower

History of Frame Buffer Devices

- Linux was developed for PC hardware
  MDA → CGA → EGA → VGA: hardware text mode
- 1993: Linux/m68k (initially Amiga & Atari)
  No hardware textmode, bitmapped graphics only
  Abstraction: `drivers/char/console.c` → `amicon.c` and `atacon.c`
- 1994: X through the **frame buffer device** (Martin Schaller on Atari)
  - **map frame buffer: `mmap()`**
  - **query resolution: `ioctl()`**
  - **change colormap: `ioctl()`**
- Merge `amicon.c` and `atacon.c` into `fbcon.c`
  Other m68k ports emerged: Mac, Apollo, . . . → more frame buffer devices

History of Frame Buffer Devices (cont'd)

- Other architectures? AXP, SPARC, PPC (PowerMac)
  - Hook into `scr_readw()`, `scr_writew()`
  - Shadow screen
  - Smart redraw
- Merge m68k with main branch (Linus)
  - Abstract console driver: fbcon and vgacon
  - Port to PPC (offb, atyfb), AXP (tgafb) and ia32 (vesafb)
  - Kernel 2.1.107: **frame buffer console = standard method for graphical consoles under Linux**
- Future: removal of VGA legacy (e.g. Cyrix MediaGX) → important for ia32, too

Design Goals for the Abstract Console Driver

Flexibility: support all kinds of consoles, no performance loss

- Hardware text consoles (VGA, MDA)
- Graphical consoles through frame buffer devices
- Graphical Signal Processors (GSP) without direct frame buffer access, e.g. TMS34010
- . . .

Implementation of the Abstract Console Driver

Small layer that provides an abstraction to a generic console.

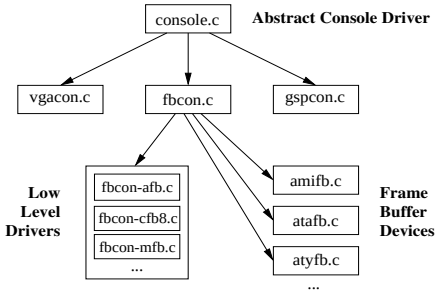
Primitives (`include/linux/console.h`):

```
struct consw {
    void (*con_clear)(...);
    void (*con_putc)(...);
    void (*con_putcs)(...);
    int  (*con_scroll)(...);
    void (*con_bmove)(...);
};
```

- Shadowscreen (optimization: not for VGA/MDA)
- Scrollback

The Frame Buffer Device Console

1. **fbdev**: frame buffer device controls the hardware
2. **fbcon**: generic frame buffer device console driver
3. **fbcon-**$*$: low level drawing routines for various screen memory organizations



Text Console Acceleration

- Use hardware tricks for acceleration
  - ypan: large virtual screen
  - ywrap: wrap around (← `amicon.c`, using the Amiga copper)
  - 2D acceleration engine (replace generic drawing operations)
  - real hardware text mode
- Smart redraw
  - Draw changed characters only
  - Reading the frame buffer is usually slow
  - PCI is fast, busy wait for blitter

Text Scrolling Benchmark Results

- ATI Mach64 GT (3D RAGE II+), PCI, 4 MB SGRAM
- CHRP LongTrail with IBM 604E at 200 MHz
- 1024×768, 75 Hz, 8×16 font
- ypan: virtual screen 1024×4000

bpp	memcpy	bitblt	memcpy+ypan	bitblt+ypan
8	20.34s	1.66s	0.41s	0.19s
16	41.52s	3.75s	N/A	N/A
32	90.67s	10.99s	N/A	N/A

Note: no results for smart redraw

Console Initialization

- We want console output as early as possible
- VGA text console is available early (on ISA bus, behind PCI/ISA bridge)
- Frame buffer devices need bus probing and memory allocation
- Solution: `dummy_con` and `take_over_console()`

```
conswitchp = &dummy_con;
console_init();
mem_init();
<bus>_init();
take_over_console();
```

- Allows booting with vgacon, and loading frame buffer device modules later

The Frame Buffer Device API

Special character device nodes: `/dev/fb[0-7]`

- **File I/O**: Frame buffer contents
- **`ioctl()`**: Query/change properties
- **`mmap()`**: Access to the **frame buffer** and the **MMIO registers**

```
include/linux/fb.h
include/video/
Documentation/fb/
http://www.tahallah.demon.co.uk/programming/prog.html
```


The Frame Buffer Device API: `ioctl()`

`FBIOGET_FSCREENINFO`

Query unchangeable information about the hardware

```
struct fb_fix_screeninfo {
    char id[16];
    char *smem_start;
    __u32 smem_len;
    __u32 type;
    __u32 visual;
    char *mmio_start;
    __u32 mmio_len;
    __u32 accel;
};
```


The Frame Buffer Device API: `ioctl()`

`FBIOGET_VSCREENINFO`, **`FBIOPUT_VSCREENINFO`**

Query or change variable information about the hardware

```
struct fb_var_screeninfo {
    __u32 xres, yres, xres_virtual, yres_virtual;
    __u32 xoffset, yoffset;
    __u32 bits_per_pixel;
    struct fb_bitfield red, green, blue, transp;
    __u32 pixclock;
    __u32 left_margin, right_margin, upper_margin,
          lower_margin;
    __u32 hsync_len, vsync_len;
};
```

Driver may round up some values to meet the hardware's capabilities

The Frame Buffer Device API: `ioctl()`

`FBIOGETCMAP`, **`FBIOPUTCMAP`**

Request or change parts of the color map

```
struct fb_cmap {
    __u32 start, len;
    __u16 *red, *green, *blue, *transp;
};
```

+ frame buffer device specific `ioctl()`s

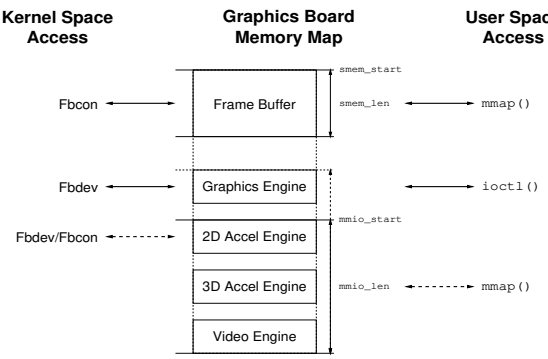
A Sample Application

```
fd = open("/dev/fb0", O_RDWR);
ioctl(fd, FBIOGET_VSCREENINFO, &var);
ioctl(fd, FBIOGET_FSCREENINFO, &fix);
cmap.start = 0;
cmap.len = 256;
cmap.red = malloc(cmap.len*sizeof(*cmap.red));
cmap.green = malloc(cmap.len*sizeof(*cmap.green));
cmap.blue = malloc(cmap.len*sizeof(*cmap.blue));
cmap.transp = malloc(cmap.len*sizeof(*cmap.transp));
ioctl(fd, FBIOGETCMAP, cmap);
line = malloc(fix.line_length);
printf("P6\n%d %d\n255\n", var.xres, var.yres);
for (i = 0; i < var.yres; i++) {
    read(fd, line, fix.line_length);
    for (j = 0; j < var.xres; j++) {
        putc(cmap.red[(int)line[j]]>>8, stdout);
        putc(cmap.green[(int)line[j]]>>8, stdout);
        putc(cmap.blue[(int)line[j]]>>8, stdout);
    }
}
close(fd);
```


The Frame Buffer Device API: `mmap()`

```
fd = open("/dev/fb0", O_RDWR);
ioctl(fd, FBIOGET_FSCREENINFO, &fix);
fb = mmap(NULL, fix.smem_start, fix.smem_len,
          PROT_READ | PROT_WRITE, MAP_SHARED, fd, 0);
ioctl(fd, FBIOGET_VSCREENINFO, &var);
var.accel &= ~FB_ACCELF_TEXT;
ioctl(fd, FBIOPUT_VSCREENINFO, &var);
mmio = mmap(NULL, fix.mmio_start, fix.mmio_len,
            PROT_READ | PROT_WRITE, MAP_SHARED,
            fd, fix.smem_len);
...
munmap(mmio, fix.mmio_len);
munmap(fb, fix.smem_len);
close(fd);
```


Graphics Hardware Access



Hardware Acceleration

No generic hardware acceleration support in the kernel

- Text console acceleration (rectcopy and rectfill) is allowed
- Hardware acceleration from user space, using `mmap()` on the Memory Mapped I/O (MMIO) registers

Motivations:

- User space acceleration experience (e.g. XFree86)
- Hardware acceleration is hardware specific
- Generic hardware acceleration is be complex → no OpenGL in the kernel

Future: 3D pipelines under kernel control? User space DMA?

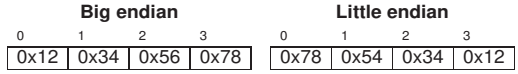
Multi-Head

- Up to 8 frame buffer devices
- Map any VC to any fbdev: **`ioctl()`s**

  `FBIOGET_CON2FBMAP`
  `FBIOPUT_CON2FBMAP`
- Multiple input devices? (PS/2, ADB, USB, Access.Bus, . . .)
- Rewrite of the input layer needed

Endianness

0x12345678



- CPU: big or little endian
- Graphics engine: usually configurable
- System bus: PCI is little endian

Example: 16 bpp little endian in a big endian machine (CyberVision64 on Amiga)

Traditional Graphics Hardware Access under Linux

PC hardware (VGA compatible)

- Kernel (virtual text consoles): VGA compatible hardware text mode (+ SVGATextMode)
- User space graphics:
  - SVGAlib (limited support)
  - X server (XFree86, Xi Graphics, Metro Link)

Advantages of the Frame Buffer Device Abstraction

◇ Unified method to access graphics hardware across different platforms

◇ Drivers can be shared among different architectures → reduces code duplication

Frame buffer device = chipset driver core + machine dependent probe code

◇ Simple multi-head: up to 8 frame buffer devices (displays)

◇ (with or without beer :-), one for each CPU

Special Case: the IA32 Platform

- vesafb: requires VESA BIOS extensions 2.0
- vga16fb: all VGA compatible hardware
- Chipset specific frame buffer devices, currently
  - atyfb: ATI Mach64
  - matroxfb: Matrox Millennium
  - pm2fb: 3DLabs Permedia 2
  - sgivwfb: SGI Visual Workstation

Quick Frame Buffer Device Writer's HOWTO

Need to know first :

- How to program a video mode (unless done by Firmware, cfr. `offb`)
- Where's the frame buffer?
- How to change the colormap?

Good starting point: `drivers/video/tgafb.c`
→ X works immediately (XF{68,86}_FBDev)

Later :

- Dynamic video mode changing
- Rectfill and rectcopy for text console acceleration
- Hardware cursor

Applications using the Frame Buffer Device

- XF68_FBDev and XF86_FBDev: X servers from the XFree86 Project
- fbset: tool to manage video modes, database in `/etc/fb.modes`
- ppmtofb: simple picture viewer
- libGGI `fbdev` target from the General Graphics Interface (GGI) Project
- oFBis (part of OSIS)

The X server

→ **XFree86** (commercial X servers?)

- XF68_FBDev: integrated since XFree86 release 3.2
  - monochrome
  - chunky 8/16/24/32 bpp
  - non-interleaved bitplanes
  - interleaved bitplanes
- Hardware acceleration? Experimental patches for XFree86 release 3.3.3.1
  - NCR77C32BLT
  - IMS Twin Turbo
  - 3DLabs Permedia 2
  - ATI Mach64
  - Matrox Millennium
- Better: integrate in existing accelerated X servers (cfr. Matrox in XF86_SVGA)

The X server

	Traditional	Fbdev
Hardware probing	Direct access	`/dev/fb* ioctl()` `FBIOGET_FSCREENINFO`
Video mode switching	Direct access	`/dev/fb* ioctl()` `FBIOPUT_VSCREENINFO`
Colormap changing	Direct access	`/dev/fb* ioctl()` `FBIOPUTCMAP`
Acceleration	Direct access	Direct access

→ **XFree86 release 4.0**: one single X server

- Use frame buffer device probing if available
- Else fallback to direct hardware probing
- Common acceleration code, no performance loss

The GGI Project

GGI = **General Graphics Interface**

- libGGI `fbdev` target
- GGI drivers masquerade as frame buffer devices

Future Development

- More and better drivers
  Currently >30 frame buffer devices, most targeted at non-ia32 platforms
- Full acceleration for various chipsets using XFree86 code
  → XFree86 release 4.0
- Real multi-head → rewrite of the input layer
- Better separation between fbdev and fbcon
- Shared video mode database to select the video mode at boot up time

Development mailing list (under majordomo):

`linux-fbdev@vuser.vu.union.edu`

Conclusions

fbdev

- Frame buffer devices provide a good abstraction for the graphics hardware
- Accelerated X servers on top of frame buffer devices are possible and perform well

abscon

- The abstract console driver allows all kinds of consoles, without performance loss

fbcon

- The frame buffer console driver provides a fast text console on graphics hardware

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My Future?

Linux kernel hacker for hire!

geert@linux-m68k.org

http://www.cs.kuleuven.ac.be/~geert/