

the GNU GRUB developer manual

The GRand Unified Bootloader, version 2.00, 29 September 2012.

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This developer manual is for GNU GRUB (version 2.00, 29 September 2012).

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1 Getting the source code

GRUB is maintained using the [Bazaar revision control system](#). To fetch the primary development branch:

```
bzr get http://bzr.savannah.gnu.org/r/grub/trunk/grub
```

The GRUB developers maintain several other branches with work in progress. Of these, the most interesting is the experimental branch, which is a staging area for new code which we expect to eventually merge into trunk but which is not yet ready:

```
bzr get http://bzr.savannah.gnu.org/r/grub/branches/experimental
```

Once you have used *bzr get* to fetch an initial copy of a branch, you can use *bzr pull* to keep it up to date. If you have modified your local version, you may need to resolve conflicts when pulling.

2 Coding style

Basically we follow the [GNU Coding Standards](#). We define additional conventions for GRUB here.

2.1 Naming Conventions

All global symbols (i.e. functions, variables, types, and macros) must have the prefix `grub_` or `GRUB_`. The all capital form is used only by macros.

2.2 Functions

If a function is global, its name must be prefixed with `grub_` and must consist of only small letters. If the function belongs to a specific function module, the name must also be prefixed with the module name. For example, if a function is for file systems, its name is prefixed with `grub_fs_`. If a function is for FAT file system but not for all file systems, its name is prefixed with `grub_fs_fat_`. The hierarchy is noted this way.

After a prefix, a function name must start with a verb (such as `get` or `is`). It must not be a noun. Some kind of abbreviation is permitted, as long as it wouldn't make code less readable (e.g. `init`).

If a function is local, its name may not start with any prefix. It must start with a verb.

2.3 Variables

The rule is mostly the same as functions, as noted above. If a variable is global, its name must be prefixed with `grub_` and must consist of only small letters. If the variable belongs to a specific function module, the name must also be prefixed with the module name. For example, if a function is for dynamic loading, its name is prefixed with `grub_dl_`. If a variable is for ELF but not for all dynamic loading systems, its name is prefixed with `grub_dl_elf_`.

After a prefix, a variable name must start with a noun or an adjective (such as `name` or `long`) and it should end with a noun. Some kind of abbreviation is permitted, as long as it wouldn't make code less readable (e.g. `i18n`).

If a variable is global in the scope of a single file (i.e. it is declared with `static`), its name may not start with any prefix. It must start with a noun or an adjective.

If a variable is local, you may choose any shorter name, as long as it wouldn't make code less readable (e.g. `i`).

2.4 Types

The name of a type must be prefixed with `grub_` and must consist of only small letters. If the type belongs to a specific function module, the name must also be prefixed with the module name. For example, if a type is for OS loaders, its name is prefixed with `grub_loader_`. If a type is for Multiboot but not for all OS loaders, its name is prefixed with `grub_loader_linux_`.

The name must be suffixed with `_t`, to emphasize the fact that it is a type but not a variable or a function.

2.5 Macros

If a macro is global, its name must be prefixed with `GRUB_` and must consist of only large letters. Other rules are the same as functions or variables, depending on whether a macro is used like a function or a variable.

2.6 Comments

All comments shall be C-style comments, of the form `/* ... */`.

Comments shall be placed only on a line by themselves. They shall not be placed together with code, variable declarations, or other non-comment entities. A comment should be placed immediately preceding the entity it describes.

Acceptable:

```
/* The page # that is the front buffer. */
int displayed_page;
/* The page # that is the back buffer. */
int render_page;
```

Unacceptable:

```
int displayed_page;          /* The page # that is the front buffer. */
int render_page;            /* The page # that is the back buffer. */
```

2.7 Multi-Line Comments

Comments spanning multiple lines shall be formatted with all lines after the first aligned with the first line.

Asterisk characters should not be repeated at the start of each subsequent line.

Acceptable:

```
/* This is a comment
   which spans multiple lines.
   It is long. */
```

Unacceptable:

```
/*
 * This is a comment
 * which spans multiple lines.
 * It is long. */
```

The opening `/*` and closing `*/` should be placed together on a line with text.

3 Finding your way around

Here is a brief map of the GRUB code base.

GRUB uses Autoconf and Automake, with most of the Automake input generated by AutoGen. The top-level build rules are in `'configure.ac'`, `'grub-core/Makefile.core.def'`, and `'Makefile.util.def'`. Each block in a `'*.def'` file represents a build target, and specifies the source files used to build it on various platforms. The `'*.def'` files are processed into AutoGen input by `'gentpl.py'` (which you only need to look at if you are extending the build system). If you are adding a new module which follows an existing pattern, such as a new command or a new filesystem implementation, it is usually easiest to grep `'grub-core/Makefile.core.def'` and `'Makefile.util.def'` for an existing example of that pattern to find out where it should be added.

In general, code that may be run at boot time is in a subdirectory of `'grub-core'`, while code that is only run from within a full operating system is in a subdirectory of the top level.

Low-level boot code, such as the MBR implementation on PC BIOS systems, is in the `'grub-core/boot/'` directory.

The GRUB kernel is in `'grub-core/kern/'`. This contains core facilities such as the device, disk, and file frameworks, environment variable handling, list processing, and so on. The kernel should contain enough to get up to a rescue prompt. Header files for kernel facilities, among others, are in `'include/'`.

Terminal implementations are in `'grub-core/term/'`.

Disk access code is spread across `'grub-core/disk/'` (for accessing the disk devices themselves), `'grub-core/partmap/'` (for interpreting partition table data), and `'grub-core/fs/'` (for accessing filesystems). Note that, with the odd specialised exception, GRUB only contains code to *read* from filesystems and tries to avoid containing any code to *write* to filesystems; this lets us confidently assure users that GRUB cannot be responsible for filesystem corruption.

PCI and USB bus handling is in `'grub-core/bus/'`.

Video handling code is in `'grub-core/video/'`. The graphical menu system uses this heavily, but is in a separate directory, `'grub-core/gfxmenu/'`.

Most commands are implemented by files in `'grub-core/commands/'`, with the following exceptions:

- A few core commands live in `'grub-core/kern/corecmd.c'`.
- Commands related to normal mode live under `'grub-core/normal/'`.
- Commands that load and boot kernels live under `'grub-core/loader/'`.
- The `'loopback'` command is really a disk device, and so lives in `'grub-core/disk/loopback.c'`.
- The `'gettext'` command lives under `'grub-core/gettext/'`.
- The `'loadfont'` and `'lsfonts'` commands live under `'grub-core/font/'`.
- The `'serial'`, `'terminfo'`, and `'background_image'` commands live under `'grub-core/term/'`.
- The `'efiemu_*'` commands live under `'grub-core/efiemu/'`.

There are a few other special-purpose exceptions; grep for them if they matter to you.

Utility programs meant to be run from a full operating system are in ‘`util/`’.

4 Contributing changes

Contributing changes to GRUB 2 is welcomed activity. However we have a bit of control what kind of changes will be accepted to GRUB 2. Therefore it is important to discuss your changes on grub-devel mailing list (see MailingLists). On this page there are some basic details on the development process and activities.

First of all you should come up with the idea yourself what you want to contribute. If you do not have that beforehand you are advised to study this manual and try GRUB 2 out to see what you think is missing from there.

Here are additional pointers:

- <https://savannah.gnu.org/task/?group=grub> GRUB's Task Tracker
- <https://savannah.gnu.org/bugs/?group=grub> GRUB's Bug Tracker

If you intended to make changes to GRUB Legacy (≤ 0.97) those are not accepted anymore.

4.1 Getting started

- Always use latest GRUB 2 source code. So get that first.

For developers it is recommended always to use the newest development version of GRUB 2. If development takes a long period of time, please remember to keep in sync with newest developments regularly so it is much easier to integrate your change in the future. GRUB 2 is being developed in a Bazaar (bzd) repository.

Please check Savannah's GRUB project page for details how to get newest bzr: [GRUB 2 bzr Repository](#)

- Compile it and try it out.

It is always good idea to first see that things work somehow and after that to start to implement new features or develop fixes to bugs.

- Study the code.

There are sometimes odd ways to do things in GRUB 2 code base. This is mainly related to limited environment where GRUB 2 is being executed. You usually do not need to understand it all so it is better to only try to look at places that relates to your work. Please do not hesitate to ask for help if there is something that you do not understand.

- Develop a new feature.

Now that you know what to do and how it should work in GRUB 2 code base, please be free to develop it. If you have not so far announced your idea on grub-devel mailing list, please do it now. This is to make sure you are not wasting your time working on the solution that will not be integrated to GRUB 2 code base.

You might want to study our coding style before starting development so you do not need to change much of the code when your patch is being reviewed. (see [Chapter 2 \[Coding style\], page 3](#))

For every accepted patch there has to exist a ChangeLog entry. Our ChangeLog consist of changes within source code and are not describing about what the change logically does. Please see examples from previous entries.

Also remember that GRUB 2 is licensed under GPLv3 license and that usually means that you are not allowed to copy pieces of code from other projects. Even if the source project's license would be compatible with GPLv3, please discuss it beforehand on grub-devel mailing list.

- Test your change.

Test that your change works properly. Try it out a couple of times, preferably on different systems, and try to find problems with it.

- Publish your change.

When you are happy with your change, first make sure it is compilable with latest development version of GRUB 2. After that please send a patch to grub-devel for review. Please describe in your email why you made the change, what it changes and so on. Please be prepared to receive even discouraging comments about your patch. There is usually at least something that needs to be improved in every patch.

Please use unified diff to make your patch (good match of arguments for diff is `'-pruN'`).

- Respond to received feedback.

If you are asked to modify your patch, please do that and resubmit it for review. If your change is large you are required to submit a copyright agreement to FSF. Please keep in mind that if you are asked to submit for copyright agreement, process can take some time and is mandatory in order to get your changes integrated.

If you are not on grub-devel to respond to questions, most likely your patch will not be accepted. Also if problems arise from your changes later on, it would be preferable that you also fix the problem. So stay around for a while.

- Your patch is accepted.

Good job! Your patch will now be integrated into GRUB 2 mainline, and if it didn't break anything it will be publicly available in the next release.

Now you are welcome to do further improvements :)

4.2 Typical Developer Experience

The typical experience for a developer in this project is the following:

1. You find yourself wanting to do something (e.g. fixing a bug).
2. You show some result in the mailing list or the IRC.
3. You are getting to be known to other developers.
4. You accumulate significant amount of contribution, so copyright assignment is processed.
5. You are free to check in your changes on your own, legally speaking.

At this point, it is rather annoying that you ought to ask somebody else every change to be checked in. For efficiency, it is far better, if you can commit it yourself. Therefore, our policy is to give you the write permission to our official repository, once you have shown your skill and will, and the FSF clerks have dealt with your copyright assignment.

4.3 When you are approved for write access to project's files

As you might know, GRUB is hosted on <https://savannah.gnu.org/projects/grub> Savannah, thus the membership is managed by Savannah. This means that, if you want to be a member of this project:

1. You need to create your own account on Savannah.
2. You can submit “Request for Inclusion” from “My Groups” on Savannah.

Then, one of the admins can approve your request, and you will be a member. If you don't want to use the Savannah interface to submit a request, you can simply notify the admins by email or something else, alternatively. But you still need to create an account beforehand.

NOTE: we sometimes receive a “Request for Inclusion” from an unknown person. In this case, the request would be just discarded, since it is too dangerous to allow a stranger to be a member, which automatically gives him a commit right to the repository, both for a legal reason and for a technical reason.

If your intention is to just get started, please do not submit a inclusion request. Instead, please subscribe to the mailing list, and communicate first (e.g. sending a patch, asking a question, commenting on another message...).

5 Porting

GRUB2 is designed to be easily portable accross platforms. But because of the nature of bootloader every new port must be done separately. Here is how I did MIPS (loongson and ARC) and Xen ports. Note than this is more of suggestions, not absolute truth.

First of all grab any architecture specifications you can find in public (please avoid NDA).

First stage is “Hello world”. I’ve done it outside of GRUB for simplicity. Your task is to have a small program which is loadable as bootloader and clearly shows its presence to you. If you have easily accessible console you can just print a message. If you have a mapped framebuffer you know address of, you can draw a square. If you have a debug facility, just hanging without crashing might be enough. For the first stage you can choose to load the bootloader across the network since format for network image is often easier than for local boot and it skips the need of small intermediary stages and nvram handling. Additionally you can often have a good idea of the needed format by running “file” on any netbootable executable for given platform.

This program should probably have 2 parts: an assembler and C one. Assembler one handles BSS cleaning and other needed setup (on some platforms you may need to switch modes or copy the executable to its definitive position). So your code may look like (x86 assembly for illustration purposes)

```

        .globl _start
_start:
movl $_bss_start, %edi
movl $_end, %ecx
subl %edi, %ecx
xorl %eax, %eax
cld
rep
stosb

        call main

static const char msg[] = "Hello, world";

void
putchar (int c)
{
    ...
}

void
main (void)
{
    const char *ptr = msg;
    while (*ptr)
        putchar (*ptr++);
    while (1);

```

```
}

```

Sometimes you need a third file: assembly stubs for ABI-compatibility.

Once this file is functional it's time to move it into GRUB2. The startup assembly file goes to `grub-core/kern/$cpu/$platform/startup.S`. You should also include `grub/symbol.h` and replace call to entry point with call to `EXT_C(grub_main)`. The C file goes to `grub-core/kern/$cpu/$platform/init.c` and its entry point is renamed to `void grub_machine_init (void)`. Keep final infinite loop for now. Stubs file if any goes to `grub-core/kern/$cpu/$platform/callwrap.S`. Sometimes either `$cpu` or `$platform` is dropped if file is used on several cpus respectively platforms. Check those locations if they already have what you're looking for.

Then modify in `configure.ac` the following parts:

CPU names:

```
case "$target_cpu" in
  i[[3456]]86) target_cpu=i386 ;;
  amd64) target_cpu=x86_64 ;;
  sparc) target_cpu=sparc64 ;;
  s390x) target_cpu=s390 ;;
  ...
esac

```

Sometimes CPU have additional architecture names which don't influence booting. You might want to have some canonical name to avoid having bunch of identical platforms with different names.

NOTE: it doesn't influence compile optimisations which depend solely on chosen compiler and compile options.

```
if test "x$with_platform" = x; then
  case "$target_cpu"-"$target_vendor" in
    i386-apple) platform=efi ;;
    i386-*) platform=pc ;;
    x86_64-apple) platform=efi ;;
    x86_64-*) platform=pc ;;
    powerpc-*) platform=ieee1275 ;;
    ...
  esac
else
  ...
fi

```

This part deals with guessing the platform from CPU and vendor. Sometimes you need to use 32-bit mode for booting even if OS runs in 64-bit one. If so add your platform to:

```
case "$target_cpu"-"$platform" in
  x86_64-efi) ;;
  x86_64-emu) ;;
  x86_64-*) target_cpu=i386 ;;
  powerpc64-ieee1275) target_cpu=powerpc ;;
esac

```


Add your platform to the list of supported ones:

```
case "$target_cpu"-"$platform" in
    i386-efi) ;;
    x86_64-efi) ;;
    i386-pc) ;;
    i386-multiboot) ;;
    i386-coreboot) ;;
    ...
esac
```

If explicit -m32 or -m64 is needed add it to:

```
case "$target_cpu" in
    i386 | powerpc) target_m32=1 ;;
    x86_64 | sparc64) target_m64=1 ;;
esac
```

Finally you need to add a conditional to the following block:

```
AM_CONDITIONAL([COND_mips_arc], [test x$target_cpu = xmips -a x$platform = xarc])
AM_CONDITIONAL([COND_sparc64_ieee1275], [test x$target_cpu = xsparc64 -a x$platform = xsparc64_ieee1275])
AM_CONDITIONAL([COND_powerpc_ieee1275], [test x$target_cpu = xpowerpc -a x$platform = xpowerpc_ieee1275])
```

Next stop is gentpl.py. You need to add your platform to the list of supported ones (sorry that this list is duplicated):

```
GRUB_PLATFORMS = [ "emu", "i386_pc", "i386_efi", "i386_qemu", "i386_coreboot",
    "i386_multiboot", "i386_ieee1275", "x86_64_efi",
    "mips_loongson", "sparc64_ieee1275",
    "powerpc_ieee1275", "mips_arc", "ia64_efi",
    "mips_qemu_mips", "s390_mainframe" ]
```

You may also want already to add new platform to one or several of available groups. In particular we always have a group for each CPU even when only one platform for given CPU is available.

Then comes grub-core/Makefile.core.def. In the block “kernel” you’ll need to define ldflags for your platform (\$cpu.\$platform_ldflags). You also need to declare startup asm file (\$cpu.\$platform_startup) as well as any other files (e.g. init.c and callwrap.S) (e.g. \$cpu.\$platform = kern/\$cpu/\$platform/init.c). At this stage you will also need to add dummy dl.c and cache.S with functions grub_err_t grub_arch_dl_check_header (void *ehdr), grub_err_t grub_arch_dl_relocate_symbols (grub_dl_t mod, void *ehdr) (dl.c) and void grub_arch_sync_caches (void *address, grub_size_t len) (cache.S). They won’t be used for now.

You will need to create directory include/\$cpu/\$platform and a file include/\$cpu/types.h. The later following this template:

```
#ifndef GRUB_TYPES_CPU_HEADER
#define GRUB_TYPES_CPU_HEADER 1

/* The size of void *. */
#define GRUB_TARGET_SIZEOF_VOID_P 4
```

```

/* The size of long. */
#define GRUB_TARGET_SIZEOF_LONG 4

/* mycpu is big-endian. */
#define GRUB_TARGET_WORDS_BIGENDIAN 1
/* Alternatively: mycpu is little-endian. */
#undef GRUB_TARGET_WORDS_BIGENDIAN

#endif /* ! GRUB_TYPES_CPU_HEADER */

```

You will also need to add a dummy file to `datetime` and `setjmp` modules to avoid any of it having no files. It can be just completely empty at this stage.

You'll need to make `grub-mkimage.c` (`util/grub_mkimage.c`) aware of the needed format. For most commonly used formats like ELF, PE, aout or raw the support is already present and you'll need to make it follow the existant code paths for your platform adding adjustments if necessary. When done compile:

```

./autogen.sh
./configure --target=$cpu --with-platform=$platform TARGET_CC=.. OBJCOPY=... STRIP=...
make > /dev/null

```

And create image

```
./grub-mkimage -d grub-core -O $format_id -o test.img
```

And it's time to test your `test.img`.

If it works next stage is to have heap, console and timer.

To have the heap working you need to determine which regions are suitable for heap usage, allocate them from firmware and map (if applicable). Then call `grub_mm_init_region` (`vois *start, grub_size_t s`) for every of this region. As a shortcut for early port you can allocate right after `_end` or have a big static array for heap. If you do you'll probably need to come back to this later. As for output console you should distinguish between an array of text, terminfo or graphics-based console. Many of real-world examples don't fit perfectly into any of these categories but one of the models is easier to be used as base. In second and third case you should add your platform to `terminfokernel` respectively `videokernel` group. A good example of array of text is `i386-pc` (`kern/i386/pc/init.c` and `term/i386/pc/console.c`). Of terminfo is `ieee1275` (`kern/ieee1275/init.c` and `term/ieee1275/console.c`). Of video is `loongson` (`kern/mips/loongson/init.c`). Note that terminfo has to be initied in 2 stages: one before (to get at least rudimentary console as early as possible) and another after the heap (to get full-featured console). For the input there are string of keys, terminfo and direct hardware. For string of keys look at `i386-pc` (same files), for terminfo `ieee1275` (same files) and for hardware `loongson` (`kern/mips/loongson/init.c` and `term/at_keyboard.c`).

For the timer you'll need to call `grub_install_get_time_ms (...)` with as sole argument a function returning a `grub_uint64_t` of a number of milliseconds elapsed since arbitrary point in the past.

Once these steps accomplished you can remove the infinite loop and you should be able to get to the minimal console. Next step is to have module loading working. For this you'll need to fill `kern/$cpu/dl.c` and `kern/$cpu/cache.S` with real handling of relocations and respectively the real sync of I and D caches. Also you'll need to decide where in the image to store the modules. Usual way is to have it concatenated at the end. In this case

you'll need to modify `startup.S` to copy modules out of `bss` to let's say `ALIGN_UP` (`_end`, 8) before cleaning out `bss`. You'll probably find useful to add `total_module_size` field to `startup.S`. In `init.c` you need to set `grub_modbase` to the address where modules can be found. You may need `grub_modules_get_end()` to avoid declaring the space occupied by modules as usable for heap. You can test modules with:

```
./grub-mkimage -d grub-core -O $format_id -o test.img hello
```

and then running "hello" in the shell.

Once this works, you should think of implementing disk access. Look around `disk/` for examples.

Then, very importantly, you probably need to implement the actual loader (examples available in `loader/`)

Last step to have minimally usable port is to add support to `grub-install` to put GRUB in a place where firmware or platform will pick it up.

Next steps are: filling `datetime.c`, `setjmp.S`, `network` (`net/drivers`), `video` (`video/`), `halt` (`lib/`), `reboot` (`lib/`).

Please add your platform to Platform limitations and Supported kernels chapter in user documentation and mention any steps you skipped which result in reduced features or performance. Here is the quick checklist of features. Some of them are less important than others and skipping them is completely ok, just needs to be mentioned in user documentation.

Checklist:

- Is heap big enough?
- Which charset is supported by console?
- Does platform have disk driver?
- Do you have network card support?
- Are you able to retrieve `datetime` (with date)?
- Are you able to set `datetime` (with date)?
- Is serial supported?
- Do you have direct disk support?
- Do you have direct keyboard support?
- Do you have USB support?
- Do you support loading through network?
- Do you support loading from disk?
- Do you support chainloading?
- Do you support network chainloading?
- Does `cpuid` command supports checking all CPU features that the user might want conditionalise on (64-bit mode, hypervisor,...)
- Do you support hints? How reliable are they?
- Does platform have ACPI? If so do "acpi" and "lsacpi" modules work?
- Do any of platform-specific operations mentioned in the relevant section of user manual makes sense on your platform?

- Does your platform support PCI? If so is there an appropriate driver for GRUB?
- Do you support badram?

6 Error Handling

Error handling in GRUB 2 is based on exception handling model. As C language doesn't directly support exceptions, exception handling behavior is emulated in software.

When exception is raised, function must return to calling function. If calling function does not provide handling of the exception it must return back to its calling function and so on, until exception is handled. If exception is not handled before prompt is displayed, error message will be shown to user.

Exception information is stored on `grub_errno` global variable. If `grub_errno` variable contains value `GRUB_ERR_NONE`, there is no active exception and application can continue normal processing. When `grub_errno` has other value, it is required that application code either handles this error or returns instantly to caller. If function is with return type `grub_err_t` is about to return `GRUB_ERR_NONE`, it should not set `grub_errno` to that value. Only set `grub_errno` in cases where there is error situation.

Simple exception forwarder.

```
grub_err_t
forwarding_example (void)
{
    /* Call function that might cause exception. */
    foobar ();

    /* No special exception handler, just forward possible exceptions. */
    if (grub_errno != GRUB_ERR_NONE)
    {
        return grub_errno;
    }

    /* All is OK, do more processing. */

    /* Return OK signal, to caller. */
    return GRUB_ERR_NONE;
}
```

Error reporting has two components, the actual error code (of type `grub_err_t`) and textual message that will be displayed to user. List of valid error codes is listed in header file `'include/grub/err.h'`. Textual error message can contain any textual data. At time of writing, error message can contain up to 256 characters (including terminating NUL). To ease error reporting there is a helper function `grub_error` that allows easier formatting of error messages and should be used instead of writing directly to global variables.

Example of error reporting.

```
grub_err_t
failing_example ()
{
    return grub_error (GRUB_ERR_FILE_NOT_FOUND,
                      "Failed to read %s, tried %d times.",
                      "test.txt",
```

```

        10);
    }

```

If there is a special reason that error code does not need to be taken account, `grub_errno` can be zeroed back to `GRUB_ERR_NONE`. In cases like this all previous error codes should have been handled correctly. This makes sure that there are no unhandled exceptions.

Example of zeroing `grub_errno`.

```

grub_err_t
probe_example ()
{
    /* Try to probe device type 1. */
    probe_for_device ();
    if (grub_errno == GRUB_ERR_NONE)
    {
        /* Device type 1 was found on system. */
        register_device ();
        return GRUB_ERR_NONE;
    }
    /* Zero out error code. */
    grub_errno = GRUB_ERR_NONE;

    /* No device type 1 found, try to probe device type 2. */
    probe_for_device2 ();
    if (grub_errno == GRUB_ERR_NONE)
    {
        /* Device type 2 was found on system. */
        register_device2 ();
        return GRUB_ERR_NONE;
    }
    /* Zero out error code. */
    grub_errno = GRUB_ERR_NONE;

    /* Return custom error message. */
    return grub_error (GRUB_ERR_UNKNOWN_DEVICE, "No device type 1 or 2 found.");
}

```

Some times there is a need to continue processing even if there is a error state in application. In situations like this, there is a needed to save old error state and then call other functions that might fail. To aid in this, there is a error stack implemented. Error state can be pushed to error stack by calling function `grub_error_push ()`. When processing has been completed, `grub_error_pop ()` can be used to pop error state from stack. Error stack contains predefined amount of error stack items. Error stack is protected for overflow and marks these situations so overflow error does not get unseen. If there is no space available to store error message, it is simply discarded and overflow will be marked as happened. When overflow happens, it most likely will corrupt error stack consistency as for pushed error there is no matching pop, but overflow message will be shown to inform user about the situation. Overflow message will be shown at time when prompt is about to be drawn.

Example usage of error stack.

```
/* Save possible old error message. */
grub_error_push ();

/* Do your stuff here. */
call_possibly_failing_function ();

if (grub_errno != GRUB_ERR_NONE)
{
    /* Inform rest of the code that there is error (grub_errno
       is set). There is no pop here as we want both error states
       to be displayed. */
    return;
}

/* Restore old error state by popping previous item from stack. */
grub_error_pop ();
```


7 CIA

If you have commit access, please setup CIA in your Bazaar config so those in IRC receive notification of your commits.

In `'~/bazaar/bazaar.conf'`, add `"cia_send_revno = true"`. Optionally, you can also add `"cia_user = myusername"` if you'd like CIA service to use a specific account (for statistical purpose).

In the `'bazaar/branch.conf'` of your checkout branch, `"set nickname = /path_to_this_branch"` and `"cia_project = GNU GRUB"`.

Additionally, please set `cia_send_revno` in the `[DEFAULT]` section of your `'~/bazaar/bazaar.conf'`. E.g.:

```
[DEFAULT]
cia_send_revno = true
```

Remember to install `cia-clients` (Debian/Ubuntu package) to be able to use CIA.

Keep in mind Bazaar sends notifications for all commits to branches that have this setting, regardless of whether they're bound branches (checkouts) or not. So if you make local commits in a non-bound branch and it bothers you that others can read them, do not use this setting.

8 BIOS port memory map

Start	End	Usage
0	0x1000 - 1	BIOS and real mode interrupts
0x07BE	0x07FF	Partition table passed to another boot loader
?	0x2000 - 1	Real mode stack
0x7C00	0x7D00 - 1	Boot sector
0x8000	?	GRUB kernel
0x68000	0x78000 - 1	Disk buffer
?	0x80000 - 1	Protected mode stack
0x80000	?	Heap
?	0xA0000 - 1	Extended BIOS Data Area
0xA0000	0xC0000 - 1	Video RAM
0xC0000	0x100000 - 1	BIOS
0x100000	?	Heap and module code

9 Video Subsystem

This document contains specification for Video Subsystem for GRUB2. Currently only the usage interface is described in this document. Internal structure of how video drivers are registering and how video driver manager works are not included here.

9.1 Video API

9.1.1 grub_video_setup

- Prototype:

```
grub_err_t
grub_video_setup (unsigned int width, unsigned int height, unsigned int mode_type)
```

- Description:

Driver will use information provided to it to select best possible video mode and switch to it. Supported values for `mode_type` are `GRUB_VIDEO_MODE_TYPE_INDEX_COLOR` for index color modes, `GRUB_VIDEO_MODE_TYPE_RGB` for direct RGB color modes and `GRUB_VIDEO_MODE_TYPE_DOUBLE_BUFFERED` for double buffering. When requesting RGB mode, highest bits per pixel mode will be selected. When requesting Index color mode, mode with highest number of colors will be selected. If all parameters are specified as zero, video adapter will try to figure out best possible mode and initialize it, platform specific differences are allowed here. If there is no mode matching request, error X will be returned. If there are no problems, function returns `GRUB_ERR_NONE`.

This function also performs following task upon succesful mode switch. Active rendering target is changed to screen and viewport is maximized to allow whole screen to be used when performing graphics operations. In RGB modes, emulated palette gets 16 entries containing default values for VGA palette, other colors are defined as black. When switching to Indexed Color mode, driver may set default VGA palette to screen if the video card allows the operation.

9.1.2 grub_video_restore

- Prototype:

```
grub_err_t
grub_video_restore (void);
```

- Description:

Video subsystem will deinitialize activated video driver to restore old state of video device. This can be used to switch back to text mode.

9.1.3 grub_video_get_info

- Prototype:

```
grub_err_t
grub_video_get_info (struct grub_video_mode_info *mode_info);
struct grub_video_mode_info
{
    /* Width of the screen. */
}
```

```

unsigned int width;
/* Height of the screen. */
unsigned int height;
/* Mode type bitmask. Contains information like is it Index color or
   RGB mode. */
unsigned int mode_type;
/* Bits per pixel. */
unsigned int bpp;
/* Bytes per pixel. */
unsigned int bytes_per_pixel;
/* Pitch of one scanline. How many bytes there are for scanline. */
unsigned int pitch;
/* In index color mode, number of colors. In RGB mode this is 256. */
unsigned int number_of_colors;
/* Optimization hint how binary data is coded. */
enum grub_video_blit_format blit_format;
/* How many bits are reserved for red color. */
unsigned int red_mask_size;
/* What is location of red color bits. In Index Color mode, this is 0. */
unsigned int red_field_pos;
/* How many bits are reserved for green color. */
unsigned int green_mask_size;
/* What is location of green color bits. In Index Color mode, this is 0. */
unsigned int green_field_pos;
/* How many bits are reserved for blue color. */
unsigned int blue_mask_size;
/* What is location of blue color bits. In Index Color mode, this is 0. */
unsigned int blue_field_pos;
/* How many bits are reserved in color. */
unsigned int reserved_mask_size;
/* What is location of reserved color bits. In Index Color mode,
   this is 0. */
unsigned int reserved_field_pos;
};

```

- Description:

Software developer can use this function to query properties of active rendering target. Information provided here can be used by other parts of GRUB, like image loaders to convert loaded images to correct screen format to allow more optimized blitters to be used. If there is no configured video driver with active screen, error `GRUB_ERR_BAD_DEVICE` is returned, otherwise `mode_info` is filled with valid information and `GRUB_ERR_NONE` is returned.

9.1.4 grub_video_get_blit_format

- Prototype:

```

enum grub_video_blit_format
grub_video_get_blit_format (struct grub_video_mode_info *mode_info);

```

```
enum grub_video_blit_format
{
    /* Follow exactly field & mask information. */
    GRUB_VIDEO_BLIT_FORMAT_RGBA,
    /* Make optimization assumption. */
    GRUB_VIDEO_BLIT_FORMAT_R8G8B8A8,
    /* Follow exactly field & mask information. */
    GRUB_VIDEO_BLIT_FORMAT_RGB,
    /* Make optimization assumption. */
    GRUB_VIDEO_BLIT_FORMAT_R8G8B8,
    /* When needed, decode color or just use value as is. */
    GRUB_VIDEO_BLIT_FORMAT_INDEXCOLOR
};
```

- Description:

Used to query how data could be optimized to suit specified video mode. Returns exact video format type, or a generic one if there is no definition for the type. For generic formats, use `grub_video_get_info` to query video color coding settings.

9.1.5 grub_video_set_palette

- Prototype:

```
grub_err_t
grub_video_set_palette (unsigned int start, unsigned int count, struct grub_video_
struct grub_video_palette_data
{
    grub_uint8_t r; /* Red color value (0-255). */
    grub_uint8_t g; /* Green color value (0-255). */
    grub_uint8_t b; /* Blue color value (0-255). */
    grub_uint8_t a; /* Reserved bits value (0-255). */
};
```

- Description:

Used to setup indexed color palettes. If mode is RGB mode, colors will be set to emulated palette data. In Indexed Color modes, palettes will be set to hardware. Color values will be converted to suit requirements of the video mode. **start** will tell what hardware color index (or emulated color index) will be set to according information in first indice of `palette_data`, after that both hardware color index and `palette_data` index will be incremented until **count** number of colors have been set.

9.1.6 grub_video_get_palette

- Prototype:

```
grub_err_t
grub_video_get_palette (unsigned int start, unsigned int count, struct grub_video_
struct grub_video_palette_data
{
    grub_uint8_t r; /* Red color value (0-255). */
    grub_uint8_t g; /* Green color value (0-255). */
```

```

        grub_uint8_t b; /* Blue color value (0-255). */
        grub_uint8_t a; /* Reserved bits value (0-255). */
    };

```

- Description:

Used to query indexed color palettes. If mode is RGB mode, colors will be copied from emulated palette data. In Indexed Color modes, palettes will be read from hardware. Color values will be converted to suit structure format. `start` will tell what hardware color index (or emulated color index) will be used as a source for first indice of `palette_data`, after that both hardware color index and `palette_data` index will be incremented until `count` number of colors have been read.

9.1.7 grub_video_set_viewport

- Prototype:

```

        grub_err_t
        grub_video_set_viewport (unsigned int x, unsigned int y, unsigned int width, unsigned int height);

```

- Description:

Used to specify viewport where draw commands are performed. When viewport is set, all draw commands coordinates relate to those specified by `x` and `y`. If draw commands try to draw over viewport, they are clipped. If developer requests larger than possible viewport, width and height will be clamped to fit screen. If `x` and `y` are out of bounds, all functions drawing to screen will not be displayed. In order to maximize viewport, use `grub_video_get_info` to query actual screen dimensions and provide that information to this function.

9.1.8 grub_video_get_viewport

- Prototype:

```

        grub_err_t
        grub_video_get_viewport (unsigned int *x, unsigned int *y, unsigned int *width, unsigned int *height);

```

- Description:

Used to query current viewport dimensions. Software developer can use this to choose best way to render contents of the viewport.

9.1.9 grub_video_map_color

- Prototype:

```

        grub_video_color_t
        grub_video_map_color (grub_uint32_t color_name);

```

- Description:

Map color can be used to support color themes in GRUB. There will be collection of color names that can be used to query actual screen mapped color data. Examples could be `GRUB_COLOR_CONSOLE_BACKGROUND`, `GRUB_COLOR_CONSOLE_TEXT`. The actual color defines are not specified at this point.

9.1.10 grub_video_map_rgb

- Prototype:


```

    grub_video_color_t
    grub_video_map_rgb (grub_uint8_t red, grub_uint8_t green, grub_uint8_t blue);

```

- Description:

Map RGB values to compatible screen color data. Values are expected to be in range 0-255 and in RGB modes they will be converted to screen color data. In index color modes, index color palette will be searched for specified color and then index is returned.

9.1.11 grub_video_map_rgba

- Prototype:

```

    grub_video_color_t
    grub_video_map_rgba (grub_uint8_t red, grub_uint8_t green, grub_uint8_t blue, grub_uint8_t alpha);

```

- Description:

Map RGBA values to compatible screen color data. Values are expected to be in range 0-255. In RGBA modes they will be converted to screen color data. In index color modes, index color palette will be searched for best matching color and its index is returned.

9.1.12 grub_video_unmap_color

- Prototype:

```

    grub_err_t
    grub_video_unmap_color (grub_video_color_t color, grub_uint8_t *red, grub_uint8_t *green, grub_uint8_t *blue, grub_uint8_t *alpha);

```

- Description:

Unmap color value from `color` to color channels in `red`, `green`, `blue` and `alpha`. Values will be in range 0-255. Active rendering target will be used for color domain. In case alpha information is not available in rendering target, it is assumed to be opaque (having value 255).

9.1.13 grub_video_fill_rect

- Prototype:

```

    grub_err_t
    grub_video_fill_rect (grub_video_color_t color, int x, int y, unsigned int width, unsigned int height);

```

- Description:

Fill specified area limited by given coordinates within specified viewport. Negative coordinates are accepted in order to allow easy moving of rectangle within viewport. If coordinates are negative, area of the rectangle will be shrinken to follow size limits of the viewport.

Software developer should use either `grub_video_map_color`, `grub_video_map_rgb` or `grub_video_map_rgba` to map requested color to `color` parameter.

9.1.14 grub_video_blit_glyph

- Prototype:

```

    grub_err_t
    grub_video_blit_glyph (struct grub_font_glyph *glyph, grub_video_color_t color, int x, int y, unsigned int width, unsigned int height);

```

```

    struct grub_font_glyph {
        /* TBD. */
    };

```

- Description:

Used to blit glyph to viewport in specified coordinates. If glyph is at edge of viewport, pixels outside of viewport will be clipped out. Software developer should use either `grub_video_map_rgb` or `grub_video_map_rgba` to map requested color to color parameter.

9.1.15 `grub_video_blit_bitmap`

- Prototype:

```

grub_err_t
grub_video_blit_bitmap (struct grub_video_bitmap *bitmap, enum grub_video_blit_oper
struct grub_video_bitmap
{
    /* TBD. */
};

enum grub_video_blit_operators
{
    GRUB_VIDEO_BLIT_REPLACE,
    GRUB_VIDEO_BLIT_BLEND
};

```

- Description:

Used to blit bitmap to viewport in specified coordinates. If part of bitmap is outside of viewport region, it will be clipped out. Offsets affect bitmap position where data will be copied from. Negative values for both viewport coordinates and bitmap offset coordinates are allowed. If data is looked out of bounds of bitmap, color value will be assumed to be transparent. If viewport coordinates are negative, area of the blitted rectangle will be shrinken to follow size limits of the viewport and bitmap. Blitting operator `oper` specifies should source pixel replace data in screen or blend with pixel alpha value.

Software developer should use `grub_video_bitmap_create` or `grub_video_bitmap_load` to create or load bitmap data.

9.1.16 `grub_video_blit_render_target`

- Prototype:

```

grub_err_t
grub_video_blit_render_target (struct grub_video_render_target *source, enum grub_v
struct grub_video_render_target {
    /* This is private data for video driver. Should not be accessed from elsewhere
};

enum grub_video_blit_operators
{

```

```

        GRUB_VIDEO_BLIT_REPLACE,
        GRUB_VIDEO_BLIT_BLEND
    };

```

- Description:

Used to blit source render target to viewport in specified coordinates. If part of source render target is outside of viewport region, it will be clipped out. If blitting operator is specified and source contains alpha values, resulting pixel color components will be calculated using formula $((src_color * src_alpha) + (dst_color * (255 - src_alpha)) / 255$, if target buffer has alpha, it will be set to `src_alpha`. Offsets affect render target position where data will be copied from. If data is looked out of bounds of render target, color value will be assumed to be transparent. Blitting operator `oper` specifies should source pixel replace data in screen or blend with pixel alpha value.

9.1.17 grub_video_scroll

- Prototype:

```

grub_err_t
grub_video_scroll (grub_video_color_t color, int dx, int dy);

```

- Description:

Used to scroll viewport to specified direction. New areas are filled with specified color. This function is used when screen is scroller up in video terminal.

9.1.18 grub_video_swap_buffers

- Prototype:

```

grub_err_t
grub_video_swap_buffers (void);

```

- Description:

If double buffering is enabled, this swaps frontbuffer and backbuffer, in order to show values drawn to back buffer. Video driver is free to choose how this operation is technically done.

9.1.19 grub_video_create_render_target

- Prototype:

```

grub_err_t
grub_video_create_render_target (struct grub_video_render_target **result, unsigned
struct grub_video_render_target {
    /* This is private data for video driver. Should not be accessed from elsewhere
};

```

- Description:

Driver will use information provided to it to create best fitting render target. `mode_type` will be used to guide on selecting what features are wanted for render target. Supported values for `mode_type` are `GRUB_VIDEO_MODE_TYPE_INDEX_COLOR` for index color modes, `GRUB_VIDEO_MODE_TYPE_RGB` for direct RGB color modes and `GRUB_VIDEO_MODE_TYPE_ALPHA` for alpha component.

9.1.20 grub_video_delete_render_target

- Prototype:

```
grub_err_t
grub_video_delete_render_target (struct grub_video_render_target *target);
```

- Description:

Used to delete previously created render target. If `target` contains NULL pointer, nothing will be done. If render target is correctly destroyed, GRUB_ERR_NONE is returned.

9.1.21 grub_video_set_active_render_target

- Prototype:

```
grub_err_t
grub_video_set_active_render_target (struct grub_video_render_target *target);
```

- Description:

Sets active render target. If this comand is successful all drawing commands will be done to specified `target`. There is also special values for target, GRUB_VIDEO_RENDER_TARGET_DISPLAY used to reference screen's front buffer, GRUB_VIDEO_RENDER_TARGET_FRONT_BUFFER used to reference screen's front buffer (alias for GRUB_VIDEO_RENDER_TARGET_DISPLAY) and GRUB_VIDEO_RENDER_TARGET_BACK_BUFFER used to reference back buffer (if double buffering is enabled). If render target is correclty switched GRUB_ERR_NONE is returned. In no any event shall there be non drawable active render target.

9.1.22 grub_video_get_active_render_target

- Prototype:

```
grub_err_t
grub_video_get_active_render_target (struct grub_video_render_target **target);
```

- Description:

Returns currently active render target. It returns value in `target` that can be subsequently issued back to `grub_video_set_active_render_target`.

9.2 Example usage of Video API

9.2.1 Example of screen setup

```
grub_err_t rc;
/* Try to initialize video mode 1024 x 768 with direct RGB. */
rc = grub_video_setup (1024, 768, GRUB_VIDEO_MODE_TYPE_RGB);
if (rc != GRUB_ERR_NONE)
{
    /* Fall back to standard VGA Index Color mode. */
    rc = grub_video_setup (640, 480, GRUB_VIDEO_MODE_TYPE_INDEX);
    if (rc != GRUB_ERR_NONE)
    {
        /* Handle error. */
    }
}
```

```

    }
}

```

9.2.2 Example of setting up console viewport

```

grub_uint32_t x, y, width, height;
grub_video_color_t color;
struct grub_font_glyph glyph;
grub_err_t rc;
/* Query existing viewport. */
grub_video_get_viewport (&x, &y, &width, &height);
/* Fill background. */
color = grub_video_map_color (GRUB_COLOR_BACKGROUND);
grub_video_fill_rect (color, 0, 0, width, height);
/* Setup console viewport. */
grub_video_set_viewport (x + 10, y + 10, width - 20, height - 20);
grub_video_get_viewport (&x, &y, &width, &height);
color = grub_video_map_color (GRUB_COLOR_CONSOLE_BACKGROUND);
grub_video_fill_rect (color, 0, 0, width, height);
/* Draw text to viewport. */
color = grub_video_map_color (GRUB_COLOR_CONSOLE_TEXT);
grub_font_get_glyph ('X', &glyph);
grub_video_blit_glyph (&glyph, color, 0, 0);

```

9.3 Bitmap API

9.3.1 grub_video_bitmap_create

- Prototype:

```
grub_err_t grub_video_bitmap_create (struct grub_video_bitmap **bitmap, unsigned int width, unsigned int height, grub_video_color_t color);
```

- Description:

Creates a new bitmap with given dimensions and blitting format. Allocated bitmap data can then be modified freely and finally blitted with `grub_video_blit_bitmap` to rendering target.

9.3.2 grub_video_bitmap_destroy

- Prototype:

```
grub_err_t grub_video_bitmap_destroy (struct grub_video_bitmap *bitmap);
```

- Description:

When bitmap is no longer needed, it can be freed from memory using this command. `bitmap` is previously allocated bitmap with `grub_video_bitmap_create` or loaded with `grub_video_bitmap_load`.

9.3.3 grub_video_bitmap_load

- Prototype:

```
grub_err_t grub_video_bitmap_load (struct grub_video_bitmap **bitmap, const char *filename);
```

- Description:
Tries to load given bitmap (`filename`) using registered bitmap loaders. In case bitmap format is not recognized or supported error `GRUB_ERR_BAD_FILE_TYPE` is returned.

9.3.4 grub_video_bitmap_get_width

- Prototype:

```
unsigned int grub_video_bitmap_get_width (struct grub_video_bitmap *bitmap);
```
- Description:
Returns bitmap width.

9.3.5 grub_video_bitmap_get_height

- Prototype:

```
unsigned int grub_video_bitmap_get_height (struct grub_video_bitmap *bitmap);
```
- Description:
Return bitmap height.

9.3.6 grub_video_bitmap_get_mode_info

- Prototype:

```
void grub_video_bitmap_get_mode_info (struct grub_video_bitmap *bitmap, struct grub_video_mode_info *mode_info);
```
- Description:
Returns bitmap format details in form of `grub_video_mode_info`.

9.3.7 grub_video_bitmap_get_data

- Prototype:

```
void *grub_video_bitmap_get_data (struct grub_video_bitmap *bitmap);
```
- Description:
Return pointer to bitmap data. Contents of the pointed data can be freely modified. There is no extra protection against going off the bounds so you have to be carefull how to access the data.

10 PFF2 Font File Format

10.1 Introduction

The goal of this format is to provide a bitmap font format that is simple to use, compact, and cleanly supports Unicode.

10.1.1 Goals of the GRUB Font Format

- Simple to read and use. Since GRUB will only be reading the font files, we are more concerned with making the code to read the font simple than we are with writing the font.
- Compact storage. The fonts will generally be stored in a small boot partition where GRUB is located, and this may be on a removable storage device such as a CD or USB flash drive where space is more limited than it is on most hard drives.
- Unicode. GRUB should not have to deal with multiple character encodings. The font should always use Unicode character codes for simple internationalization.

10.1.2 Why Another Font Format?

There are many existing bitmap font formats that GRUB could use. However, there are aspects of these formats that may make them less than suitable for use in GRUB at this time:

- ‘BDF’ Inefficient storage; uses ASCII to describe properties and hexadecimal numbers in ASCII for the bitmap rows.
- ‘PCF’ Many format variations such as byte order and bitmap padding (rows padded to byte, word, etc.) would result in more complex code to handle the font format.

10.2 File Structure

A file **section** consists of a 4-byte name, a 32-bit big-endian length (not including the name or length), and then *length* more section-type-specific bytes.

The standard file extension for PFF2 font files is ‘.pf2’.

10.2.1 Section Types

- ‘FILE’ **File type ID** (ASCII string). This must be the first section in the file. It has length 4 and the contents are the four bytes of the ASCII string ‘PFF2’.
- ‘NAME’ **Font name** (ASCII string). This is the full font name including family, weight, style, and point size. For instance, "Helvetica Bold Italic 14".
- ‘FAMI’ **Font family name** (ASCII string). For instance, "Helvetica". This should be included so that intelligent font substitution can take place.
- ‘WEIG’ **Font weight** (ASCII string). Valid values are ‘bold’ and ‘normal’. This should be included so that intelligent font substitution can take place.
- ‘SLAN’ **Font slant** (ASCII string). Valid values are ‘italic’ and ‘normal’. This should be included so that intelligent font substitution can take place.

'PTSZ'	Font point size (uint16be).
'MAXW'	Maximum character width in pixels (uint16be).
'MAXH'	Maximum character height in pixels (uint16be).
'ASCE'	Ascent in pixels (uint16be). See Section 10.3 [Font Metrics] , page 37, for details.
'DESC'	Descent in pixels (uint16be). See Section 10.3 [Font Metrics] , page 37, for details.
'CHIX'	Character index. The character index begins with a 32-bit big-endian unsigned integer indicating the total size of the section, not including this size value. For each character, there is an instance of the following entry structure:

- **Unicode code point.** (32-bit big-endian integer.)
- **Storage flags.** (byte.)
 - Bits 2..0:

If equal to 000 binary, then the character data is stored uncompressed beginning at the offset indicated by the character's **offset** value.

If equal to 001 binary, then the character data is stored within a compressed character definition block that begins at the offset within the file indicated by the character's **offset** value.
- **Offset.** (32-bit big-endian integer.)

A marker that indicates the remainder of the file is data accessed via the character index (CHIX) section. When reading this font file, the rest of the file can be ignored when scanning the sections. The length should be set to -1 (0xFFFFFFFF).

Supported data structures:

Character definition Each character definition consists of:

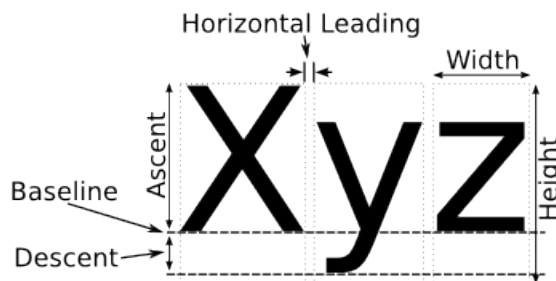
- **Width.** Width of the bitmap in pixels. The bitmap's extents represent the glyph's bounding box. **uint16be**.
- **Height.** Height of the bitmap in pixels. The bitmap's extents represent the glyph's bounding box. **uint16be**.
- **X offset.** The number of pixels to shift the bitmap by horizontally before drawing the character. **int16be**.
- **Y offset.** The number of pixels to shift the bitmap by vertically before drawing the character. **int16be**.
- **Device width.** The number of pixels to advance horizontally from this character's origin to the origin of the next character. **int16be**.
- **Bitmap data.** This is encoded as a string of bits. It is organized as a row-major, top-down, left-to-right bitmap. The most significant bit of each byte is taken to be the leftmost or uppermost bit in the byte. For the sake of compact storage, rows are not padded to byte boundaries (i.e., a single byte may contain bits belonging to multiple rows). The last byte of the bitmap **is** padded with zero bits in the bits positions to the right of the last used bit if the bitmap data does not fill the last byte.

The length of the **bitmap data** field is $(width * height + 7) / 8$ using integer arithmetic, which is equivalent to $\text{ceil}(width * height / 8)$ using real number arithmetic.

It remains to be determined whether bitmap fonts usually make all glyph bitmaps the same height, or if smaller glyphs are stored with bitmaps having a lesser height. In the latter case, the baseline would have to be used to calculate the location the bitmap should be anchored at on screen.

10.3 Font Metrics

- **Ascent.** The distance from the baseline to the top of most characters. Note that in some cases characters may extend above the ascent.
- **Descent.** The distance from the baseline to the bottom of most characters. Note that in some cases characters may extend below the descent.
- **Leading.** The amount of space, in pixels, to leave between the descent of one line of text and the ascent of the next line. This metrics is not specified in the current file format; instead, the font rendering engine calculates a reasonable leading value based on the other font metrics.
- **Horizontal leading.** The amount of space, in pixels, to leave horizontally between the left and right edges of two adjacent glyphs. The **device width** field determines the effective leading value that is used to render the font.



An illustration of how the various font metrics apply to characters.

11 Graphical Menu Software Design

11.1 Introduction

The ‘`gfxmenu`’ module provides a graphical menu interface for GRUB 2. It functions as an alternative to the menu interface provided by the ‘`normal`’ module, which uses the grub terminal interface to display a menu on a character-oriented terminal.

The graphical menu uses the GRUB video API, which is currently for the VESA BIOS extensions (VBE) 2.0+. This is supported on the i386-pc platform. However, the graphical menu itself does not depend on using VBE, so if another GRUB video driver were implemented, the ‘`gfxmenu`’ graphical menu would work on the new video driver as well.

11.2 Startup Sequence

- `grub_enter_normal_mode` [`normal/main.c`]
- `grub_normal_execute` [`normal/main.c`]
- `read_config_file` [`normal/main.c`]
- (When ‘`gfxmenu.mod`’ is loaded with `insmod`, it will call `grub_menu_viewer_register()` to register itself.)
- `GRUB_MOD_INIT` (`gfxmenu`) [`gfxmenu/gfxmenu.c`]
- `grub_menu_viewer_register` [`kern/menu_viewer.c`]
- `grub_menu_viewer_show_menu` [`kern/menu_viewer.c`]
- `get_current_menu_viewer()` [`kern/menu_viewer.c`]
- `show_menu()` [`gfxmenu/gfxmenu.c`]
- `grub_gfxmenu_model_new` [`gfxmenu/model.c`]
- `grub_gfxmenu_view_new` [`gfxmenu/view.c`]
- `set_graphics_mode` [`gfxmenu/view.c`]
- `grub_gfxmenu_view_load_theme` [`gfxmenu/theme_loader.c`]

11.3 GUI Components

The graphical menu implements a GUI component system that supports a container-based layout system. Components can be added to containers, and containers (which are a type of component) can then be added to other containers, to form a tree of components. Currently, the root component of this tree is a ‘`canvas`’ component, which allows manual layout of its child components.

Components (non-container):

- `label`
- `image`
- `progress_bar`
- `circular_progress`
- `list` (currently hard coded to be a boot menu list)

Containers:

- `canvas`
- `hbox`
- `vbox`

The GUI component instances are created by the theme loader in `'gfxmenu/theme_loader.c'` when a theme is loaded. Theme files specify statements such as `'+vbox{ +label { text="Hello" } +label{ text="World" } }'` to add components to the component tree root. By nesting the component creation statements in the theme file, the instantiated components are nested the same way.

When a component is added to a container, that new child is considered **owned** by the container. Great care should be taken if the caller retains a reference to the child component, since it will be destroyed if its parent container is destroyed. A better choice instead of storing a pointer to the child component is to use the component ID to find the desired component. Component IDs do not have to be unique (it is often useful to have multiple components with an ID of `"_timeout_"`, for instance).

In order to access and use components in the component tree, there are two functions (defined in `'gfxmenu/gui_util.c'`) that are particularly useful:

- `grub_gui_find_by_id (root, id, callback, userdata):`

This function recursively traverses the component tree rooted at *root*, and for every component that has an ID equal to *id*, calls the function pointed to by *callback* with the matching component and the void pointer *userdata* as arguments. The callback function can do whatever is desired to use the component passed in.

- `grub_gui_iterate_recursively (root, callback, userdata):`

This function calls the function pointed to by *callback* for every component that is a descendant of *root* in the component tree. When the callback function is called, the component and the void pointer *userdata* as arguments. The callback function can do whatever is desired to use the component passed in.

11.4 Command Line Window

The terminal window used to provide command line access within the graphical menu is managed by `'gfxmenu/view.c'`. The `'gfxterm'` terminal is used, and it has been modified to allow rendering to an offscreen render target to allow it to be composed into the double buffering system that the graphical menu view uses. This is bad for performance, however, so it would probably be a good idea to make it possible to temporarily disable double buffering as long as the terminal window is visible. There are still unresolved problems that occur when commands are executed from the terminal window that change the graphics mode. It's possible that making `grub_video_restore()` return to the graphics mode that was in use before `grub_video_setup()` was called might fix some of the problems.

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