Writing an OS in Rust Philipp Oppermann's blog

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A Minimal Rust Kernel

Feb 10, 2018

In this post we create a minimal 64-bit Rust kernel for the x86 architecture. We build upon the freestanding Rust binary from the previous post to create a bootable disk image, that prints something to the screen.

This blog is openly developed on GitHub. If you have any problems or questions, please open an issue there. You can also leave comments at the bottom. The complete source code for this post can be found in the `post-02` branch.

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The Boot Process

When you turn on a computer, it begins executing firmware code that is stored in motherboard ROM. This code performs a power-on self-test, detects available RAM, and pre-initializes the CPU and hardware. Afterwards it looks for a bootable disk and starts booting the operating system kernel.

On x86, there are two firmware standards: the "Basic Input/Output System" (**BIOS**) and the newer "Unified Extensible Firmware Interface" (**UEFI**). The BIOS standard is old and outdated, but simple and well-supported on any x86 machine since the 1980s. UEFI, in contrast, is more modern and has much more features, but is more complex to set up (at least in my opinion).

Currently, we only provide BIOS support, but support for UEFI is planned, too. If you'd like to help us with this, check out the Github issue.

BIOS Boot

Almost all x86 systems have support for BIOS booting, including newer UEFI-based machines that use an emulated BIOS. This is great, because you can use the same boot logic across all machines from the last centuries. But this wide compatibility is at the same time the biggest disadvantage of BIOS booting, because it means that the CPU is put into a 16-bit compatibility mode called real mode before booting so that archaic bootloaders from the 1980s would still work.

But let's start from the beginning:

When you turn on a computer, it loads the BIOS from some special flash memory located on the motherboard. The BIOS runs self test and initialization routines of the hardware, then it looks for bootable disks. If it finds one, the control is transferred to its *bootloader*, which is a 512-byte portion of executable code stored at the disk's beginning. Most bootloaders are larger than 512 bytes, so bootloaders are commonly split into a small first stage, which fits into 512 bytes, and a second stage, which is subsequently loaded by the first stage.

The bootloader has to determine the location of the kernel image on the disk and load it into memory. It also needs to switch the CPU from the 16-bit real mode first to the 32-bit protected mode, and then to the 64-bit long mode, where 64-bit registers and the complete main memory are available. Its third job is to query certain information (such as a memory map) from the BIOS and pass it to the OS kernel.

Writing a bootloader is a bit cumbersome as it requires assembly language and a lot of non insightful steps like “write this magic value to this processor register”. Therefore we don't cover bootloader creation in this post and instead provide a tool named bootimage that automatically prepends a bootloader to your kernel.

If you are interested in building your own bootloader: Stay tuned, a set of posts on this topic is already planned!

The Multiboot Standard

To avoid that every operating system implements its own bootloader, which is only compatible with a single OS, the Free Software Foundation created an open bootloader standard called Multiboot in 1995. The standard defines an interface between the bootloader and operating system, so that any Multiboot compliant bootloader can load any Multiboot compliant operating system. The reference implementation is GNU GRUB, which is the most popular bootloader for Linux systems.

To make a kernel Multiboot compliant, one just needs to insert a so-called Multiboot header at the beginning of the kernel file. This makes it very easy to boot an OS in GRUB. However, GRUB and the Multiboot standard have some problems too:

- They support only the 32-bit protected mode. This means that you still have to do the CPU configuration to switch to the 64-bit long mode.
- They are designed to make the bootloader simple instead of the kernel. For example, the kernel needs to be linked with an adjusted default page size, because GRUB can't find the Multiboot header otherwise. Another example is that the boot information, which is passed to the kernel, contains lots of architecture dependent structures instead of providing clean abstractions.
- Both GRUB and the Multiboot standard are only sparsely documented.

- GRUB needs to be installed on the host system to create a bootable disk image from the kernel file. This makes development on Windows or Mac more difficult.

Because of these drawbacks we decided to not use GRUB or the Multiboot standard. However, we plan to add Multiboot support to our bootimage tool, so that it's possible to load your kernel on a GRUB system too. If you're interested in writing a Multiboot compliant kernel, check out the first edition of this blog series.

UEFI

(We don't provide UEFI support at the moment, but we would love to! If you'd like to help, please tell us in the Github issue.)

A Minimal Kernel

Now that we roughly know how a computer boots, it's time to create our own minimal kernel. Our goal is to create a disk image that prints a “Hello World!” to the screen when booted. For that we build upon the freestanding Rust binary from the previous post.

As you may remember, we built the freestanding binary through `cargo`, but depending on the operating system we needed different entry point names and compile flags. That's because `cargo` builds for the *host system* by default, i.e. the system you're running on. This isn't something we want for our kernel, because a kernel that runs on top of e.g. Windows does not make much sense. Instead, we want to compile for a clearly defined *target system*.

Installing Rust Nightly

Rust has three release channels: *stable*, *beta*, and *nightly*. The Rust Book explains the difference between these channels really well, so take a minute and check it out. For building an operating system we will need some experimental features that are only available on the nightly channel, so we need to install a nightly version of Rust.

To manage Rust installations I highly recommend rustup. It allows you to install nightly, beta, and stable compilers side-by-side and makes it easy to update them. With rustup you can use a nightly compiler for the current directory by running `rustup override set nightly`. Alternatively, you can add a file called `rust-toolchain` with the content `nightly` to the project's root directory. You can check that you have a nightly version installed by running `rustc --version`: The version number should contain `-nightly` at the end.

The nightly compiler allows us to opt-in to various experimental features by using so-called *feature flags* at the top of our file. For example, we could enable the experimental `asm!` macro for inline assembly by adding `#![feature(asm)]` to the top of our `main.rs`. Note that such experimental features are completely unstable, which means that future Rust versions might change or remove them without prior warning. For this reason we will only use them if absolutely necessary.

Target Specification

Cargo supports different target systems through the `--target` parameter. The target is described by a so-called *target triple*, which describes the CPU architecture, the vendor, the operating system, and the ABI. For example, the `x86_64-unknown-linux-gnu` target triple describes a system with a `x86_64` CPU, no clear vendor and a Linux operating system with the GNU ABI. Rust supports many different target triples, including `arm-linux-androideabi` for Android or `wasm32-unknown-unknown` for WebAssembly.

For our target system, however, we require some special configuration parameters (e.g. no underlying OS), so none of the existing target triples fits. Fortunately, Rust allows us to define our own target through a JSON file. For example, a JSON file that describes the `x86_64-unknown-linux-gnu` target looks like this:

```
{
    "llvm-target": "x86_64-unknown-linux-gnu",
    "data-layout": "e-m:e-i64:64-f80:128-n8:16:32:64-S128",
    "arch": "x86_64",
    "target-endian": "little",
    "target-pointer-width": "64",
    "target-c-int-width": "32",
    "os": "linux",
    "executables": true,
    "linker-flavor": "gcc",
    "pre-link-args": ["-m64"],
    "morestack": false
}
```

Most fields are required by LLVM to generate code for that platform. For example, the `data-layout` field defines the size of various integer, floating point, and pointer types. Then there are fields that Rust uses for conditional compilation, such as `target-pointer-width`. The third kind of fields define how the crate should be built. For example, the `pre-link-args` field specifies arguments passed to the linker.

We also target `x86_64` systems with our kernel, so our target specification will look very similar to the one above. Let's start by creating a `x86_64-blog_os.json` file (choose any name you like) with the common content:

```
{
    "llvm-target": "x86_64-unknown-none",
    "data-layout": "e-m:e-i64:64-f80:128-n8:16:32:64-S128",
    "arch": "x86_64",
```

```
    "target-endian": "little",
    "target-pointer-width": "64",
    "target-c-int-width": "32",
    "os": "none",
    "executables": true
}
```

Note that we changed the OS in the `llvm-target` and the `os` field to `none`, because we will run on bare metal.

We add the following build-related entries:

```
"linker-flavor": "ld.lld",
"linker": "rust-lld",
```

Instead of using the platform's default linker (which might not support Linux targets), we use the cross platform LLD linker that is shipped with Rust for linking our kernel.

```
"panic-strategy": "abort",
```

This setting specifies that the target doesn't support stack unwinding on panic, so instead the program should abort directly. This has the same effect as the `panic = "abort"` option in our Cargo.toml, so we can remove it from there. (Note that in contrast to the Cargo.toml option, this target option also applies when we recompile the `core` library later in this post. So be sure to add this option, even if you prefer to keep the Cargo.toml option.)

```
"disable-redzone": true,
```

We're writing a kernel, so we'll need to handle interrupts at some point. To do that safely, we have to disable a certain stack pointer optimization called the *"red zone"*, because it would cause stack corruptions otherwise. For more information, see our separate post about disabling the red zone.

```
"features": "-mmx,-sse,+soft-float",
```

The `features` field enables/disables target features. We disable the `mmx` and `sse` features by prefixing them with a minus and enable the `soft-float` feature by prefixing it with a plus. Note that there must be no spaces between different flags, otherwise LLVM fails to interpret the features string.

The `mmx` and `sse` features determine support for Single Instruction Multiple Data (SIMD) instructions, which can often speed up programs significantly. However, using the large SIMD registers in OS kernels leads to performance problems. The reason is that the kernel needs to restore all registers to their original state before continuing an interrupted program. This means that the kernel has to save the complete SIMD state to main memory on each system call or hardware interrupt. Since the SIMD state is very large (512–1600 bytes) and interrupts can occur very often, these additional save/restore operations considerably harm performance. To avoid this, we disable SIMD for our kernel (not for applications running on top!).

A problem with disabling SIMD is that floating point operations on `x86_64` require SIMD registers by default. To solve this problem, we add the `soft-float` feature, which emulates all floating point operations through software functions based on normal integers.

For more information, see our post on disabling SIMD.

Putting it Together

Our target specification file now looks like this:

```
{
  "llvm-target": "x86_64-unknown-none",
  "data-layout": "e-m:e-i64:64-f80:128-n8:16:32:64-S128",
  "arch": "x86_64",
  "target-endian": "little",
  "target-pointer-width": "64",
  "target-c-int-width": "32",
  "os": "none",
  "executables": true,
  "linker-flavor": "ld.lld",
  "linker": "rust-lld",
  "panic-strategy": "abort",
  "disable-redzone": true,
  "features": "-mmx,-sse,+soft-float"
}
```

Building our Kernel

Compiling for our new target will use Linux conventions (I'm not quite sure why, I assume that it's just LLVM's default). This means that we need an entry point named `_start` as described in the previous post:

```
// src/main.rs

#![no_std] // don't link the Rust standard library
#![no_main] // disable all Rust-level entry points

use core::panic::PanicInfo;

/// This function is called on panic.
#[panic_handler]
fn panic(_info: &PanicInfo) -> ! {
```

```
    loop {}
}

#[no_mangle] // don't mangle the name of this function
pub extern "C" fn _start() -> ! {
    // this function is the entry point, since the linker looks for a function
    // named `_start` by default
    loop {}
}
```

Note that the entry point needs to be called `_start` regardless of your host OS.

We can now build the kernel for our new target by passing the name of the JSON file as `--target`:

```
> cargo build --target x86_64-blog_os.json

error[E0463]: can't find crate for `core`
```

It fails! The error tells us that the Rust compiler no longer finds the `core` library. This library contains basic Rust types such as `Result`, `Option`, and iterators, and is implicitly linked to all `no_std` crates.

The problem is that the core library is distributed together with the Rust compiler as a *precompiled* library. So it is only valid for supported host triples (e.g., `x86_64-unknown-linux-gnu`) but not for our custom target. If we want to compile code for other targets, we need to recompile `core` for these targets first.

The `build-std` Option

That's where the `build-std` feature of cargo comes in. It allows to recompile `core` and other standard library crates on demand, instead of using the precompiled versions shipped with the Rust installation. This feature is very new and still not finished, so it is marked as "unstable" and only available on nightly Rust compilers.

To use the feature, we need to create a cargo configuration file at `.cargo/config.toml` with the following content:

```
# in .cargo/config.toml

[unstable]
build-std = ["core", "compiler_builtins"]
```

This tells cargo that it should recompile the `core` and `compiler_builtins` libraries. The latter is required because it is a dependency of `core`. In order to recompile these libraries, cargo needs access to the rust source code, which we can install with `rustup component add rust-src`.

> **Note:** The `unstable.build-std` configuration key requires at least the Rust nightly from 2020-07-15.

After setting the `unstable.build-std` configuration key and installing the `rust-src` component, we can rerun the our build command:

```
> cargo build --target x86_64-blog_os.json
   Compiling core v0.0.0 (/…/rust/src/libcore)
   Compiling rustc-std-workspace-core v1.99.0 (/…/rust/src/tools/rustc-std-workspac
   Compiling compiler_builtins v0.1.32
   Compiling blog_os v0.1.0 (/…/blog_os)
    Finished dev [unoptimized + debuginfo] target(s) in 0.29 secs
```

We see that `cargo build` now recompiles the `core`, `rustc-std-workspace-core` (a dependency of `compiler_builtins`), and `compiler_builtins` libraries for our custom target.

Memory-Related Intrinsics

The Rust compiler assumes that a certain set of built-in functions is available for all systems. Most of these functions are provided by the `compiler_builtins` crate that we just recompiled. However, there are some memory-related functions in that crate that are not enabled by default because they are normally provided by the C library on the system. These functions include `memset`, which sets all bytes in a memory block to a given value, `memcpy`, which copies one memory block to another, and `memcmp`, which compares two memory blocks. While we didn't need any of these functions to compile our kernel right now, they will be required as soon as we add some more code to it (e.g. when copying structs around).

Since we can't link to the C library of the operating system, we need an alternative way to provide these functions to the compiler. One possible approach for this could be to implement our own `memset` etc. functions and apply the `#[no_mangle]` attribute to them (to avoid the automatic renaming during compilation). However, this is dangerous since the slightest mistake in the implementation of these functions could lead to undefined behavior. For example, you might get an endless recursion when implementing `memcpy` using a `for` loop because `for` loops implicitly call the `IntoIterator::into_iter` trait method, which might call `memcpy` again. So it's a good idea to reuse existing well-tested implementations instead.

Fortunately, the `compiler_builtins` crate already contains implementations for all the needed functions, they are just disabled by default to not collide with the implementations from the C library. We can enable them by setting cargo's `build-std-features` flag to `["compiler-`

builtins-mem"]`. Like the `build-std` flag, this flag can be either passed on the command line as `-Z` flag or configured in the `unstable` table in the `.cargo/config.toml` file. Since we always want to build with this flag, the config file option makes more sense for us:

```
# in .cargo/config.toml

[unstable]
build-std-features = ["compiler-builtins-mem"]
build-std = ["core", "compiler_builtins"]
```

(Support for the `compiler-builtins-mem` feature was only added very recently, so you need at least Rust nightly `2020-09-30` for it.)

Behind the scenes, this flag enables the `mem` feature of the `compiler_builtins` crate. The effect of this is that the `#[no_mangle]` attribute is applied to the `memcpy` etc. implementations of the crate, which makes them available to the linker.

With this change, our kernel has valid implementations for all compiler-required functions, so it will continue to compile even if our code gets more complex.

Set a Default Target

To avoid passing the `--target` parameter on every invocation of `cargo build`, we can override the default target. To do this, we add the following to our cargo configuration file at `.cargo/config.toml`:

```
# in .cargo/config.toml

[build]
target = "x86_64-blog_os.json"
```

This tells `cargo` to use our `x86_64-blog_os.json` target when no explicit `--target` argument is passed. This means that we can now build our kernel with a simple `cargo build`. For more information on cargo configuration options, check out the official documentation.

We are now able to build our kernel for a bare metal target with a simple `cargo build`. However, our `_start` entry point, which will be called by the boot loader, is still empty. It's time that we output something to screen from it.

Printing to Screen

The easiest way to print text to the screen at this stage is the VGA text buffer. It is a special memory area mapped to the VGA hardware that contains the contents displayed on screen. It normally consists of 25 lines that each contain 80 character cells. Each character cell displays an ASCII character with some foreground and background colors. The screen output looks like this:

We will discuss the exact layout of the VGA buffer in the next post, where we write a first small driver for it. For printing “Hello World!”, we just need to know that the buffer is located at address `0xb8000` and that each character cell consists of an ASCII byte and a color byte.

The implementation looks like this:

```
static HELLO: &[u8] = b"Hello World!";

#[no_mangle]
pub extern "C" fn _start() -> ! {
    let vga_buffer = 0xb8000 as *mut u8;

    for (i, &byte) in HELLO.iter().enumerate() {
        unsafe {
            *vga_buffer.offset(i as isize * 2) = byte;
            *vga_buffer.offset(i as isize * 2 + 1) = 0xb;
        }
    }

    loop {}
}
```

First, we cast the integer `0xb8000` into a raw pointer. Then we iterate over the bytes of the static `HELLO` byte string. We use the `enumerate` method to additionally get a running variable `i`. In the body of the for loop, we use the `offset` method to write the string byte and the corresponding color byte (`0xb` is a light cyan).

Note that there's an `unsafe` block around all memory writes. The reason is that the Rust compiler can't prove that the raw pointers we create are valid. They could point anywhere and lead to data corruption. By putting them into an `unsafe` block we're basically telling the compiler that we are absolutely sure that the operations are valid. Note that an `unsafe` block does not turn off Rust's safety checks. It only allows you to do five additional things.

I want to emphasize that **this is not the way we want to do things in Rust!** It's very easy to mess up when working with raw pointers inside unsafe blocks, for example, we could easily write beyond the buffer's end if we're not careful.

So we want to minimize the use of `unsafe` as much as possible. Rust gives us the ability to do this by creating safe abstractions. For example, we could create a VGA buffer type that encapsulates all unsafety and ensures that it is *impossible* to do anything wrong from the outside. This way, we would only need minimal amounts of `unsafe` and can be sure that we don't violate memory safety. We will create such a safe VGA buffer abstraction in the next post.

Running our Kernel

Now that we have an executable that does something perceptible, it is time to run it. First, we need to turn our compiled kernel into a bootable disk image by linking it with a bootloader. Then we can run the disk image in the QEMU virtual machine or boot it on real hardware using a USB stick.

Creating a Bootimage

To turn our compiled kernel into a bootable disk image, we need to link it with a bootloader. As we learned in the section about booting, the bootloader is responsible for initializing the CPU and loading our kernel.

Instead of writing our own bootloader, which is a project on its own, we use the `bootloader` crate. This crate implements a basic BIOS bootloader without any C dependencies, just Rust and inline assembly. To use it for booting our kernel, we need to add a dependency on it:

```
# in Cargo.toml

[dependencies]
bootloader = "0.9.8"
```

Adding the bootloader as dependency is not enough to actually create a bootable disk image. The problem is that we need to link our kernel with the bootloader after compilation, but cargo has no support for post-build scripts.

To solve this problem, we created a tool named `bootimage` that first compiles the kernel and bootloader, and then links them together to create a bootable disk image. To install the tool, execute the following command in your terminal:

```
cargo install bootimage
```

For running `bootimage` and building the bootloader, you need to have the `llvm-tools-preview` rustup component installed. You can do so by executing `rustup component add llvm-tools-preview`.

After installing `bootimage` and adding the `llvm-tools-preview` component, we can create a bootable disk image by executing:

```
> cargo bootimage
```

We see that the tool recompiles our kernel using `cargo build`, so it will automatically pick up any changes you make. Afterwards it compiles the bootloader, which might take a while. Like all crate dependencies it is only built once and then cached, so subsequent builds will be much faster. Finally, `bootimage` combines the bootloader and your kernel to a bootable disk image.

After executing the command, you should see a bootable disk image named `bootimage-blog_os.bin` in your `target/x86_64-blog_os/debug` directory. You can boot it in a virtual machine or copy it to an USB drive to boot it on real hardware. (Note that this is not a CD image, which have a different format, so burning it to a CD doesn't work).

How does it work?

The `bootimage` tool performs the following steps behind the scenes:

- It compiles our kernel to an ELF file.
- It compiles the bootloader dependency as a standalone executable.
- It links the bytes of the kernel ELF file to the bootloader.

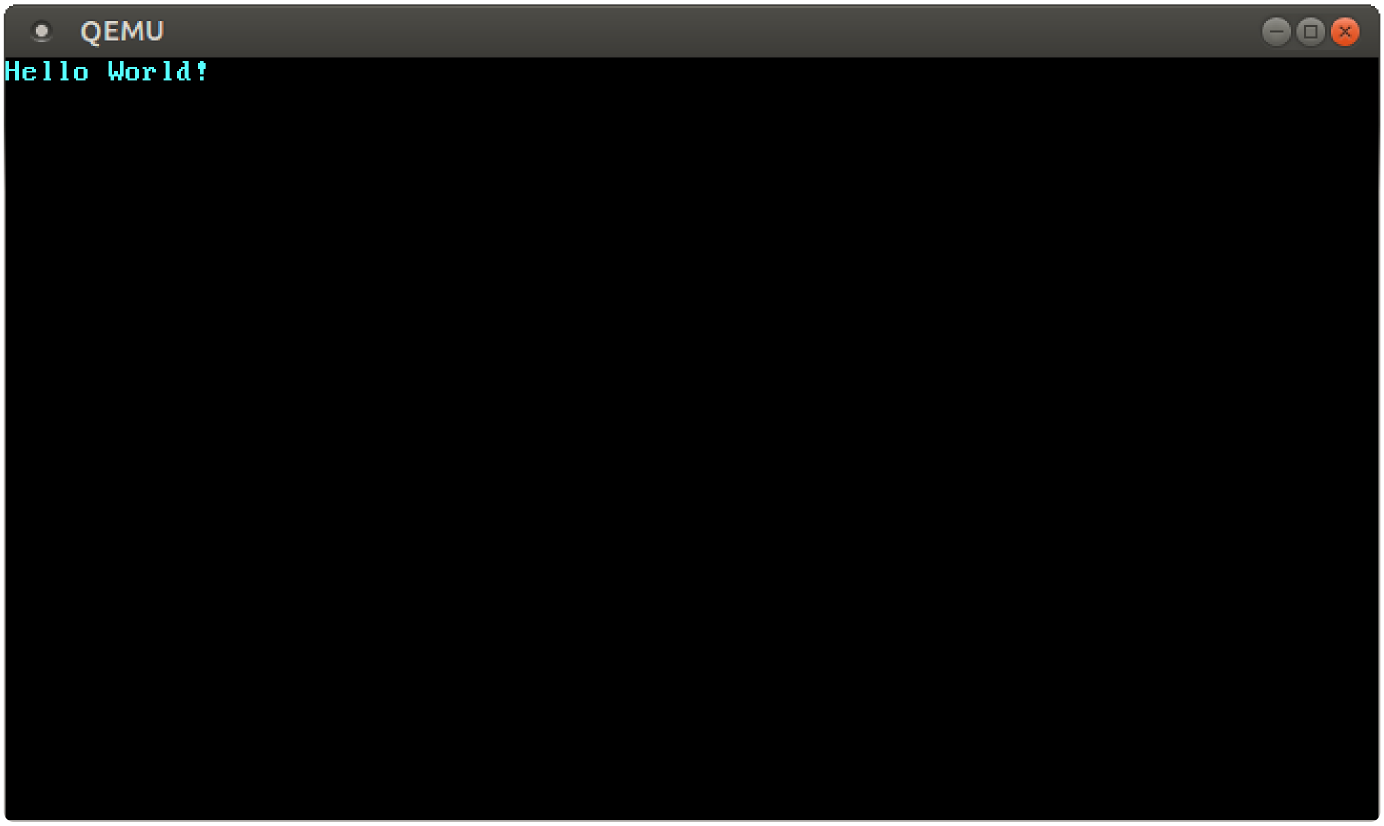
When booted, the bootloader reads and parses the appended ELF file. It then maps the program segments to virtual addresses in the page tables, zeroes the `.bss` section, and sets up a stack. Finally, it reads the entry point address (our `_start` function) and jumps to it.

Booting it in QEMU

We can now boot the disk image in a virtual machine. To boot it in QEMU, execute the following command:

```
> qemu-system-x86_64 -drive format=raw,file=target/x86_64-blog_os/debug/bootimage-b
warning: TCG doesn't support requested feature: CPUID.01H:ECX.vmx [bit 5]
```

This opens a separate window with that looks like this:



We see that our "Hello World!" is visible on the screen.

Real Machine

It is also possible to write it to an USB stick and boot it on a real machine:

```
> dd if=target/x86_64-blog_os/debug/bootimage-blog_os.bin of=/dev/sdX && sync
```

Where `sdX` is the device name of your USB stick. **Be careful** to choose the correct device name, because everything on that device is overwritten.

After writing the image to the USB stick, you can run it on real hardware by booting from it. You probably need to use a special boot menu or change the boot order in your BIOS configuration to boot from the USB stick. Note that it currently doesn't work for UEFI machines, since the `bootloader` crate has no UEFI support yet.

Using `cargo run`

To make it easier to run our kernel in QEMU, we can set the `runner` configuration key for cargo:

```
# in .cargo/config.toml

[target.'cfg(target_os = "none")']
runner = "bootimage runner"
```

The `target.'cfg(target_os = "none")'` table applies to all targets that have set the `"os"` field of their target configuration file to `"none"`. This includes our `x86_64-blog_os.json` target. The `runner` key specifies the command that should be invoked for `cargo run`. The command is run after a successful build with the executable path passed as first argument. See the cargo documentation for more details.

The `bootimage runner` command is specifically designed to be usable as a `runner` executable. It links the given executable with the project's bootloader dependency and then launches QEMU. See the Readme of `bootimage` for more details and possible configuration options.

Now we can use `cargo run` to compile our kernel and boot it in QEMU.

What's next?

In the next post, we will explore the VGA text buffer in more detail and write a safe interface for it. We will also add support for the `println` macro.

Support Me

Creating and maintaining this blog and the associated libraries is a lot of work, but I really enjoy doing it. By supporting me, you allow me to invest more time in new content, new features, and continuous maintenance.

The best way to support me is to *sponsor me on GitHub*, since they don't charge any fees. If you prefer other platforms, I also have *Patreon* and *Donorbox* accounts. The latter is the most flexible as it supports multiple currencies and one-time contributions.

Thank you!

« A Freestanding Rust Binary VGA Text Mode »

I'm not really a fan of using this magic utility to turn our blob of Rust into a bootable image. The parts in raw assembly in the first edition were a bit tedious but I liked how they gave us a deeper understanding about how the process worked. I hope that this utility won't be sticking around for the post on UEFI booting...

👍 8

0 replies

1

pixelherodev Mar 10, 2018

"They are designed to make the bootloader simple instead of the kernel. For example, the kernel needs to be linked with an adjusted default page size, because GRUB can't find the Multiboot header otherwise."

WRONG!

That is true of Multiboot2, a later standard which is less used and NOT multiboot-compatible.

However, the actual Multiboot standard does not have that problem at all.

👍 1 👎 3

0 replies

1

phil-opp Mar 11, 2018 Owner

@Redrield Fair point. On the other hand we already used `grub-mkrescue` as such a magic utility in the first edition, which did exactly the same thing (transforming a Rust binary into a bootable image). The only difference was that GRUB only put us into protected mode, so we had to do the last steps ourselves.

Apart from a less tedious start, the new bootloader gives us an opportunity for an even deeper understanding of the boot process than before: We're planning to write several posts on how the tool and the underlying bootloader works, in a similar fashion as the other posts (i.e. every line of code is in the post and you can follow along). Thus, we can hide the complexity at the beginning of the main post series and directly start with the more interesting part, but also provide resources to those who want to understand it all the way down.

👍 17

0 replies

1

phil-opp Mar 11, 2018 Owner

@pixelherodev Huh? I was under the impression that Multiboot2 was the successor of Multiboot? Either way, Multiboot 1 is not a better solution for us since it does have other problems (if I remember correctly it does not support 64-bit ELF files at all).

👍 2

0 replies

1

pixelherodev Mar 11, 2018

Fair enough. Multiboot 2 is essentially the spiritual successor to multiboot IIRC. I also remember multiboot being easier to get started with, but that's neither here nor there :p Honestly, while I don't think ignoring multiboot was a good idea, I can understand why you did so.

0 replies

1

phil-opp Mar 12, 2018 Owner

> Honestly, while I don't think ignoring multiboot was a good idea, I can understand why you did so.

Yeah, there are clear tradeoffs in this case. I really like the idea behind multiboot, but the standard and the implementation not so much. I plan to add grub compatibility to the bootimage tool, so that you can boot it in a multi-OS setting too.

0 replies

1

ghost Mar 20, 2018

First of all, great tutorial, thanks a lot for the effort!
If you're on Ubuntu, like me, and building openssl-sys when trying to `cargo install bootimage` fails, make sure you have libssl-dev installed!

0 replies

1

phil-opp Mar 23, 2018 Owner

@FuzzyHerbivore Thanks a lot! I added a hint to the post in `5f195a8` .

0 replies

1

kylegalloway Mar 23, 2018 edited

Disclaimer: I'm on Windows.

There is a problem with running `qemu-system-x86_64 -drive format=raw,file=bootimage.bin` on windows. QEMU opens and flashes but doesn't display the "Hello World!" text.

Also, converting to a VDI for VirtualBox doesn't seem to work. I get:

```
 $ VBoxManage convertdd .\bootimage.bin bootimage.vdi --format VDI
Converting from raw image file=".\bootimage.bin" to file="bootimage.vdi"...
Creating dynamic image with size 86016 bytes (1MB)...
VBoxManage.exe: error: Cannot create the disk image "bootimage.vdi": VERR_VD_INV
```

👍 1

0 replies

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AaronCoad Mar 23, 2018

@kyle I'm also using Windows with cargo 1.26.0 nightly and xargo 0.3.11. Are these the same versions for you? I'm stuck with building using xargo:

`xargo build --target hyenaos` results in error: multiple input filenames provided
`set RUST_TARGET_PATH=cd xargo build --target hyenaos` results in nothing (including no build folder) as does `RUST_TARGET_PATH=cd xargo build --target hyenaos` .

Using cargo 1.26.0 nightly and xargo 0.3.11.

0 replies

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AaronCoad Mar 23, 2018

@kylegalloway sorry

0 replies

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AaronCoad Mar 24, 2018

Feeling a little silly, still stuck on the above, but realised I was setting the path incorrectly. The following steps still fail:

`set RUST_TARGET_PATH=C:\HyenaOS\` or `set RUST_TARGET_PATH=C:\HyenaOS`
`xargo build --target hyenaos` or `xargo build --target C:\HyenaOS\hyenaos`

These are always with the multiple input filenames provided error.

Apologies for the multiple posts.

0 replies

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phil-opp Mar 24, 2018 Owner

@kylegalloway

> There is a problem with running qemu-system-x86_64 -drive format=raw,file=bootimage.bin on windows. QEMU opens and flashes but doesn't display the "Hello World!" text.

I pushed a new version of the bootloader yesterday, seems like this is the cause of the error. I reverted the change for now, so it should work again. Thanks for reporting!

> Also, converting to a VDI for VirtualBox doesn't seem to work. I get:

Hmm, I have no idea about this error. I only found https://forum.lede-project.org/t/error-convert-img-to-vdi/152, which indicates that the image needs to be padded somehow before converting.

0 replies

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phil-opp Mar 24, 2018 Owner

@AaronCoad Strange, I've never seen this error. Could you try it with `--verbose` ?

0 replies

0

SomeAnotherDude Mar 24, 2018 Contributor

Hi, I have a little problem with bootimage.
When I run it in debug mode and pass a created "bootimage.bin" file to qemu it fails with this:

```
 qemu-system-x86_64: Trying to execute code outside RAM or ROM at 0x00000001
This usually means one of the following happened:

(1) You told QEMU to execute a kernel for the wrong machine type, and it cra
(2) You didn't give QEMU a kernel or BIOS filename at all, and QEMU executed
(3) Your guest kernel has a bug and crashed by jumping off into nowhere

This is almost always one of the first two, so check your command line and t
If you think option (3) is likely then you can try debugging your guest with

Execution cannot continue; stopping here.
```

But when I run it with --release flag everything works properly. Why could it happen?

.S my host OS is Kubuntu 17.10

0 replies

331 hidden items
Load more...

1

r00ster91 Apr 10

> If you are interested in building your own bootloader: Stay tuned, a set of posts on this topic is already planned!

Hello, thank you for this great series. Is this still planned? Or is this perhaps depended on rust-osdev/bootloader#24?

0 replies

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atultw Apr 21

For windows people like myself:

The process for creating bootimage worked as written in the guide. I didn't have qemu so I chose to test with virtualbox:

- Add your virtualbox installation directory to path so we can use the `VBoxManage` utility. (for me it was `C:\Program Files\Oracle\VirtualBox`)
- Virtualbox utility may fail to convert because of the image size. I went into WSL and used `qemu-img resize YOURFILENAME.bin 1M` which fixed the issue. (the command may also work with qemu for windows but I don't know)
- From cmd or powershell, navigate to the directory with your `.bin` image and run `VBoxManage convertfromraw YOURFILENAME.bin disk.vdi --format VDI` . This converts the raw bin into a disk image usable by vbox.
- I set the OS type as redhat in virtualbox and it worked. This was necessary since selecting unknown raised an error about long mode at boot.

Hope this helps someone!

👍 1

0 replies

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hello01-debug Apr 23

I followed the instructions, installed rust-src, and ran the build after cloning the repository, and I still get an error that the crate for std cannot be found. It only happens when I try to install bootimage.

0 replies

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phil-opp Apr 27 Owner

@r00ster91 I already started writing about creating an UEFI bootloader in the upcoming third edition of the blog. I'm not sure when there will be post about BIOS booting, but it probably makes sense to wait for rust-osdev/bootloader#24 as it will simplify some things.

❤️ 1

0 replies

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phil-opp Apr 27 Owner edited

@hello01-debug

> I followed the instructions, installed rust-src, and ran the build after cloning the repository, and I still get an error that the crate for std cannot be found. It only happens when I try to install bootimage.

Could you post a link to your code so that we can look into your issue?

0 replies

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hello01-debug Apr 28

Sure, as soon as I can.

...

0 replies

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kennystrawnmusic May 2 edited

Starting from scratch and noticing this problem with bootloader 0.10.2 — host OS is Fedora Rawhide and Rust version is 1.54.0-nightly (4de757209 2021-05-01):

```
Error: An error occured while trying to build the bootloader: The `bootloader` 
```

Particularly bizarre since I'm following this to the T and it worked fine last year. Oh, and obviously 0.10.2 > 0.5.1.

0 replies

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kennystrawnmusic May 2 edited

This blog post needs to be updated for bootloader 0.10.x. Causing *way* too many problems. Case in point, after following the updated docs.rs/bootloader instructions:

```
--- stderr
 thread 'main' panicked at 'The UEFI bootloader must be compiled for the `x86_6
```

This is from attempting to add `uefi_bin` as a feature requirement to the `bootloader` crate dependency. Meanwhile if I don't do that, `builder` fails with this message:

```
error: none of the selected packages contains these features: uefi_bin
```

So either there's a bug in the code that's looking for the wrong target or this post needs to be fundamentally overhauled.

0 replies

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bjorn3 May 3 Contributor

@phil-opp is currently working on a third edition of blog os that uses bootloader 0.10.x. This is taking a while as there are major changed between 0.9.x and 0.10.x to support not just BIOS booting, but also UEFI. In addition UEFI requires APIC (advanced programmable interrupt controller) instead of the legacy PIC that is currently used by blog os. For now you may want to stay on bootloader 0.9.x.

0 replies

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kennystrawnmusic May 3

Alright, guess I'll just have to patiently wait until that new edition comes out, thanks.

0 replies

1

InterestingBrainPoops 1 month ago

> Could you post a link to your code so that we can look into your issue?
> Ive run into the same issue, here is the link to the gh repo:
> https://github.com/InterestingBrainPoops/learning/tree/master/alcolu/alcolu

0 replies

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InterestingBrainPoops 1 month ago

wait shoot, the quotes went down too far. But yea, I encountered the same problem, and I put the src on github at the link above
cc: **@phil-opp**

0 replies

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phil-opp 27 days ago Owner

@InterestingBrainPoops I just tried your code and it compiled fine using the following build command:

```
cargo build --target x86_64-alcolu.json -Z build-std=core -Z build-std-features=
```

Instead of these command line parameters, you can also create a `.cargo/config.json` file [as described in the post](#).

0 replies

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Sevendaye 16 days ago

> Starting from scratch and noticing this problem with bootloader 0.10.2 — host OS is Fedora Rawhide and Rust version is 1.54.0-nightly (4de757209 2021-05-01):
>
> ```
> Error: An error occured while trying to build the bootloader: The `bootloa
> ```
>
> Particularly bizarre since I'm following this to the T and it worked fine last year. Oh, and obviously 0.10.2 > 0.5.1.

Hi,

I had the same problem, I was able to solve it by:

- bootloader = "0.9.18" // In Cargo.toml

```
$cargo clean
$cargo bootimage --target .\x86_64-blog_os.json
```

```
$cargo run
```

It seems that there is a problem after version 0.9.18 of the bootlader crate

👍 2

0 replies

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ty-newton 3 hours ago

Really loving reading this blog. For anyone else who is a bit nervous about using brew/macports on MacOS (to get qemu), I managed to get qemu working in an Ubuntu guest with VMware Fusion. Setting up VS Code for Rust in Ubuntu is also simple; so it ends up being a nice developer experience.

0 replies

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Other Languages

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- Japanese
- Chinese (simplified)

About Me

I'm a Rust freelancer with a master's degree in computer science. I love systems programming, open source software, and new challenges.

If you want to work with me, reach out on LinkedIn or write me at job@phil-opp.com.