Rust on STM32: Blinking an LED

06 February 2019

GOAL: Blink the onboard LED on a BluePill board using Rust on a Linux Mint (Ubuntu based) machine.

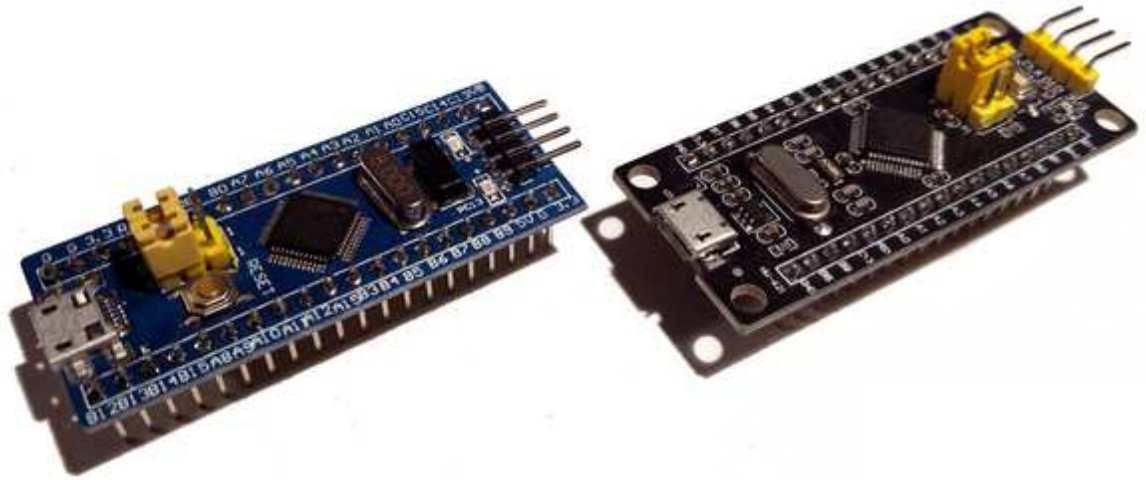
Update/Information: The rustc version I used is `rustc 1.31.1` (stable) and you need to install the ARM target with `rustup target add thumbv7m-none-eabi` beforehand.

I also put the code on Gitlab (https://gitlab.com/jounathaen/stm32_blink).

Preface

I have mainly used Atmel microcontrollers so far, but they are rather expensive, slow and have a totally confusing pinout. (And I think, they have no real future). So I wanted to use a better controller and setup the flow to program it on my Linux Mint machine (should work on Ubuntu as well). **I assume, that the reader already has at least a little knowledge in Rust, Linux, and Microcontrollers**

One of the possibly cheapest and general purpose boards is the STM32F103 board aka “BluePill”. These sell for less than 2€ on AliExpress (https://www.aliexpress.com/item/STM32F103C8T6-ARM-STM32-Minimum-System-Development-Board-Module-For-Arduino/32278016818.html), but I’d recommend you the more up-to-date version, the “BlackPill” (AliExpress (https://www.aliexpress.com/item/STM32F103C8T6-ARM-STM32-Minimum-Development-Board-Module-MCU-Core-Board-MicroUSB-for-Arduino-Diy-Kit/32969629826.html)), because the BluePill usually has a wrong resistor which causes trouble when using the USB port. Besides a slightly different pinout and the BlackPill being one row larger than the BluePill, they are basically the same.



(https://jonathanklimt.de/assets/images/stm32_flash/IMG_20190207_005342_edit.jpg)

BluePill and BlackPill

Setting up the Cargo Project

First, we initialize a new Cargo project

```
> cargo init stm32_blink
> cd stm32_blink
```

We modify our `Cargo.toml` file as follows to include the required libraries:

```
[package]
name = "stm32_blink"
version = "0.1.0"
edition = "2018"

[profile.release]
# optimize for size ('z' would optimize even more)
opt-level = 's'
# link with link time optimization (lto).
lto = true
# enable debugging in release mode.
debug = true

[dependencies]
# Gives us access to the STM32F1 registers
stm32f1 = {version = "0.6.0", features = ["stm32f103", "rt"]}
# provides startup code for the ARM CPU
cortex-m-rt = "0.6.7"
# provides access to low level ARM CPU registers (used for delay)
cortex-m = "0.5.8"
# provies a panic-handler (halting cpu)
# (required when not using stdlib)
panic-halt = "0.2.0"
```

I the `cortex-m-rt` crate also requires a `memory.x` file, which specifies the memory layout of the board (See the documentation (https://docs.rs/cortex-m-rt/0.6.7/cortex_m_rt/#memoryx)).
The documentation already provides the file for the BluePill as an example, so we only have to create the file `memory.x` with the following content:

```
/* Linker script for the STM32F103C8T6 */
MEMORY
{
  FLASH : ORIGIN = 0x08000000, LENGTH = 64K
  RAM : ORIGIN = 0x20000000, LENGTH = 20K
}
```

We can now compile the program using `cargo rustc --target thumbv7m-none-eabi -- -C link-arg=-Tlink.x`, but that would be a bit inconvenient. Therefore, we create the file `.cargo/config` (and the folder `.cargo`) with the following content (based on this file (https://github.com/rust-embedded/cortex-m-quickstart/blob/master/.cargo/config)):

```
[build]
# Instruction set of Cortex-M3 (used in BluePill)
target = "thumbv7m-none-eabi"

rustflags = [
  # use the Tlink.x scrip from the cortex-m-rt crate
  "-C", "link-arg=-Tlink.x",
]
```

Hoooray, now we can compile Rust code into an ARM *elf* file! (However, the code we have does not compile yet)

```
> cargo build --release
> file target/thumbv7m-none-eabi/release/stm32_blink
target/thumbv7m-none-eabi/release/stm32_blink:
ELF 32-bit LSB executable, ARM, EABI5 version 1 (SYSV),
statically linked, with debug_info, not stripped
```

The Blink Program

This is the content of the `src/main.rs` file:

```
// std and main are not available for bare metal software
#![no_std]
#![no_main]

extern crate stm32f1;
extern crate panic_halt;
extern crate cortex_m_rt;

use cortex_m_rt::entry;
use stm32f1::stm32f103;

// use `main` as the entry point of this application
#[entry]
fn main() -> ! {
    // get handles to the hardware
    let peripherals = stm32f103::Peripherals::take().unwrap();
    let gpioc = &peripherals.GPIOC;
    let rcc = &peripherals.RCC;

    // enable the GPIO clock for IO port C
    rcc.apb2enr.write(|w| w.iopcen().set_bit());
    gpioc.crh.write(|w| unsafe{
        w.mode13().bits(0b11);
        w.cnf13().bits(0b00)
    });

    loop{
        gpioc.bsrr.write(|w| w.bs13().set_bit());
        cortex_m::asm::delay(2000000);
        gpioc.brr.write(|w| w.br13().set_bit());
        cortex_m::asm::delay(2000000);
```

```
    }
}
```

Explanation: `#![no_std]` is required, because we build a bare-metal application but the standard library requires an operating system. `#![no_main]` tells the compiler that we don't use the default `main` function with the argument vector and return type. This wouldn't make sense, since we don't have an OS or other kind of runtime which would call the function and handle the return value. Instead, the `cortex_m_rt` crate contains a minimal runtime and the `#[entry]` macro, which specifies our custom entry function (`fn main() -> ! {}`), which we call `main` as well (don't be confused). More information about bare metal software in Rust can be found for example in the "Writing an OS in Rust" (https://os.phil-opp.com/) Blog.

Inside the `main` function we create a handle to the peripheral object, which "owns" all the peripherals and registers with `stm32f103::Peripherals::take()`. `rcc` and `gpioc` are handles to the "reset and clock control" and GPIO register bank C (the onboard LED on my BluePill is connected to pin C13 but this might differ).

To use a pin as output we have to enable the clock for that specific GPIO pin bank by setting the *IOPCEN* bit in the *APB2EN* register. Writing a byte in a peripheral register using the `stm32f1` crate is done by calling the `write` function on that register struct (`rcc.apb2enr.write()`). This function takes a `FnOnce` (https://doc.rust-lang.org/std/ops/trait.FnOnce.html) function as an argument. The parameter which is passed to this function is in the first case of type `gpioc::crh::W` which implements functions to access the single bit fields in that very register (here: `w.iopcen()`). This in turn has a function `set_bit` , which is used to set the bit in that hardware register and thus enabling the clock for the GPIO C bank.

The same applies for the *CRH* register, which is used to configure the pin as an output pin at highest speed (*MODE*=0b11 and *CNF*=00). The `bits` function of the `mode13` and `cnf13` bit field is unsafe, but I can't tell you why. Therefore, we have to mark the functions inside the closure as unsafe as well.

Hint: To get a documentation of the stm32f1 crate, generate it yourself with `cargo doc --open`

In the infinite loop, we write to the *Port bit set/reset register (BSRR)* and the *Port bit reset register (BRR)* to set pin C13 to high respectively low.

The `delay` function (https://docs.rs/cortex-m/0.5.8/cortex_m/asm/fn.delay.html) *busy waits* for at least the given number of cycles. The number here was just randomly taken and represents around 250ms. The better approach would be to utilize the onboard timers, but for this simple example, `delay` is sufficient.

Creating the Binary

For the next steps, we need an ARM toolchain installed on our system. On Linux Mint (Ubuntu), this can be done with:

```
> sudo apt install binutils-arm-none-eabi
```

Update: I use the toolchain from the Ubuntu package manager. The toolchain which is installed with the thumbv7m target can also be invoked using Cargo (https://github.com

/rust-embedded/cargo-binutils) (I'll try this next time).

Optional: Disassembly

We can now view the disassembly of the *elf* file:

```
> arm-none-eabi-objdump --disassemble \
  target/thumbv7m-none-eabi/release/stm32_blink | less
```

So far, we only operated with the *elf* file. This format does not only contain the binary code but also some headers and stuff (see Wikipedia (https://en.wikipedia.org/wiki/Executable_and_Linkable_Format)). This is useful, when another software like an operating system or bootloader launches the file. However, to run the program bare-metal we don't need an *elf* file, but rather a *bin* file. This is an image of the software which can be written byte-by-byte into the memory of the microcontroller.

An *elf* file can be converted into a *bin* file with `objcopy`.

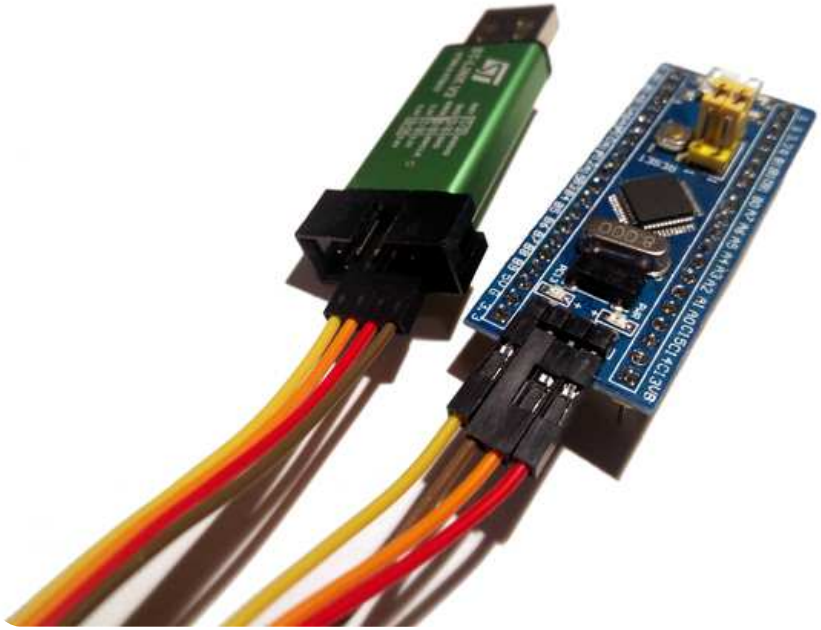
```
> arm-none-eabi-objcopy -O binary \
  target/thumbv7m-none-eabi/release/stm32_blink stm32_blink.bin
```

The `stm32_blink.bin` is now ready to flash.

Flashing the Binary

There are multiple ways to program the board, for example using the UART, using a USB bootloader (like the Arduino has), or using a programmer like an ST-Link. I'm using a ST-Link-V2 clone, which are almost as cheap as the Pill itself (AliExpress (https://www.aliexpress.com/item/1PCS-ST-LINK-Stlink-ST-Link-V2-Mini-STM8-STM32-Simulator-Download-Programmer-Programming-With-Cover/32920031233.html)). You can even flash one yourself (https://medium.com/@paramaggarwal/converting-an-stm32f103-board-to-a-black-magic-probe-c013cf2cc38c) out of a BluePill/BlackPill.

Connect the 4 pins *SWDIO*, *GND*, *SWCLK*, and *3.3V* on the programmer with the corresponding pins on the BluePill and plug it into your PC. **Important:** Disconnect any other power supply from the board, otherwise you can damage the board or in the worst case your PC.



(https://jonathanklimt.de/assets/images/stm32_flash/IMG_20190207_005543_edit.jpg)

Connection between the ST-Link and the BluePill

There are other ways to program the board with the ST-Link, such as openocd (https://github.com/rogerclarkmelbourne/Arduino_STM32/wiki/Programming-an-STM32F103XXX-with-a-generic-%22ST-Link-V2%22-programmer-from-Linux), but I will use the open-source stlink (https://github.com/texane/stlink) tools. Unfortunately, this software is not available via the apt package manager, therefore we have to compile it from source (https://github.com/texane/stlink/blob/master/doc/compiling.md).

```
# in a directory of your choice:
> sudo apt install libusb-1.0 libusb-1.0-0-dev
> git clone https://github.com/texane/stlink
> cd stlink
> make all
```

This creates the executables `st-flash` and `st-info`, which reside now in `build/Release/`. There are different approaches to "install" these executables. I will now copy them into a system folder. However, it may be desirable to only copy them into a folder in your home directory which is added to `$PATH` or simply prefix all commands with the full path to the executable instead.

```
> sudo cp build/Release/st-{flash,info} \
  build/Release/src/gdbserver/st-util /usr/local/bin
> which st-info
/usr/local/bin/st-info
```

Optional: Udev Rules

To access the ST-Link without root permissions, copy the udev rules from the source code to `/etc/udev/rules.d/`

```
> sudo cp etc/udev/rules.d/*.rules /etc/udev/rules.d
> sudo udevadm control --reload-rules && udevadm trigger
```

We can verify the connection:

```
> st-info --descr
F1 Medium-density device
```

Optional: Erase existing software/bootloaders:

I had a stm32duino bootloader running on my BluePill, which lead to errors like `WARN common.c: unknown chip id! 0x5fa0004` upon flashing. To fix that, I had to erase the chip. This is done by executing the following command *right after pressing the reset button* on the board:

```
> st-flash erase
```

To flash the *bin* file, we execute:

```
> st-flash write stm32_blink.bin 0x8000000
st-flash 1.5.1-12-g30de1b3
2019-02-07T00:23:15 INFO common.c: Loading device parameters....
#[...]
2019-02-07T00:23:15 INFO common.c: Flash written and verified!
  jolly good!
```

Success!

Summary of Commands to Build and Flash the Software:

```
> cargo build --release
> arm-none-eabi-objcopy -O binary \
  target/thumbv7m-none-eabi/release/stm32_blink stm32_blink.bin
> st-flash write stm32_blink.bin 0x8000000
```

That's it! Now the LED on the board is blinking!

(https://jonathanklimt.de/assets/images/stm32_flash/IMG_20190207_005642_edit.jpg)

Blinking LED on BluePill

TODO: Create a single Cargo Command to Flash the Board

Tags: BluePill LED Linux Rust st-flash STM32 STM32F103 toolchain

Categories: Electrics Programming

Updated: February 08, 2019