A Beginner's Complete Guide to Microcontroller Programming with Ruby

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Part 1

Preparation

Part 2

Getting Started with Microcontroller

Part 3

Exploring PicoRuby Further

Part 4

PicoRuby Under the Hood

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self.inspect

- Hitoshi HASUMI
- hasumikin (GitHub, ex-Twitter, Bluesky and Threads)
- Creator of PicoRuby and PRK Firmware
- Committer of CRuby's IRB and Reline
- First prize of Fukuoka Ruby Award (2020 and 2022✌)
- A final nominee of Ruby Prize 2021

Part 1

Preparation

Setup (minimal)

- Raspberry Pi Pico
  - Or other **RP2040**-based controller
- USB cable
- Terminal emulator on laptop

Raspberry Pi Pico

- Raspberry Pi Pico: Microcontroller board
  - MCU: RP2040
    - Cortex-Mzero+ (dual)
    - 264 KB RAM
    - 2 MB flash ROM
  - It generally runs without an OS (bere metal)
- ref) Raspberry Pi: Single-board computer
  - It generally needs an OS like Raspberry Pi OS or Windows for Arm

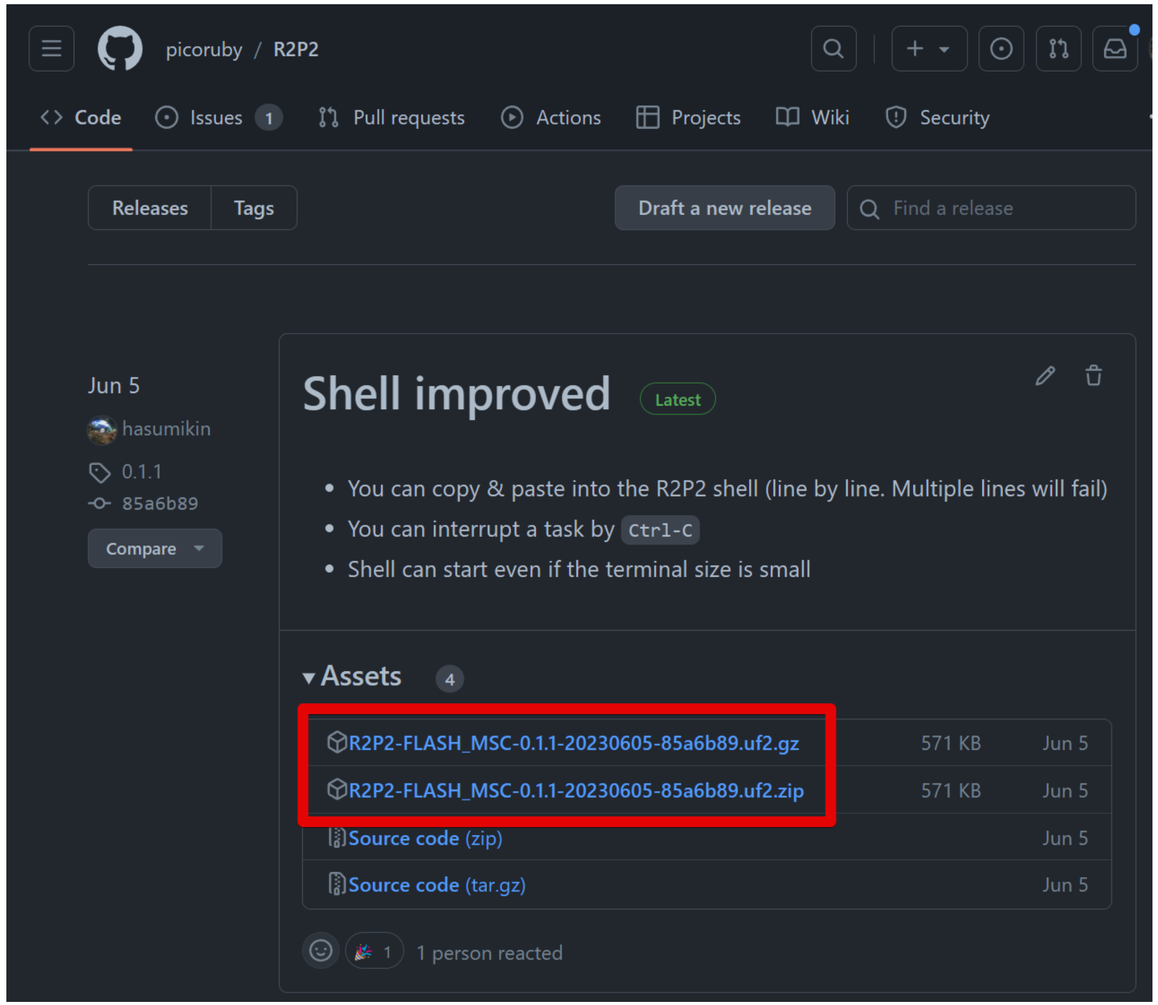
Terminal emulator

- Linux -> GTKTerm👍
- Windows -> Tera Term🙆
- macOS -> PuTTY (I'm not sure)
- Traditional CUI/TUI tools may have CR/LF trouble
  - cu
  - screen
  - minicom

Let's begin 1/4

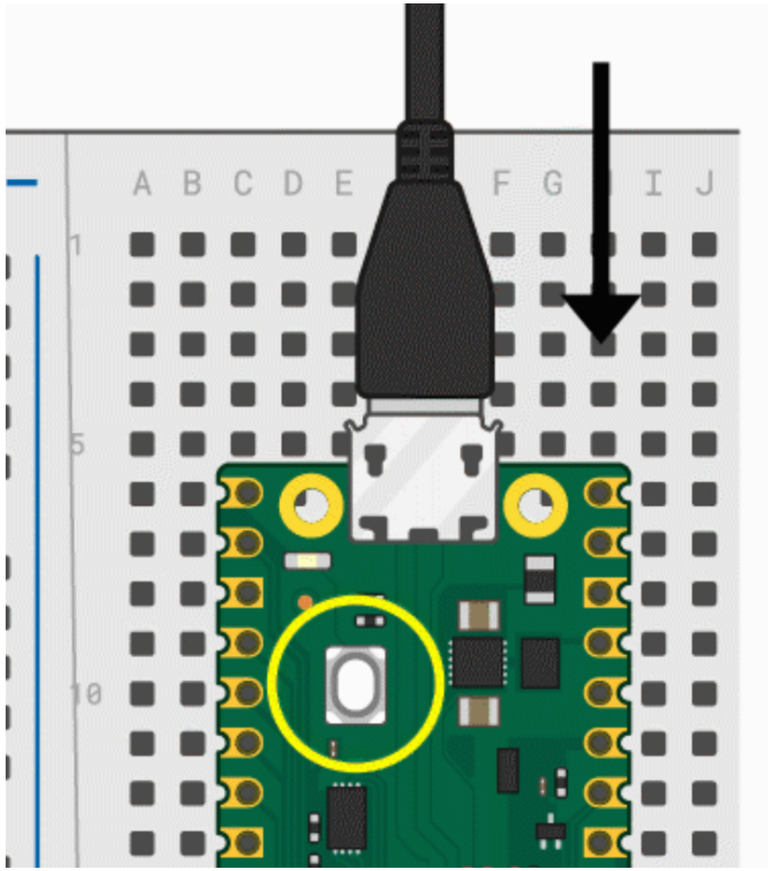
- Download the latest `R2P2-*.(zip|gz)` from GitHub then unzip it into `R2P2-*.uf2`

github.com/picoruby/R2P2/releases



Let's begin 2/4

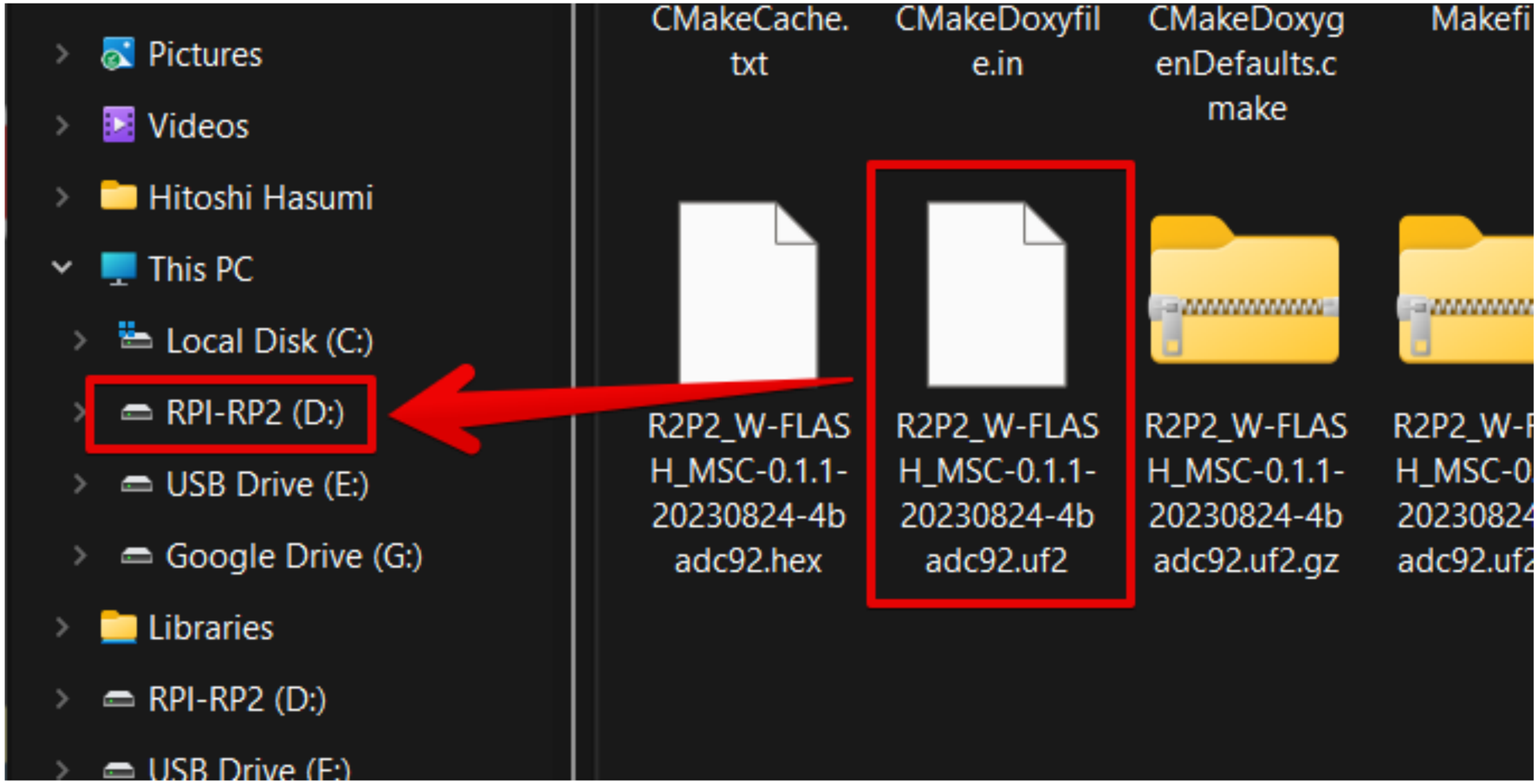
- Connect Pi Pico and PC while pressing the BOOTSEL button
  - You'll find "RPI-RP2" drive in file manager



https://www.raspberrypi.org/documentation/rp2040/getting-started

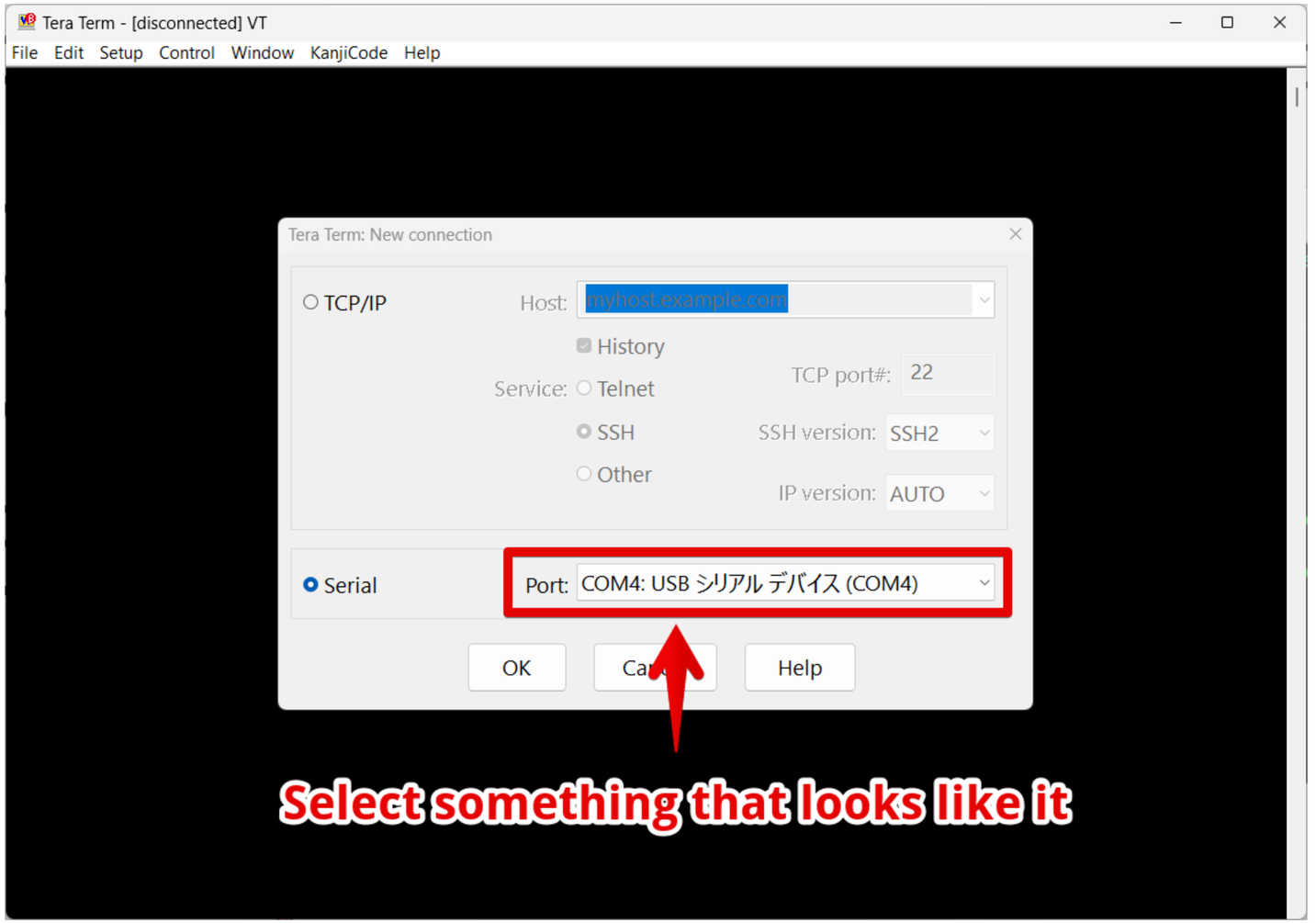
Let's begin 3/4

- Drag & drop `R2P2-*.uf2` into RPI-RP2 drive



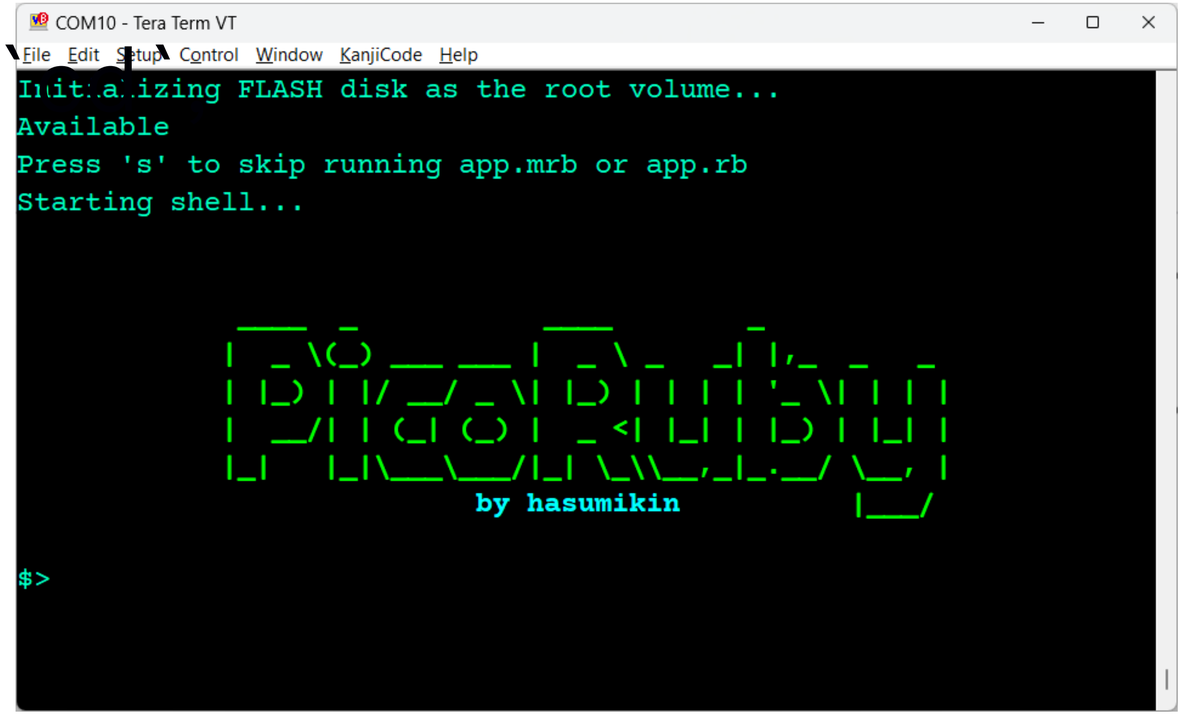
Let's begin 4/4

- Open a proper serial port on terminal emulator



R2P2 Shell should start [Demo]

- Unix-like shell running on Raspberry Pi Pico
- You can use some commands like `pwd`, `ls`, `mkdir`
- It apparently has a filesystem (written in Ruby!)



PicoIRB [Demo]

- PicoRuby's IRB is running within the R2P2 shell on Raspberry Pi Pico
- Your Ruby snippet is going to be compiled into mruby VM code and executed **on the fly**
  - It means PicoRuby contains an mruby compiler which can run on a one-chip microcontroller (will be mentioned later)

Part 2

Getting Started with Microcontroller

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GPIO (General Purpose Input/Output)

- Fundamental digital I/O
- Variety of uses:
  - Input: Detects on-off state of switch and button
  - Output: Makes a voltage
  - You can even implement a communication protocol by controlling GPIO in milli/micro sec

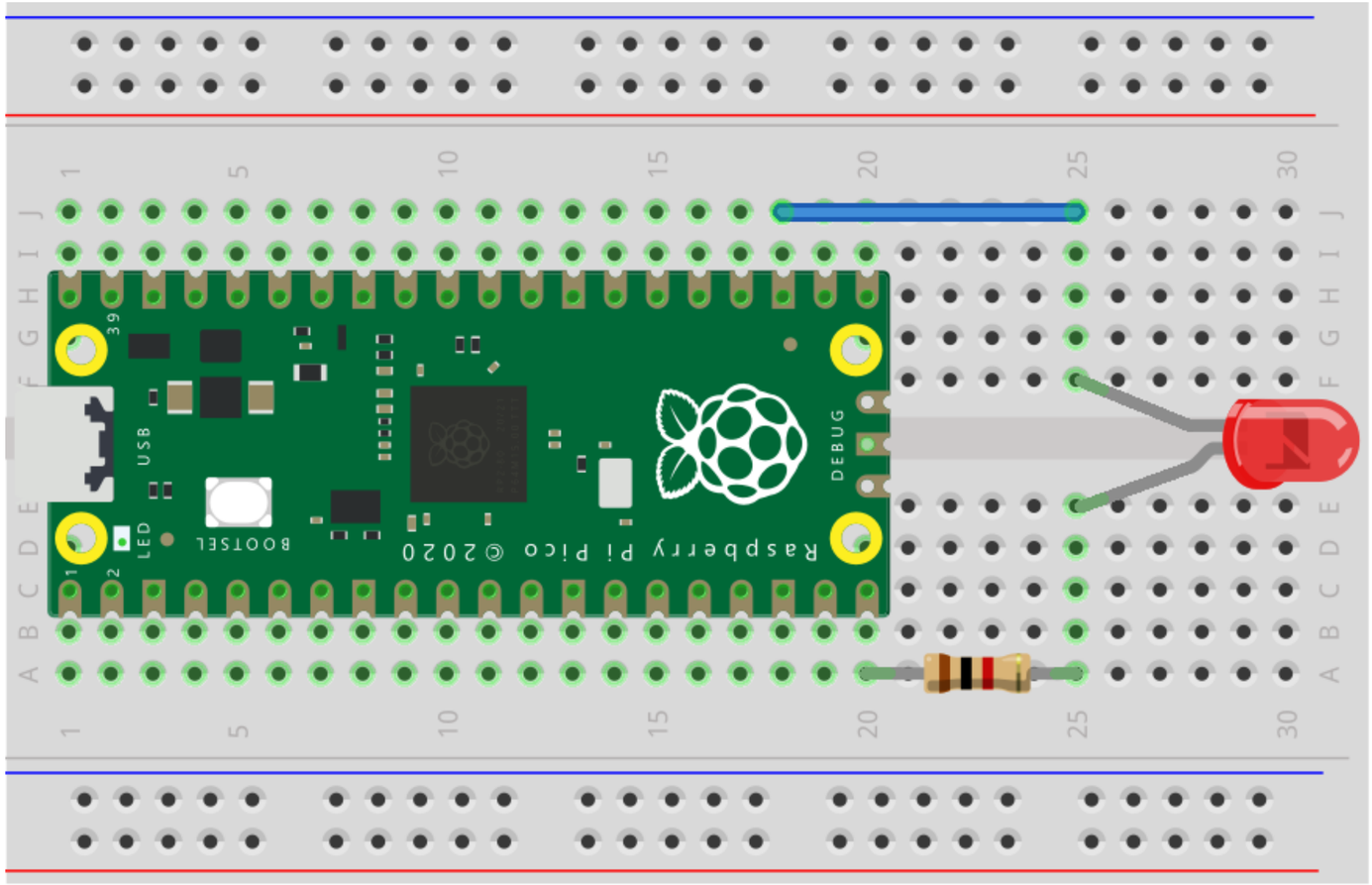
GPIO --- Blinking LED [Demo]

```
irb> led = GPIO.new(25, GPIO::OUT)
irb> 3.times do
irb*   led.write 1
irb*   sleep 1
irb*   led.write 0
irb*   sleep 1
irb* end
```

GPIO25 internally connects to on-board LED through a resistor

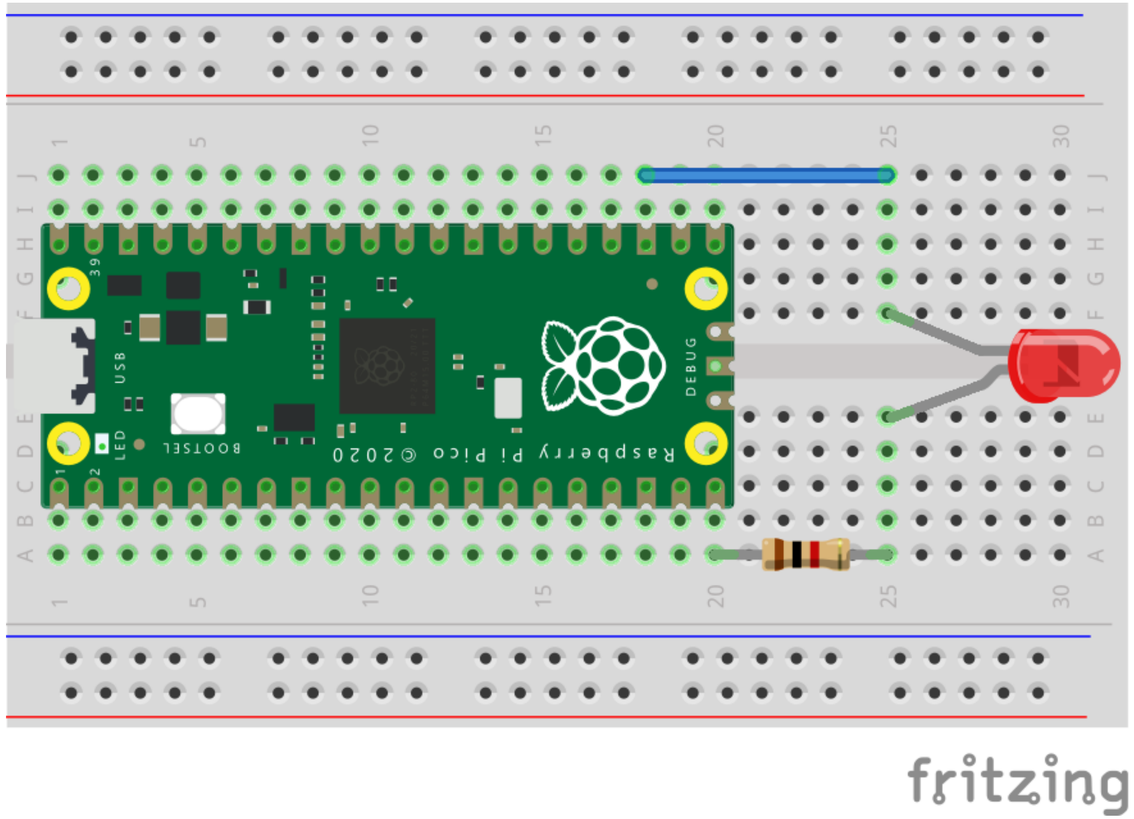
GPIO --- Blinking LED by discrete parts

- Parts list:
  - LED (RED)
  - Resistor (1kΩ)



GPIO --- Blinking LED by discrete parts

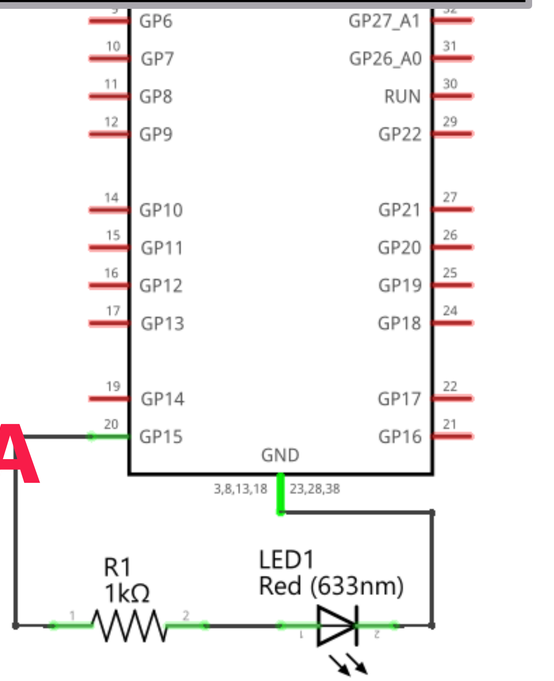
```
irb> pin = GPIO.new(15, GPIO::OUT)
```



GPIO --- Blinking LED by discrete parts

```
GPIO15 ===> 1kΩ ===> LED ===> GND
<----- 1.5V -----><--- 1.8V ---->
<------------ 3.3V ------------->
```

- RP2040's logic level: 3.3V
- LED voltage drop: **1.8V**
  (according to LED's datasheet)
- Current: (3.3V - 1.8V) / 1kΩ = **1.5mA**
  (calculated by Ohm's Law)



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🏫 Study time: Electromagnetism | Physics

- Ohm's Law
  - V = I * R ⇔ I = V / R ⇔ R = V / I
- Kirchhoff's Circuit Laws
  - Current law: The algebraic sum of currents in a network of conductors meeting at a point is zero
  - Voltage law: The directed sum of the potential differences (voltages) around any closed loop is zero

ADC (Analog to Digital Converter)

- ADC handles values from 0 to logic-level by converting an analog voltage to a digital value
- e.g. RP2040's ADC has **12 bits** depth and accordingly takes a raw value from **0 (0 V)** to **4095 (3.3 V)**
- Typical usage:
  - Temperature sensor 🌡️
  - Joystick 🕹️

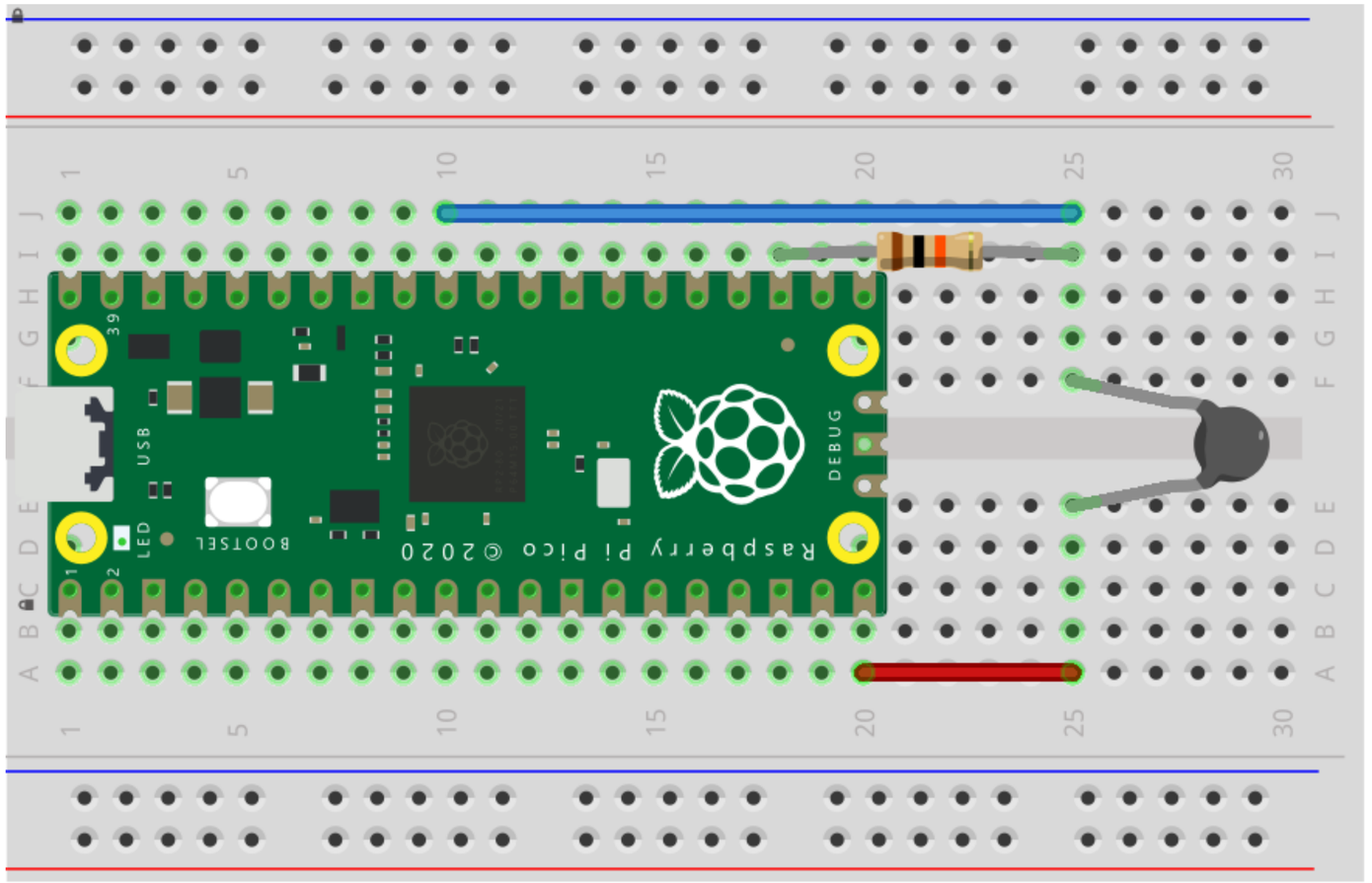
ADC --- Temperature [Demo]

```
irb> require 'adc'
irb> adc = ADC.new(:temperature)
irb> adc.read_raw
irb> while true
irb*   voltage = adc.read_voltage
irb*   puts 27 - (voltage - 0.706) / 0.001721
irb*   sleep 1
irb* end
```

RP2040 has an in-chip temperature sensor that connects to an ADC channel

ADC --- Temperature by discrete parts

- Parts list:
  - Resistor
    - Rref: 10kΩ
  - Thermistor
    - 10kΩ (at 25℃ = 298.15K)
    - B const: 3950
    - T0: 298.15 (kelvin)



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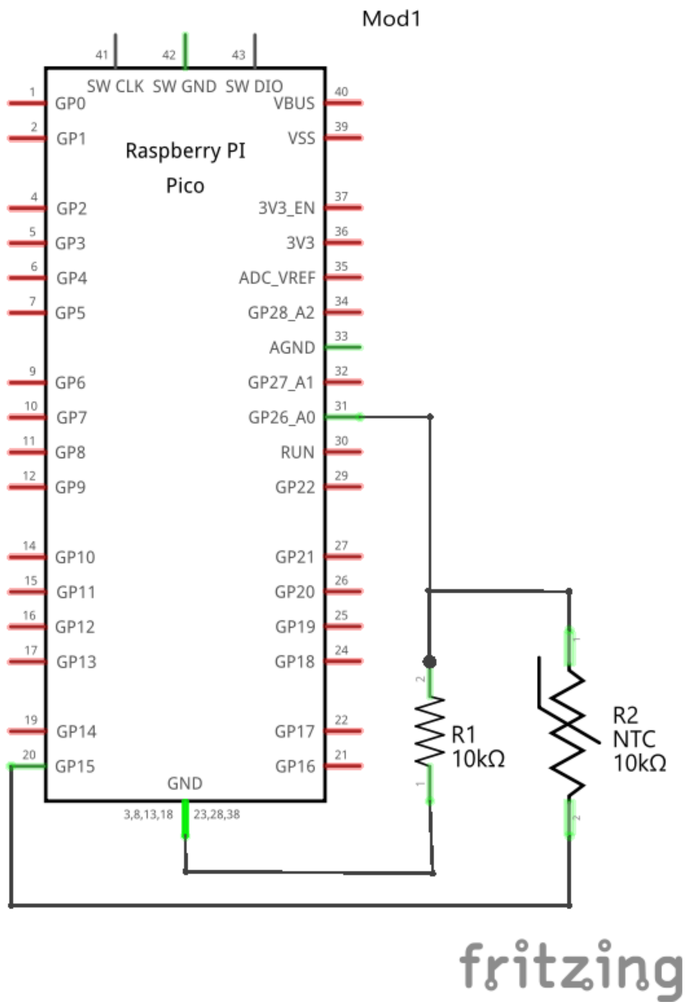

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ADC --- Temperature by discrete parts

```
irb> require 'adc'
irb> Rref = 10000.0
irb> B = 3950.0
irb> T0 = 298.15
irb> def kelvin_temp(rth)
irb*   temp_inverse = 1 / B * Math.log(rth / Rref) + (1 / T0)
irb*   1 / temp_inverse
irb* end
irb> rth = (3.3 / adc.read_voltage - 1) * Rref
irb> puts "#{kelvin_temp(rth) - 273.15} C"
=> 28.1234 C
```

Part 3

Exploring PicoRuby Further

PicoRuby applications

- R2P2
  - Unix-like shell system written in PicoRuby
  - You may want to say an Operating System in Ruby
- PRK Firmware
  - Keyboard firmware framework for DIY keyboard
  - You can write your keymap and keyboard's behavior with Ruby

R2P2 (again)

- IRB
  - Multiple-line editor
- Built-in commands and executables (all written in Ruby)
  - You can write your own external command

Executables in R2P2

```
# date
puts Time.now.to_s

# mkdir
Dir.mkdir(ARGV[0])
```

Write a Ruby script file [Demo]

```
$> vim hello.rb
```

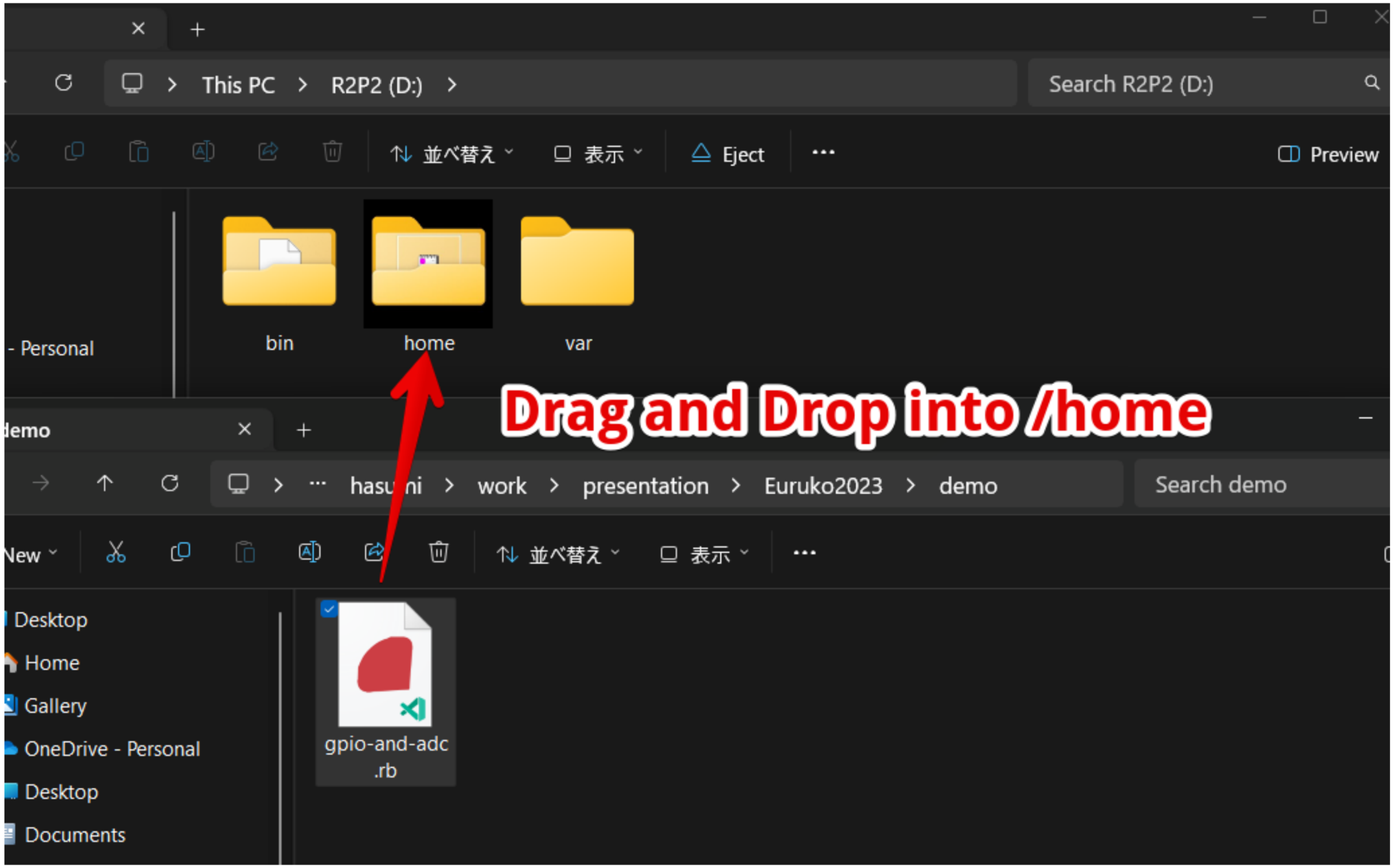
Edit the file and save it.

```
puts "Hello World!"
```

Then run it.

```
$> ./hello.rb
```

Or just drag and drop [Demo]



GPIO and ADC work together [Demo]

```ruby
require 'adc'
def calc_temp(volt)
  27 - (volt - 0.706) / 0.001721
end
adc = ADC.new(:temperature)
led = GPIO.new(25, GPIO::OUT)
while true
  temp = calc_temp(adc.read_voltage)
  puts "temp: #{temp} C"
  led.write(30 < temp ? 1 : 0)
  sleep 1
end
```

R2P2 [Demo]

- `/home/app.rb` automatically runs on start up

```
# You can stop by Ctrl-C
led = GPIO.new(25, GPIO::OUT)
while true
  led.write 1
  puts "Hello World!"
  sleep 1
  led.write 0
  sleep 1
end
```

BTW,

R2P2 stands for

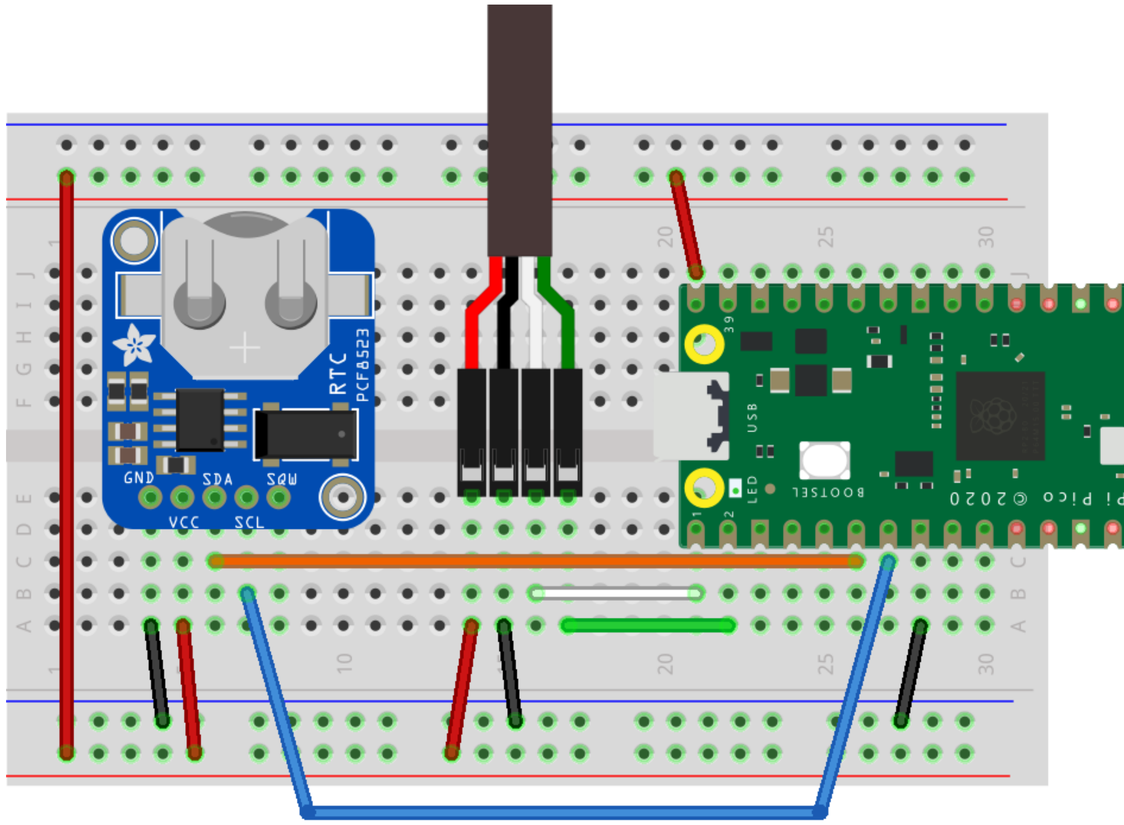
Ruby on **R**aspberry **P**i **P**ico

[FYI] Serial communication protocols

- SPI: High speed, full duplex. e.g. Acceleration sensor, Color display, etc.
- I2C: Low speed, Addressing network with fewer wires. e.g. RTC, Temperature sensor and Charactor display, etc.
- UART: Buffered asyncronous communication. e.g. Terminal emulator, Wireless module like BLE and LTE/5G, etc.

[FYI] I2C and UART

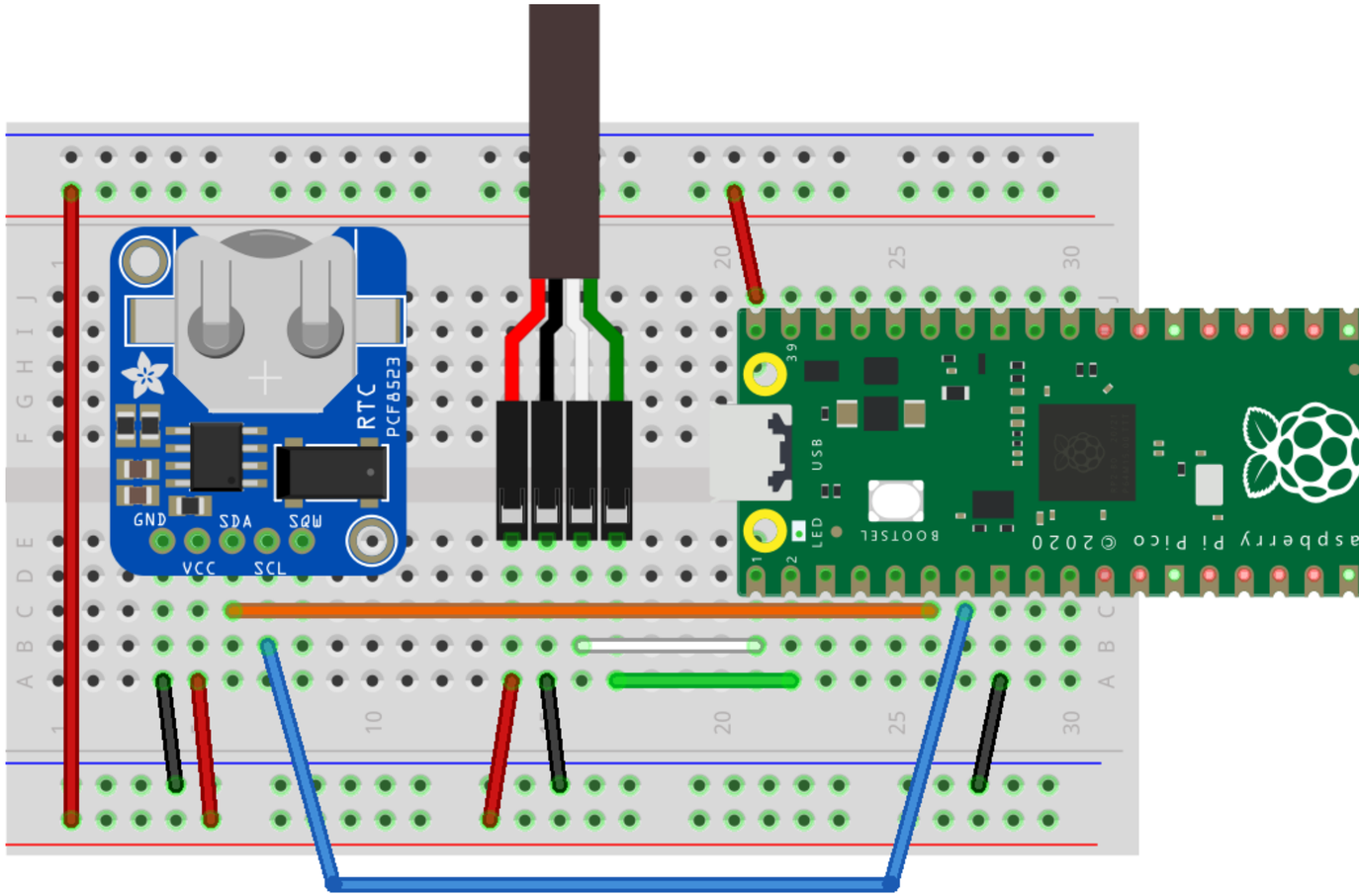
- Example of I2C (RTC) and UART (USB serial)
- Watch the demo video in README.md
- It's also an example of how to build your own app



github.com/picoruby/rp2040-peripheral-demo

[FYI] I2C and UART

- Parts list:
  - PCF8523 RTC module
  - FTDI USB to TTL Serial Adapter Cable (3.3V)



PRK Firmware - Corne (CRKBD)

PRK Firmware - Meishi2 (4-keys pad)

```
require "consumer_key"
kbd = Keyboard.new
kbd.init_pins(
  [ 6, 7 ],    # row0, row1
  [ 28, 27 ]   # col0, col1
)
kbd.add_layer :default, %i[ ZERO_RAISE  KC_1  KC_2  KC_3 ]
kbd.define_mode_key :ZERO_RAISE, [ :KC_0, :raise, 200, 200 ]
kbd.add_layer :raise,   %i[ ZERO_RAISE
                            KC_AUDIO_VOL_UP
                            KC_AUDIO_VOL_DOWN
                            KC_AUDIO_MUTE ]
kbd.start!
```

Part 4

PicoRuby Under the Hood

mruby and PicoRuby

- mruby
  - General purpose embedded Ruby implementation written by Matz
- PicoRuby (PicoRuby compiler + mruby/c VM)
  - Another implementation of murby targeting on one-chip microcontroller (**smaller foot print**)
- The VM code specifications are common to both
  - So the compilers are interchangeable

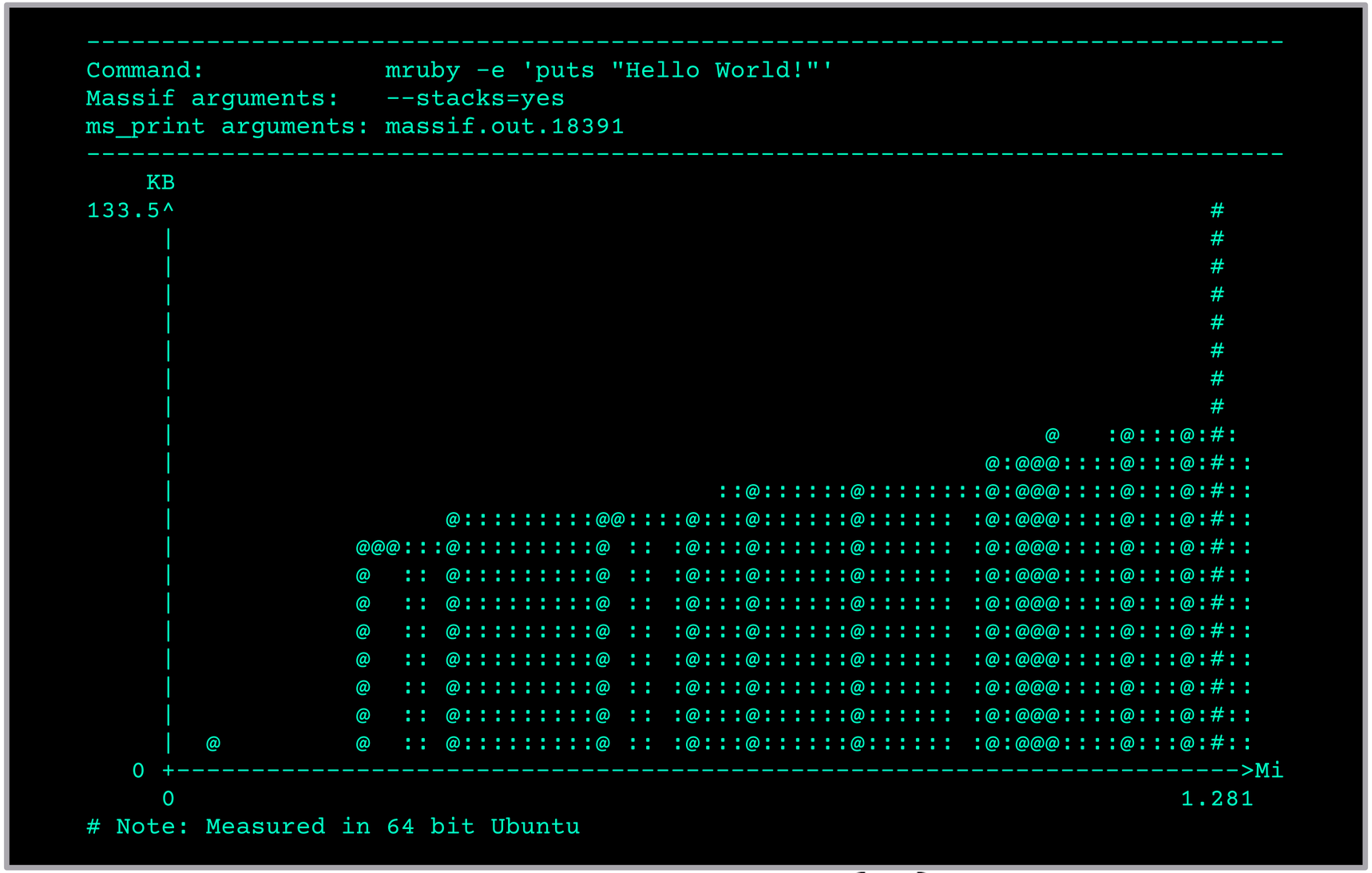
Small foot print

```
$ valgrind                                  \
    --tool=massif                           \
    --stacks=yes                            \
    path/to/(mruby|picoruby)                \
    -e 'puts "Hello World!"'
```

`massif.out.[pid]` file will be created. Then,

```
$ ms_print massif.out.1234 | less
```

Small foot print



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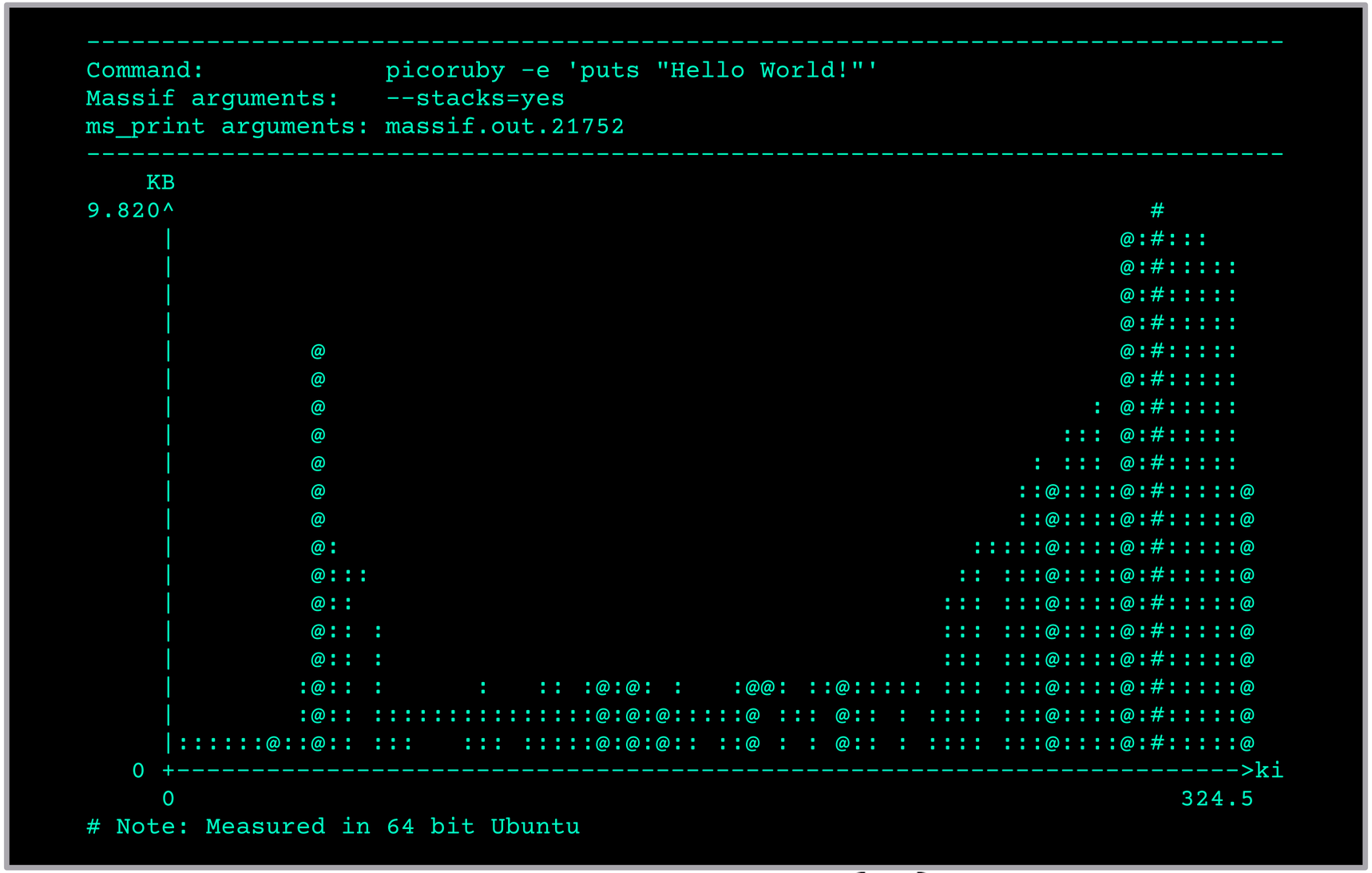
Small foot print



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Small foot print

- RAM consumption of `puts "Hello World!"`
  - mruby: 133.5 KB (on 64 bit)
  - PicoRuby: 9.82 KB (on 64 bit)
- RP2040 (32 bit) has 264 KB RAM
  - Only small applications running with mruby works
  - Big apps like R2P2 and PRK Firmware should be written in PicoRuby

PicoRuby ecosystem

- Picogems
  - PRK Firmware is also a Picogem
  - Peripheral gems
    - picoruby-gpio
    - picoruby-adc
    - picoruby-i2c
    - picoruby-spi
    - picoruby-uart
  - Peripheral interface guide
    - https://github.com/mruby/microcontroller-peripheral-interface-guide

PicoRuby ecosystem

- Build system forked from mruby
  - You can build your application in a similar way to mruby
  - You can also write your gem and host it on your GitHub
- RP2040 is the only target as of now. So,
  - You can port PicoRuby (Picogems) to other microcontrollers

Restrictions of PicoRuby

- Minimum built-in classes and methods
- Doesn't support some syntax like heredoc and numbered parameters
- No meta-programming features
- No strict distinction between instance methods and singleton methods
- Some bugs (because I'm lazy🥺).
  See github.com/picoruby/picoruby/issues

Conclusion

- PicoRuby is a Ruby implementaiton targeting on one-chip microcontroller
- Essential peripheral libraries: GPIO, ADC, I2C, SPI, and UART are ready
- You can develop your microcontroller application step by step using the R2P2 and IRB
- You need only R2P2 to write small applications
- Future work:
  - Bluetooth for "Raspberry Pi Pico **W**" (soon 🤞)


RubyKaigi 2024
In Okinawa 🏝 May 15th - 17th
1000+ attendees, tons of tech talks
All Japanese talks come with simultaneous interpretation into English
Various parties 🍻
https://098free.com/photos/14262/

That's all! Visit repos and stargaze🌟

github.com/picoruby/picoruby

github.com/picoruby/R2P2

github.com/picoruby/prk_firmware

github.com/picoruby/rp2040-peripheral-demo