A Beginner's Complete Guide to Microcontroller Programming with Ruby

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Today’s content

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Preparation

Part 2

Getting Started with Microcontroller

Part 3

Exploring PicoRuby Further

Part 4

PicoRuby Under the Hood

self.inspect

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- ANDPAD: construction tech 👷
- Creator of PicoRuby
- Contributor to CRuby and mruby
- Member of IRB maintainer team

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The former IRB maintainer

Itoyanagi-san

RubyConf Africa 2019

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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
  - Generally runs without an OS
- Raspberry Pi: Single-board computer
  - Generally needs an OS like Raspberry Pi OS or Windows for Arm

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Terminal emulator (recommendation)

- Linux -> GTKTerm
- Windows -> Tera Term
- macOS -> PuTTY

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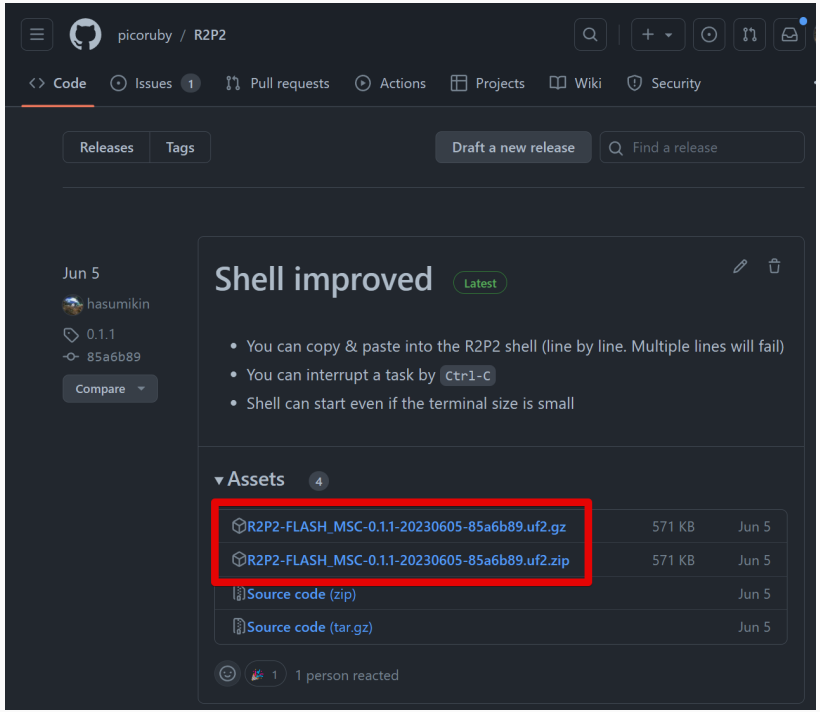
Let’s begin 1/4

- Download the latest `R2P2-*.uf2` from GitHub



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Let’s begin 1/4

BTW, R2P2 stands for
Ruby on Raspberry Pi Pico

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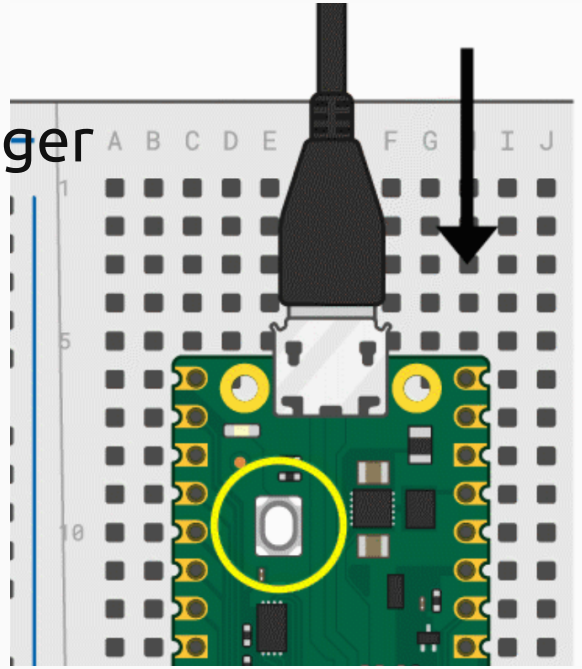
Let’s begin 2/4

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



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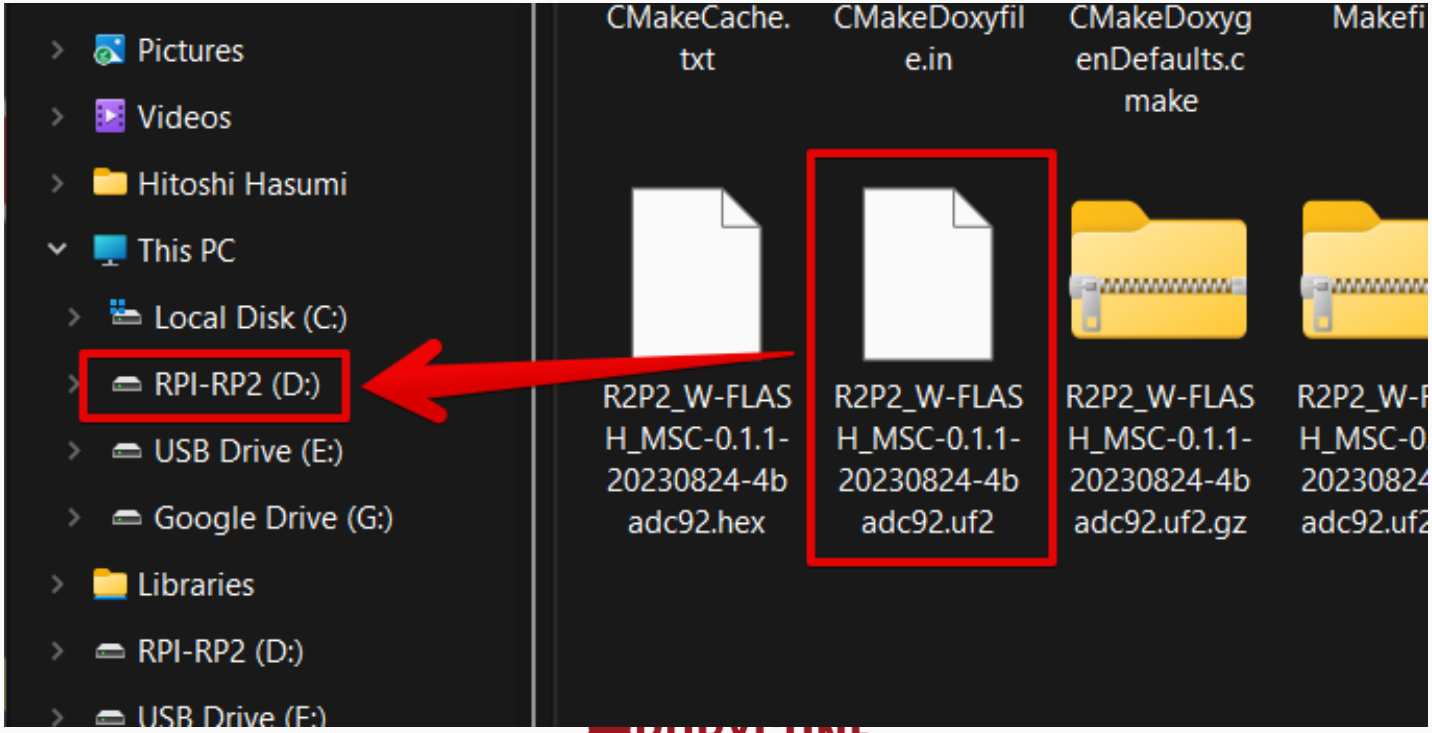
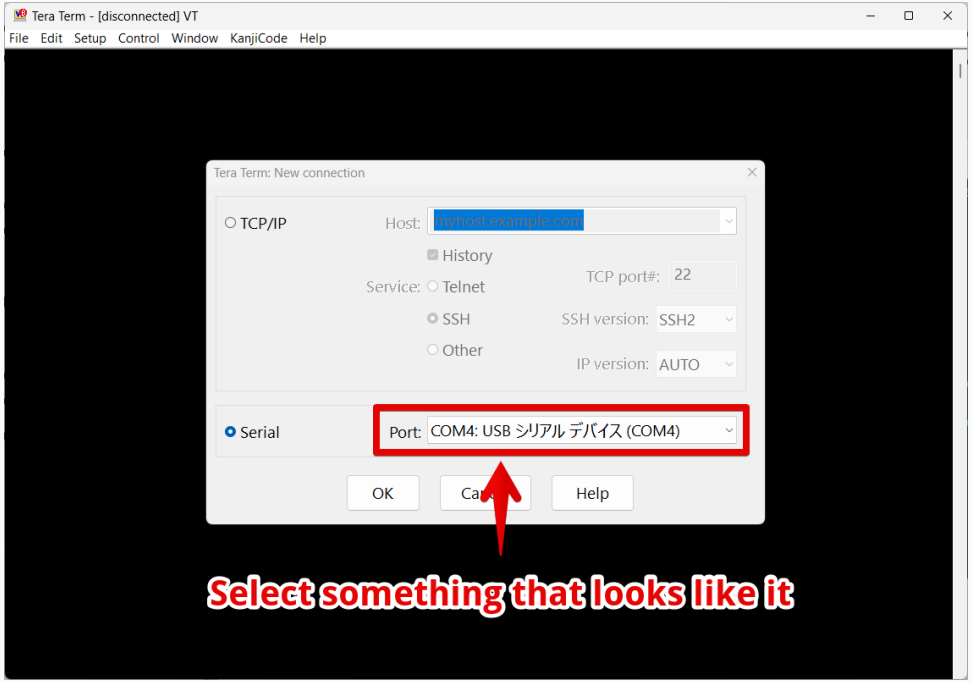
Let’s begin 3/4

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



Let’s begin 4/4

- Open a proper serial port on terminal emulator



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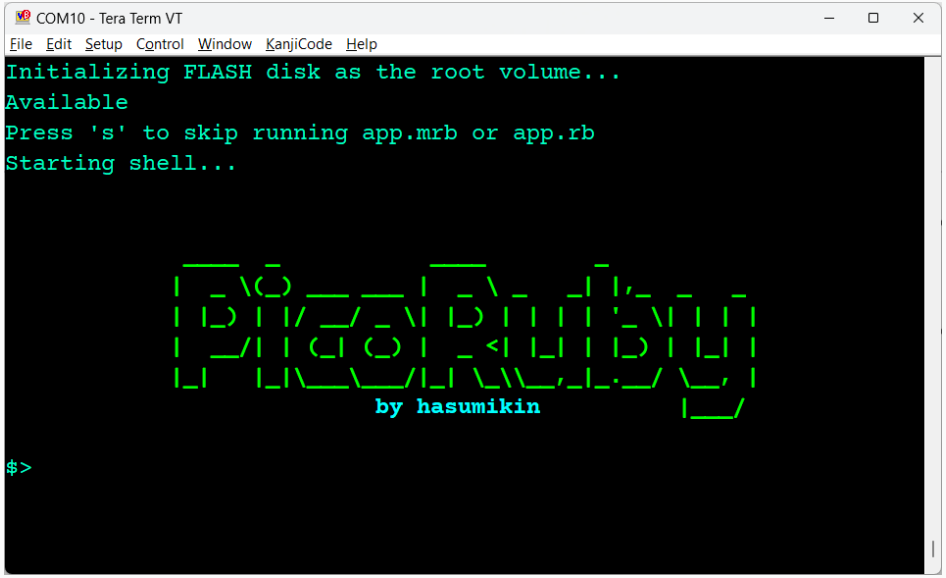
R2P2 Shell should start [Demo]

- Unix-like shell running on Raspberry Pi Pico
- You can use some commands like `cd`, `ls`, `mkdir`, and `irb`



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PicoIRB [Demo]

- PicoRuby's IRB is running within the R2P2 shell on Raspberry Pi Pico
- Your Ruby snippet is 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

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> 5.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

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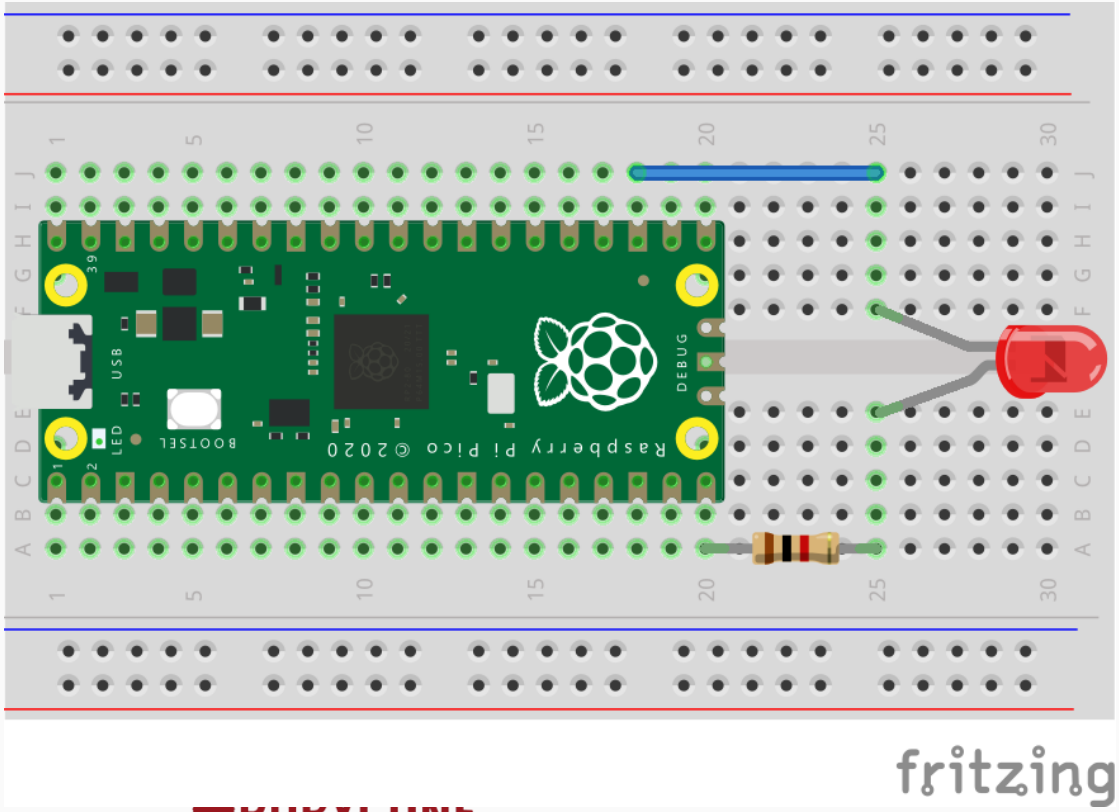
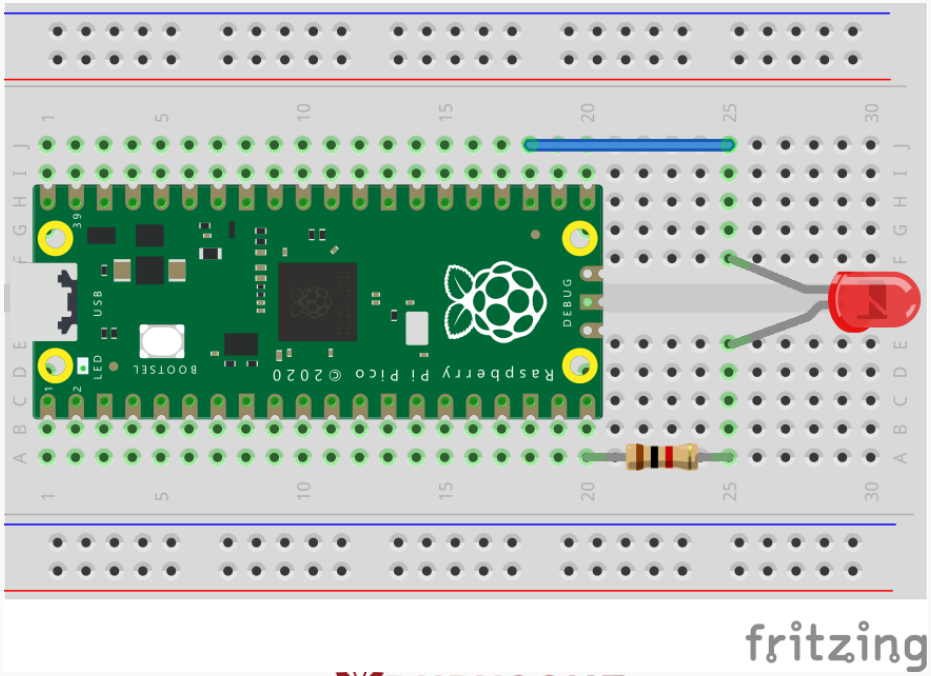
GPIO — Blinking LED by discrete parts

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



GPIO — Blinking LED by discrete parts

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



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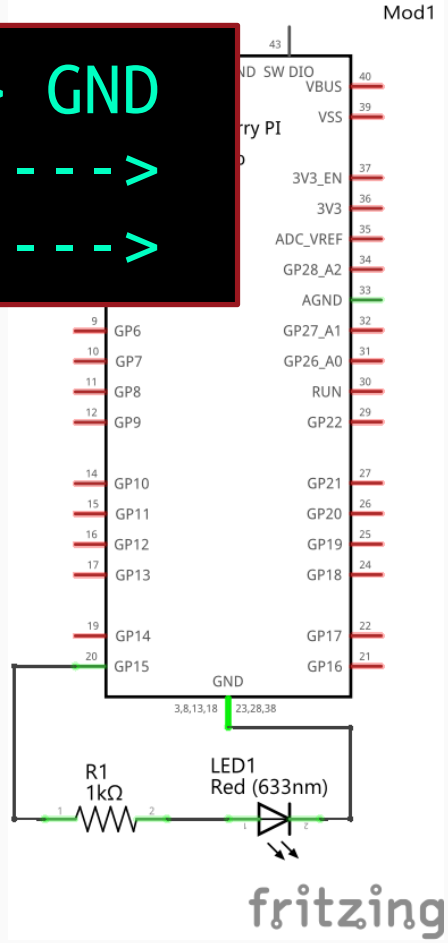
GPIO — Blinking LED by discrete parts

```
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: Physics

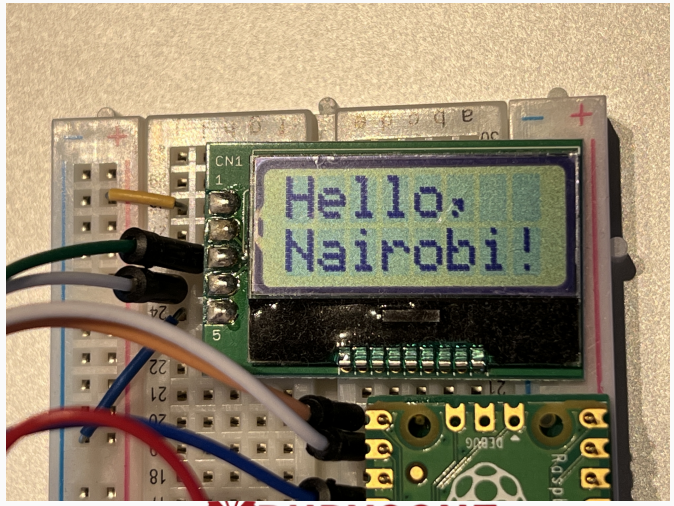
- Ohm's Law
  - $V = I - R \Leftrightarrow I = V / R \Leftrightarrow R = V / I$
- Kirchhoff's Circuit Laws
  - Current law: The algebraic sum of currents in a network of conductors meeting at a point is zero
  - Voltage law: The directed sum of the potential differences (voltages) around any closed loop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

Peripherals for serial communication

- I²C: To communicate between integrated circuits with support for multiple devices connected to the same bus
- SPI: To facilitate high-speed communication between microcontrollers and peripheral devices
- UART: To establish asynchronous serial communication between devices

I²C — Inter-Integrated Circuit

```
irb> require 'i2c'
irb> i2c = I2C.new(unit: :RP2040_I2C1, sda_pin: 26, scl_pin: 27)
irb> [0x38, 0x39, 0x14, 0x70, 0x56, 0x6c].each { |i| i2c.write(0x3e, 0, i); sleep_ms 1 }
irb> [0x38, 0x0c, 0x01].each { |i| i2c.write(0x3e, 0, i); sleep_ms 1 }
irb> "Hello,".bytes.each { |c| i2c.write(0x3e, 0x40, c); sleep_ms 1 }
irb> i2c.write(0x3e, 0, 0x80|0x40)
irb> "Nairobi!".bytes.each { |c| i2c.write(0x3e, 0x40, c); sleep_ms 1 }
```



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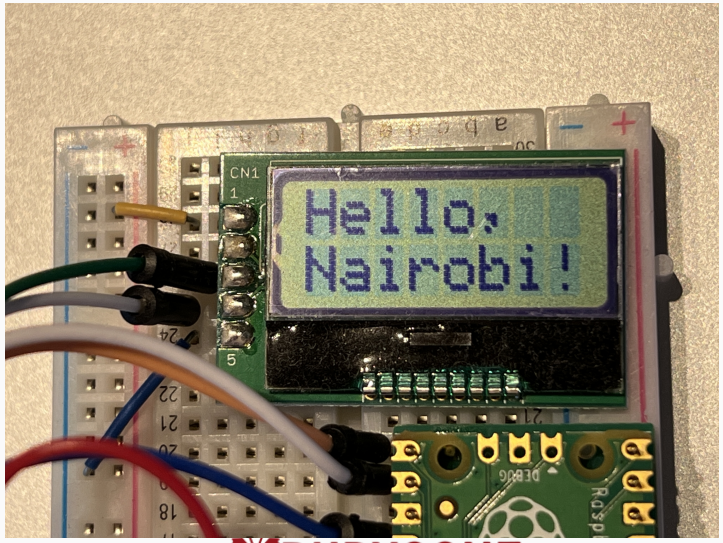
LCD wraps I²C

```ruby
# /lib/lcd.rb in R2P2 drive
require 'i2c'
class LCD
  ADDRESS = 0x3e # 0x7c == (0x3e << 1) + 0 (R/W)
  def initialize(i2c:)
    @i2c = i2c
    reset
  end
  def reset
    [0x38, 0x39, 0x14, 0x70, 0x56, 0x6c].each { |i| @i2c.write(ADDRESS, 0, i) }
    sleep_ms 200
    [0x38, 0x0c, 0x01].each { |i| @i2c.write(ADDRESS, 0, i) }
  end
  def putc(c)
    @i2c.write(ADDRESS, 0x40, c)
    sleep_ms 1
  end
  def print(line)
    line.bytes.each { |c| putc c }
  end
# ...
# See https://github.com/picoruby/picoruby/tree/master/mrbgems
#   /picoruby-ble/example/broadcaster-observer
```

LCD wraps I²C

```
irb> require 'lcd'
irb> lcd = LCD.new(i2c: I2C.new(unit: :RP2040_I2C1, sda_pin: 26, scl_pin: 27))
irb> lcd.print "Hello,"
irb> lcd.break_line
irb> lcd.print "Nairobi!"
```



SPI — Serial Peripheral Interface

```
irb> require 'spi'
irb> spi = SPI.new(unit: :RP2040_SPI0, cipo_pin: 16,
           cs_pin: 17, sck_pin: 18, copi_pin: 19)
irb> spi.select
irb> spi.write(255,255,255,255) # Reset
irb> spi.write(0x54)            # Start continuous mode
irb> data = spi.read(2).bytes
irb> temp = data[0] << 8 | data[1]
irb> temp / 128.0               # Convert to Celsius
=> 19.5621
```

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THERMO wraps SPI

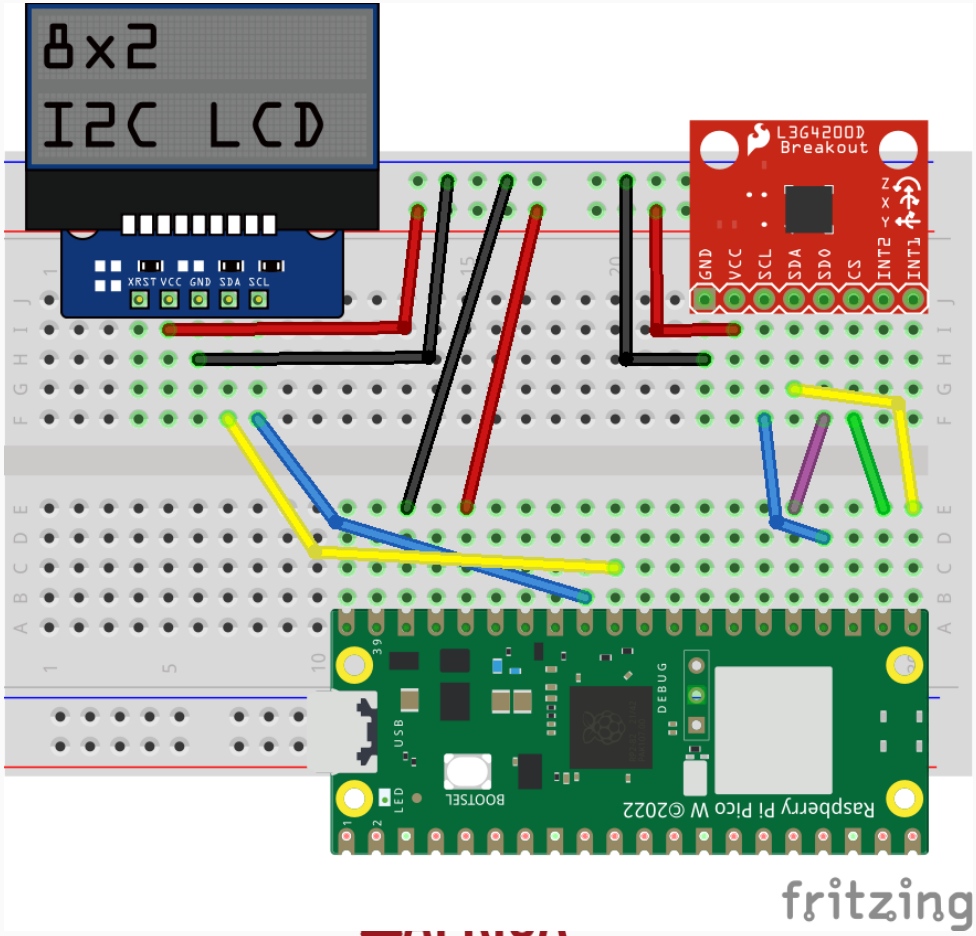
```ruby
#/lib/thermo.rb in R2P2 drive
require 'spi'
class THERMO
  def initialize(unit:, sck_pin:, cipo_pin:, copi_pin:, cs_pin:)
    @spi = SPI.new(unit: unit, frequency: 500_000, mode: 0, cs_pin: cs_pin,
      sck_pin: sck_pin, cipo_pin: cipo_pin, copi_pin: copi_pin
    )
    @spi.select
    @spi.write 0xFF, 0xFF, 0xFF, 0xFF # Reset
    @spi.write 0x54 # Start continuous mode
    sleep_ms 240
  end

  def read
    data = @spi.read(2).bytes
    temp = (data[0] << 8 | data[1]) >> 3
    # If it minus?
    temp -= 0x2000 if 0 < temp & 0b1_0000_0000_0000
    temp / 16.0  # Convert to Celsius
  end
end
# See https://github.com/picoruby/picoruby/tree/master/mrbgems
```

THERMO wraps SPI

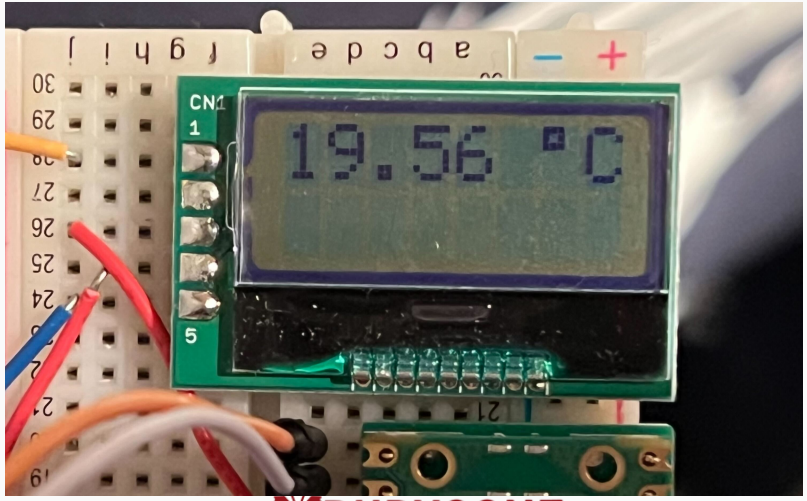
```
irb> require 'thermo'
irb> thermo = THERMO.new(unit: :RP2040_SPI0,
                         cipo_pin: 16, cs_pin: 17, sck_pin: 18, copi_pin: 19)
irb> thermo.read
=> 19.5621
```

LCD and THERMO



LCD and THERMO

```
irb> require 'lcd'
irb> lcd = LCD.new(i2c: I2C.new(unit: :RP2040_I2C1, sda_pin: 26, scl_pin: 27))
irb> require 'thermo'
irb> thermo = THERMO.new(unit: :RP2040_SPI0,
               cipo_pin: 16, cs_pin: 17, sck_pin: 18, copi_pin: 19)
irb> lcd.print sprintf("%5.2f \xdfC", thermo.read)
```



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Part 3

Exploring PicoRuby Further

PicoRuby killer applications

- R2P2
  - Microcontroller application framework
  - Unix-like shell system and IRB written in PicoRuby
- 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, for example,

```ruby
# date
puts Time.now.to_s
```

```ruby
# 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
```

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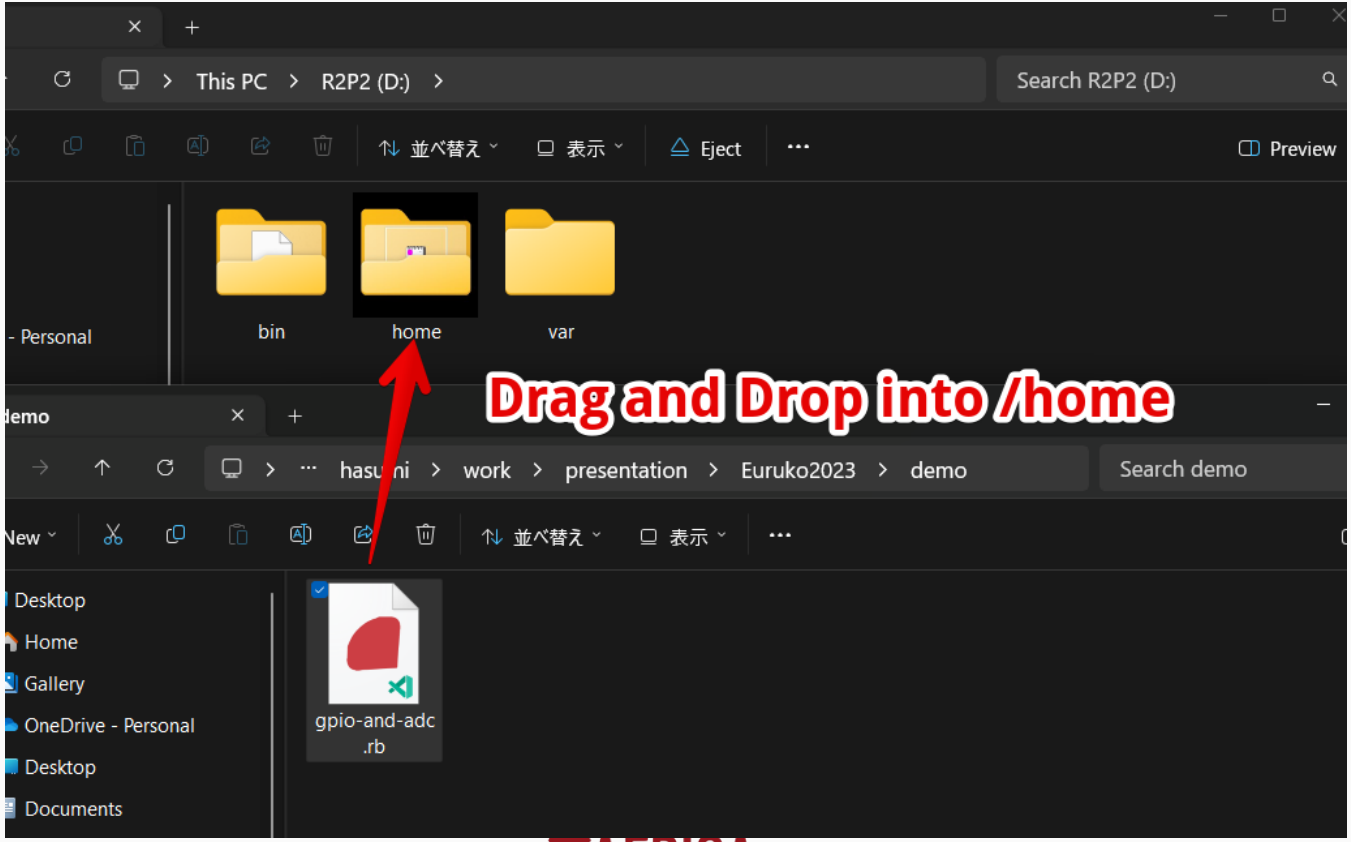
Make a standalone IoT device

```ruby
# `/home/app.rb` automatically runs
require 'lcd'
require 'thermo'




led = GPIO.new(25, GPIO::OUT)
lcd = LCD.new(i2c: I2C.new(unit: :RP2040_I2C1,
                           sda_pin: 26, scl_pin: 27))
thermo = THERMO.new(unit: :RP2040_SPI0, cipo_pin: 16,
                    cs_pin: 17, sck_pin: 18, copi_pin: 19)




# Stop infinite loop by Ctrl-C
while true
  temp = thermo.read
```

Make a standalone IoT device



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)
  - Based on the mruby's VM code standard

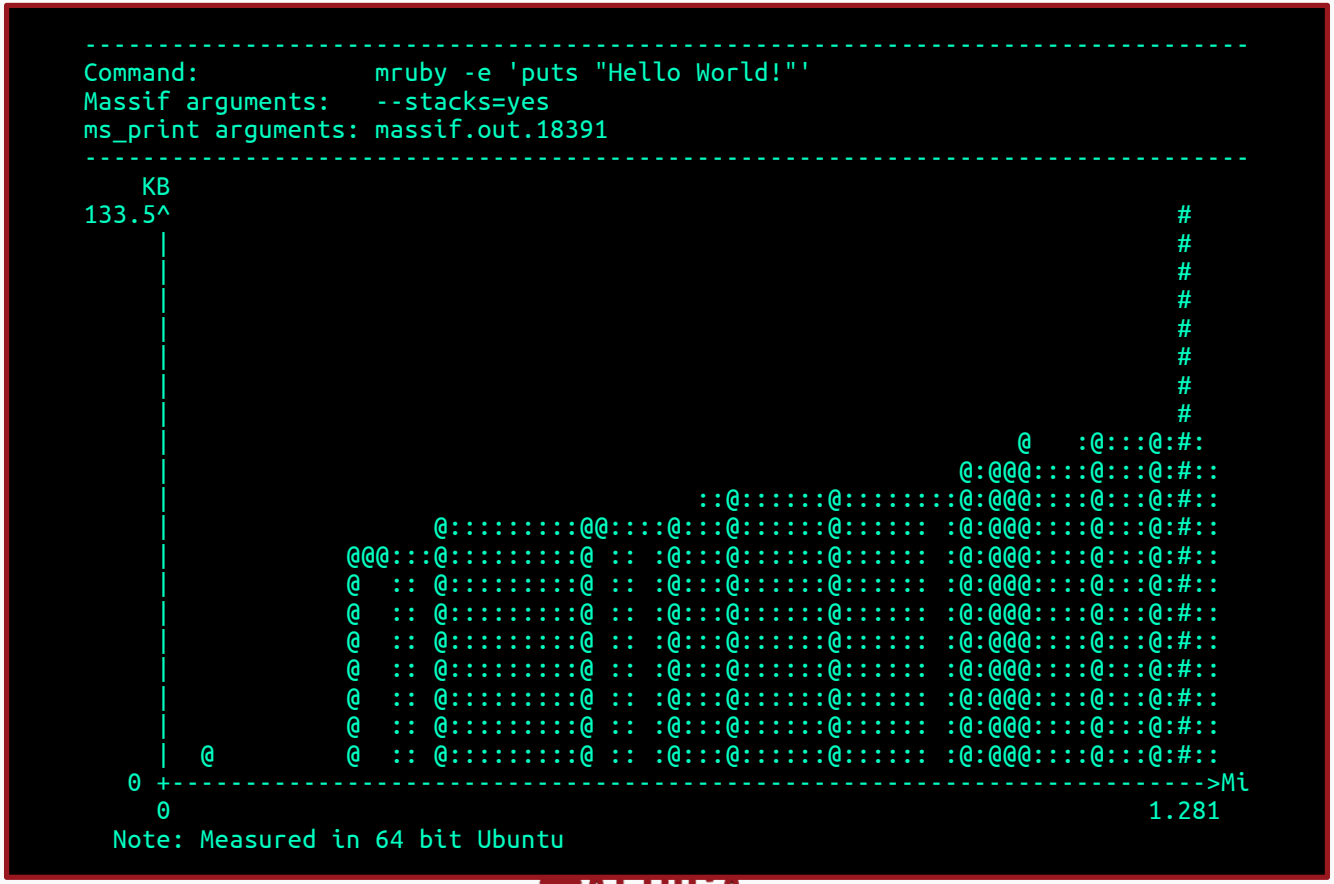
Small foot print

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

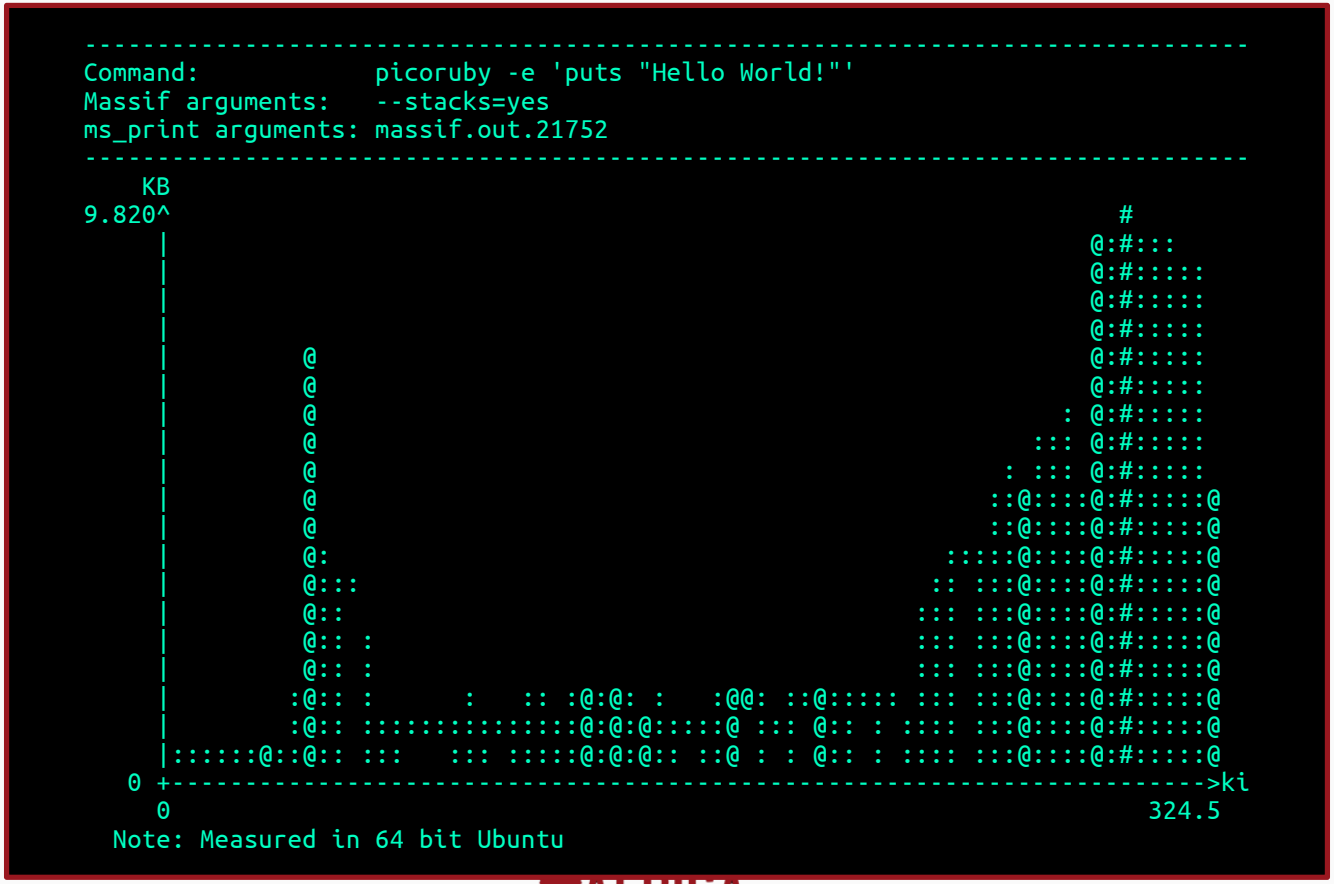
`massif.out.[pid]` file will be created. Then,

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

Small foot print



Small foot print



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 written in mruby should work
  - R2P2 and PRK Firmware should be written in PicoRuby

PRK Firmware: DIY keyboard firmware

PRK Firmware on Meishi2 (4-keys macro pad)

PRK Firmware on Meishi2 (4-keys macro pad)

```
require "consumer_key"
kbd = Keyboard.new
kbd.init_pins(
    [ 6, 7 ],   # row0, row1
    [ 28, 27 ]  # col0, col1
)
kbd.add_layer :default, %i[ RAISE  KC_2  KC_A  KC_4 ]
kbd.add_layer :raise,   %i[ RAISE
                            KC_AUDIO_VOL_UP
                            KC_AUDIO_VOL_DOWN
                            KC_AUDIO_MUTE ]
kbd.define_mode_key :RAISE, [ :KC_SPACE, :raise, 200, 200 ]
kbd.start!
```

PicoRuby ecosystem

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

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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 though,
  - Carefully designed to keep portability

Conclusion

- PicoRuby is a Ruby implementaiton targeting on one-chip microcontroller
- You can prototype your microcontroller application step-by-step using R2P2 and IRB
- You don’t need any compiler or linker
- Educational and fun to learn about microcontroller programming

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Stargaze at

github.com/picoruby/picoruby

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