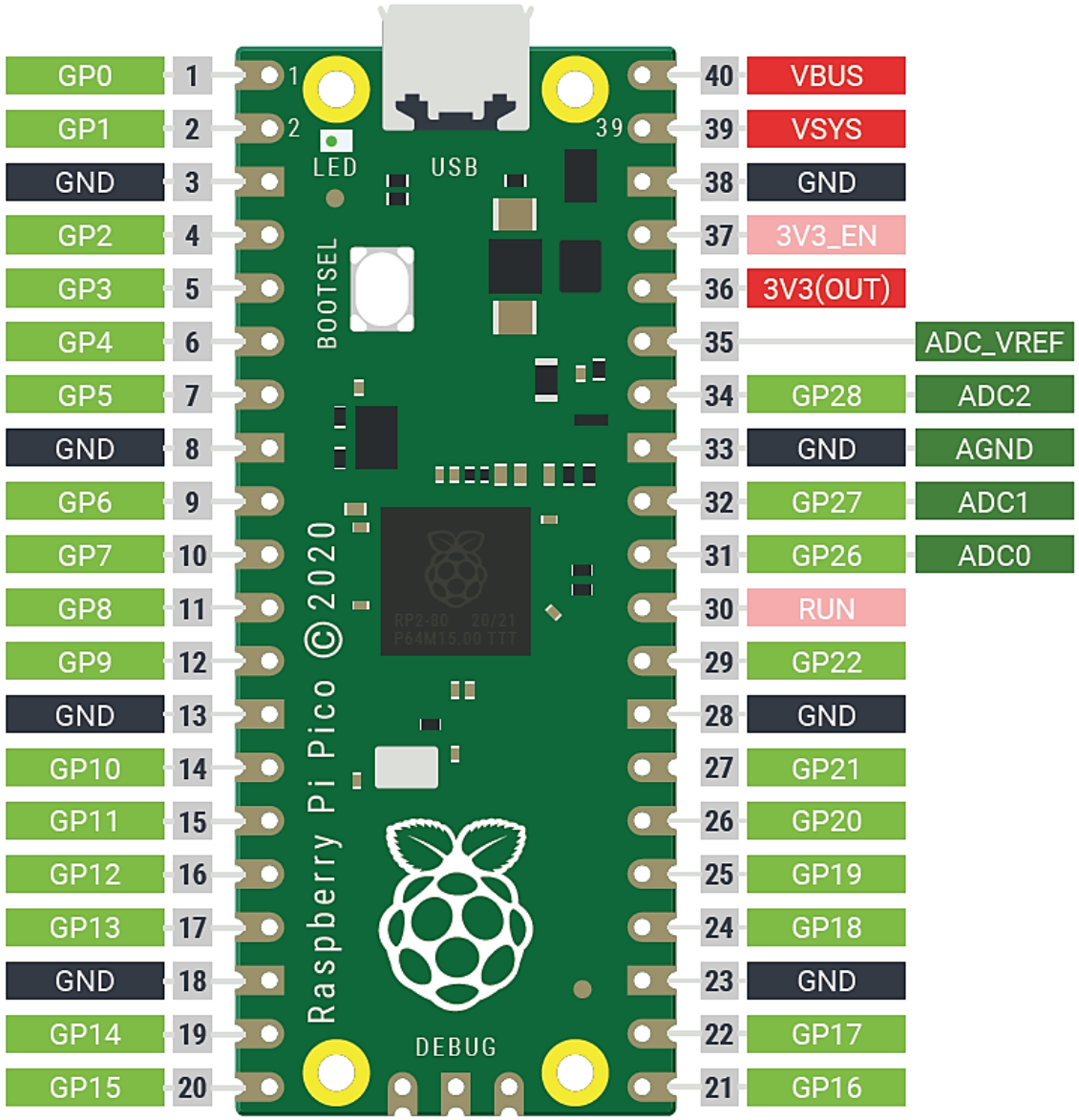
Measuring temperatures using the Raspberry Pi Pico: inside the RP2040, not outside

Kruno Peter

Research and Teaching Department

Andrija Stampar Teaching Institute of Public Health

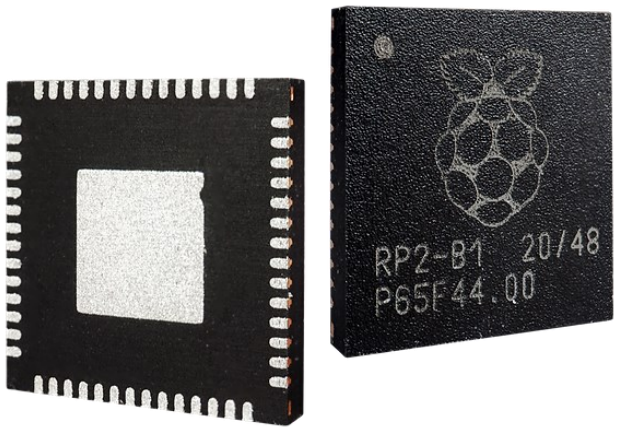
the Raspberry Pi Pico microcontroller board*



- the RP2040 microcontroller:
  - dual-core Arm Cortex-M0+
  - 264 KB on-chip SRAM
  - a temperature sensor
- on-board
  - 2 MB flash memory
  - a micro-USB port
  - a green LED
- operating temperature: -20 °C to +85 °C
- programming:
  - C/C++
  - MicroPython
  - CircuitPython
  - Arduino IDE

* Raspberry Pi Ltd 2022, 'Raspberry Pi Pico Datasheet – An RP2040-based microcontroller board'; Pico W and Pico H have different schemas.

the internal temperature sensor[#]



- connected to the fifth channel of ADC[#]

  sensor_temp = machine.ADC(4)

- Pico runs internally at 3.3 volts of power

- read_u16() reads an analogue input as a 16-bit integer[#]

  conversion_factor = 3.3 / (65535)

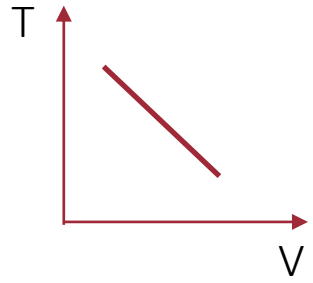
  voltage = sensor_temp.read_u16() * conversion_factor

3.3 V internally

- the sensor measures the V_{BE} voltage of a biased bipolar diode[#]

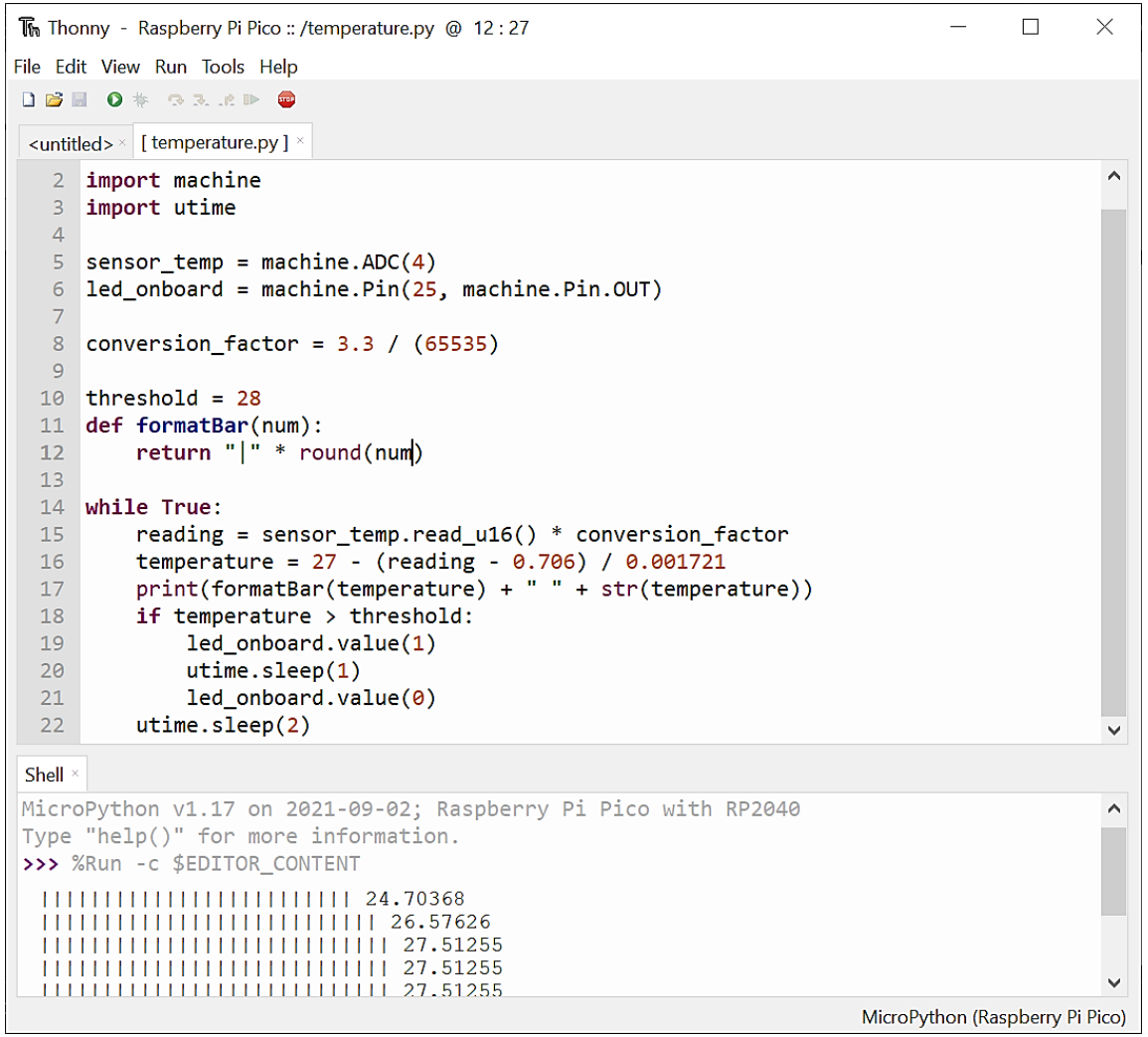
- typically, V_{BE} = 0.706 V at 27 °C, with a slope of -1.721 mV (0.001721 V) per degree[#]

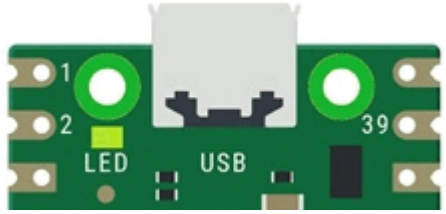
  temperature = 27 - (voltage - 0.706) / 0.001721



[#] Raspberry Pi Ltd 2022, 'Raspberry Pi Pico Python SDK – A MicroPython environment for RP2040 microcontrollers'

```
# added*: visualizing temperatures and signalizing a breach
import machine
import utime

sensor_temp = machine.ADC(4)
led_onboard = machine.Pin(25, machine.Pin.OUT)

conversion_factor = 3.3 / (65535)

threshold = 28
def formatBar(num):
    return "|" * round(num)

while True:
    reading = sensor_temp.read_u16() * conversion_factor
    temperature = 27 - (reading - 0.706) / 0.001721
    print(formatBar(temperature) + " " + str(temperature))
    if temperature > threshold:
        led_onboard.value(1)
        utime.sleep(1)
        led_onboard.value(0)
    utime.sleep(2)
```

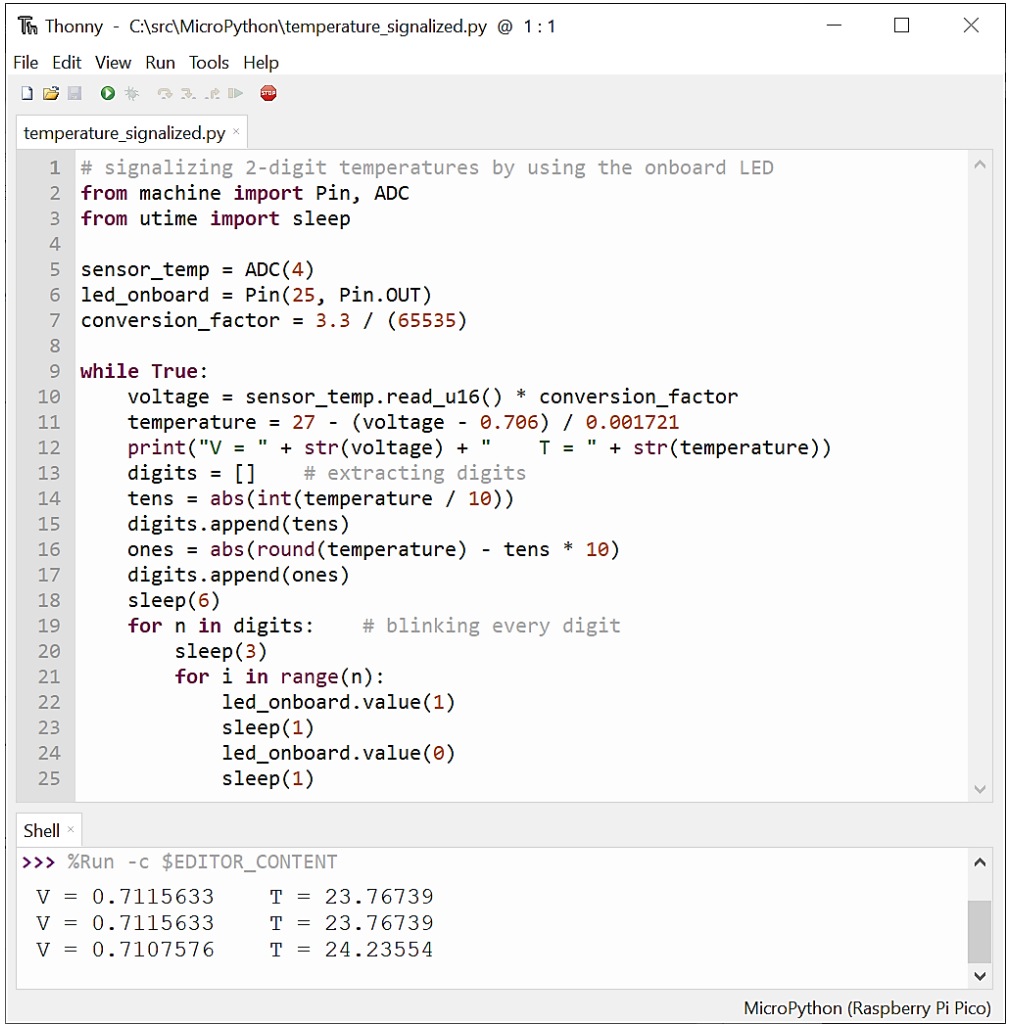


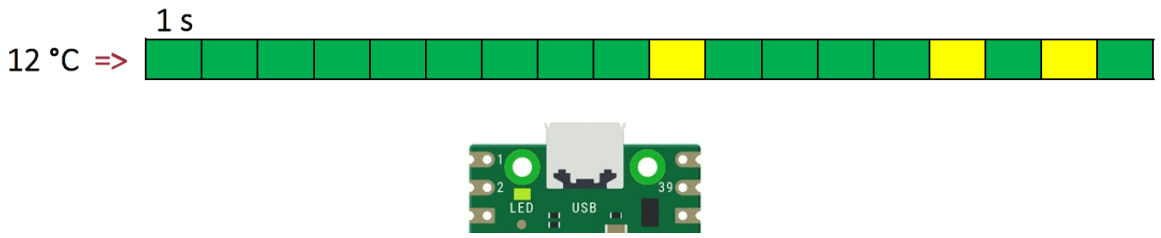


* https://github.com/raspberrypi/pico-micropython-examples/tree/master/adc/temperature.py; https://github.com/kruno-peter/pico-temperature/blob/main/temperature.py

signalizing 2-digit temperatures by using the onboard LED*

```
from machine import Pin, ADC
from utime import sleep

sensor_temp = machine.ADC(4)
led_onboard = Pin(25, Pin.OUT)
conversion_factor = 3.3 / (65535)

while True:
    voltage = sensor_temp.read_u16() * conversion_factor
    temperature = 27 - (voltage - 0.706) / 0.001721
    print("V = " + str(voltage) + "    T = " + str(temperature))
    digits = []                                    # extracting digits
    tens = abs(int(temperature / 10))
    digits.append(tens)
    ones = abs(round(temperature) - tens * 10)
    digits.append(ones)
    utime.sleep(6)
    for x in digits:                               # blinking every digit
        utime.sleep(3)
        for i in range(x):
            led_onboard.value(1)
            utime.sleep(1)
            led_onboard.value(0)
            utime.sleep(1)
```

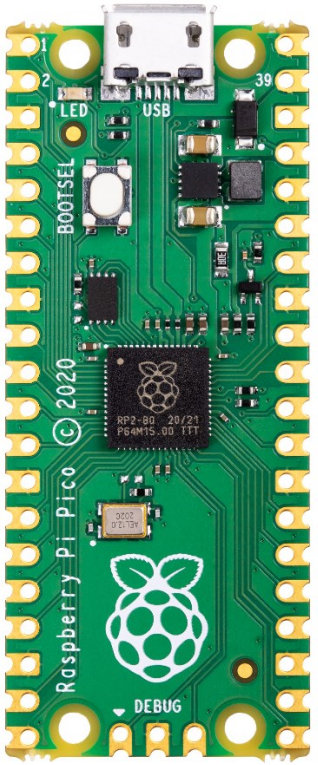




* https://github.com/kruno-peter/pico-temperature/blob/main/temperature_signalized.py

the temperature inside the microcontroller and the ambient temperature

- is it possible to measure the environment temperature using the internal temperature sensor?
- Pico may report different temperatures than actual ambient temperatures
  - the microcontroller generates heat of its own*
  - intensive data processing increases the internal temperature of the RP2040*
- a solution: a temperature sensor, for example, the DHT11 temperature & humidity sensor

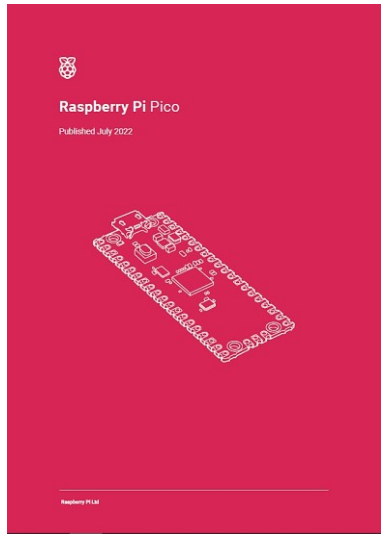


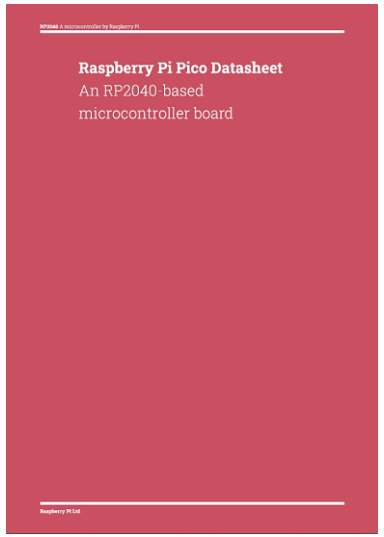
* Halfacree G, Everard B 2021, 'Get started with MicroPython on Raspberry Pi Pico', Raspberry Pi (Trading) Ltd, pp. 100

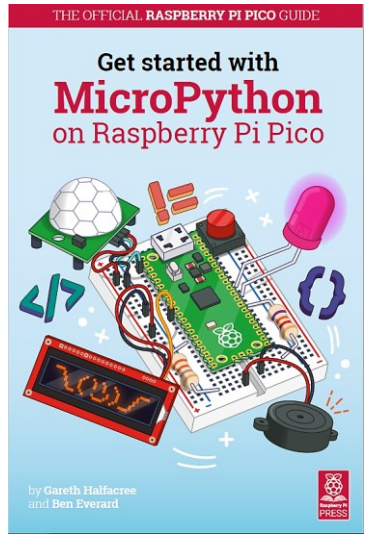
conclusions

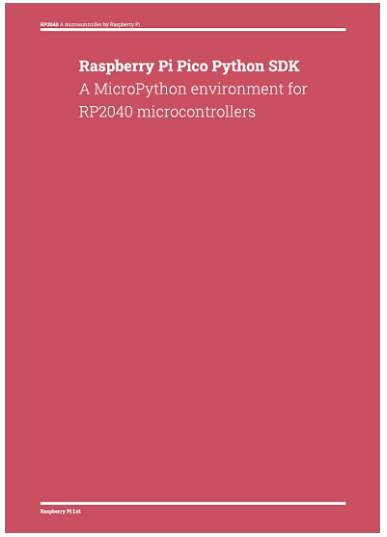
- the internal temperature sensor suitable for measuring temperatures inside RP2040 (not outside)
- documented and reusable MicroPython source code for that purpose

literature









raspberrypi.com

MicroPython

micropython.org

HS

hackspace.raspberrypi.com