Part1:

Measurement of the response time INPUT -> OUTPUT.

The measurement is done with a oszilloscope. Therefore a input pin is connected to the Channel2 and the output to Channel1. With the connection to 3.3V the input pin is set to "high". The response time is defined by the time difference between the rising edge of the input and output.

For the evaluation of the methods additional measurements with a fully loaded CPU and the allocation of priorities are made.

For stressing the CPU the `stress` command is used. Setting the priority: `sudo nice -n -10`

bash script using gpiod

Give permissions to file using: `chmod u+x flash_new.sh` Execute bash script using: `./flash_new.sh &`

The `&` sends the process to the background and the cpu load can be determined using the `top` command:

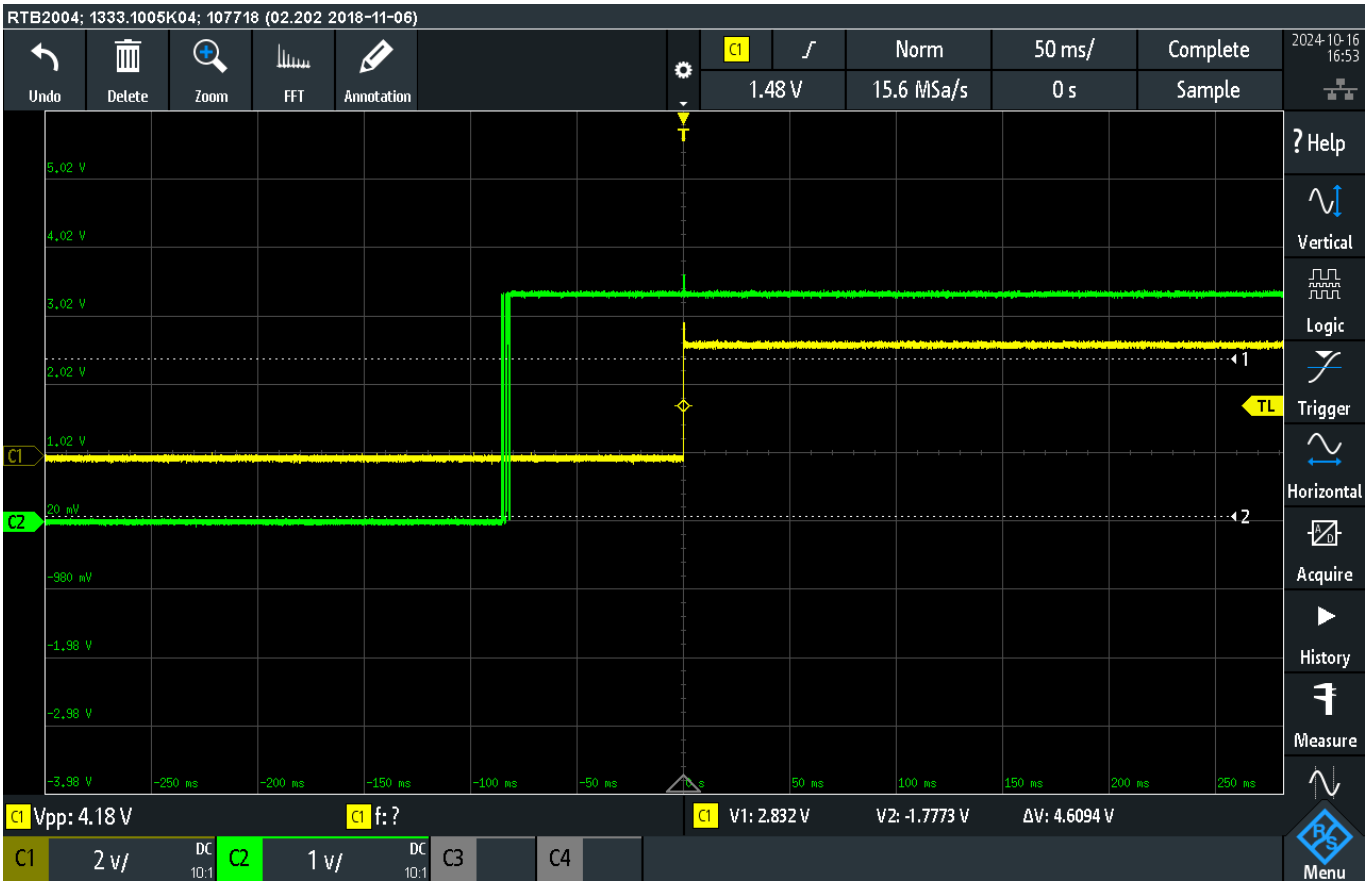
```
PID USER PR  NI  VIRT   RES   SHR S  %CPU  %MEM  TIME+ CMD
2493 pi  20   0  8128  3500  2132 R  22.8   0.8  0:09.64 bash

pi@rpi-matthiasr24:~/Linux_Motor_Encoder/part1 $ kill 2493
[1]+  Terminated              ./flash_new.sh
```

CH2: input connected to pin20

CH1: output connected to pin17

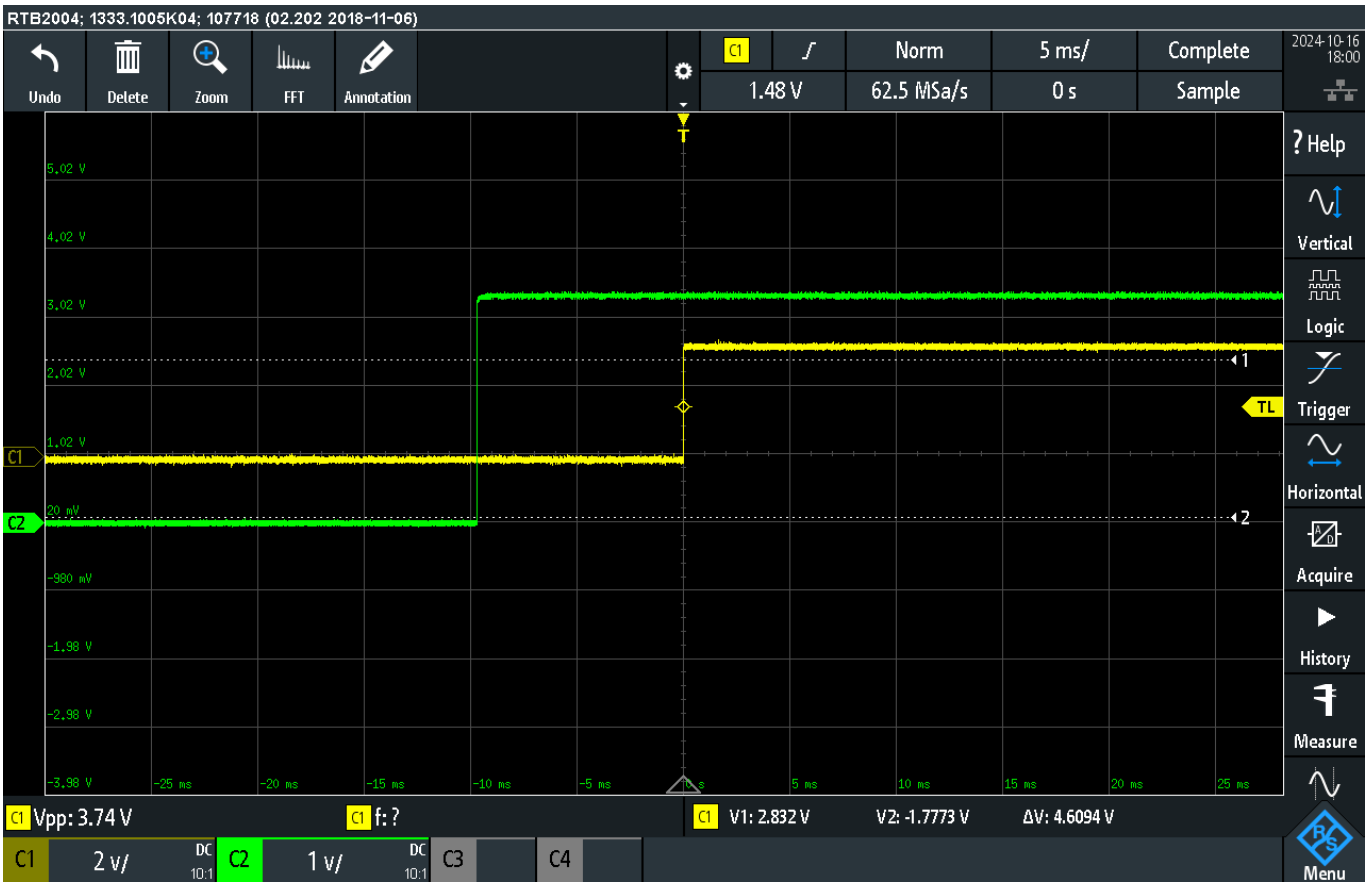
Stressed CPU: the delay gets bigger The script isnt executed that often because of other applications that occupies the CPU.



CH2: input connected to pin20
CH1: output connected to pin17

Higher Priority: the delay gets smaller

The reason for the smaller delay is that the script runs more often.



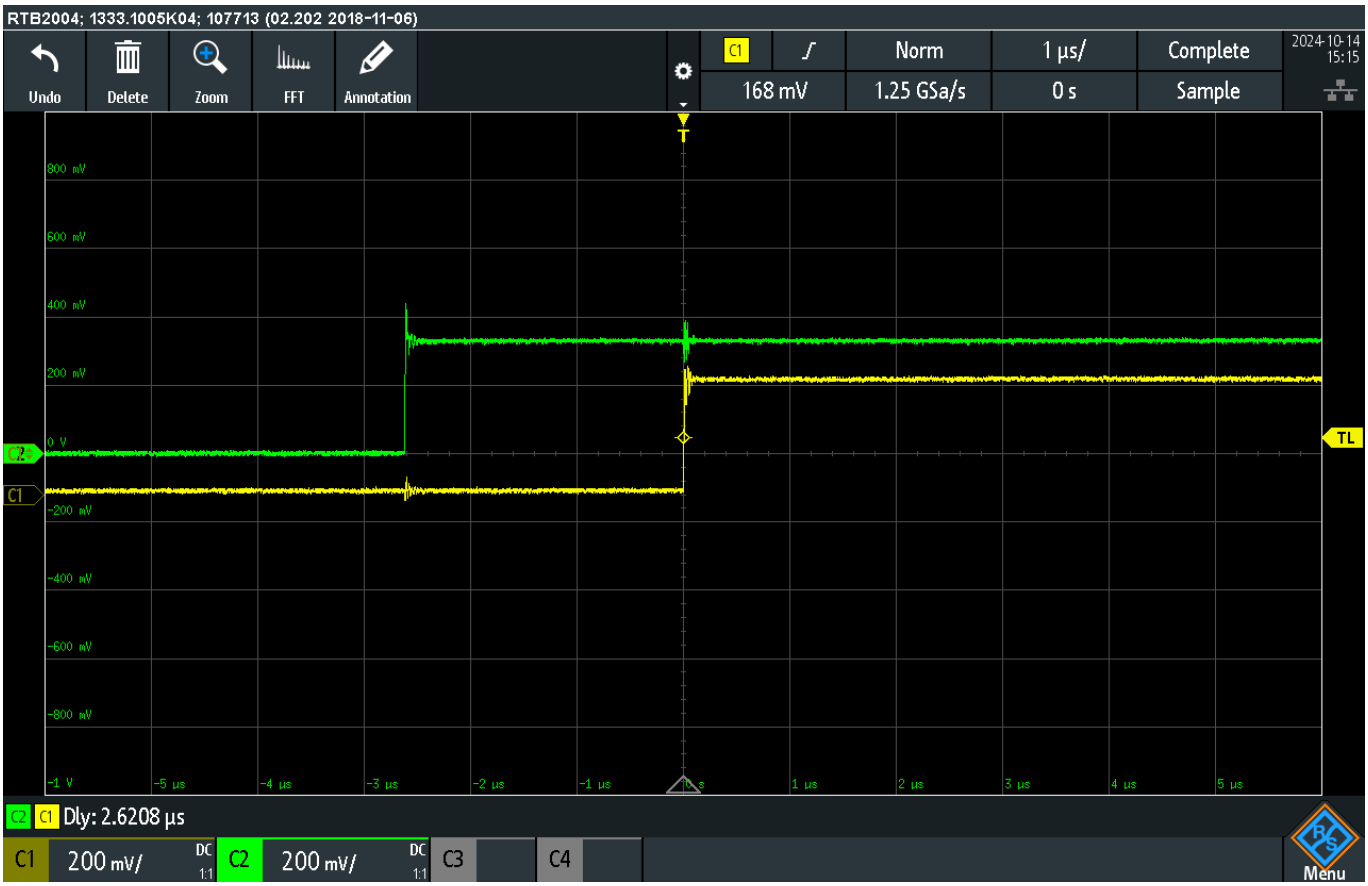
CH2: input connected to pin20

CH1: output connected to pin17

polling programm

The application polls the input data and maps it directly to the output.

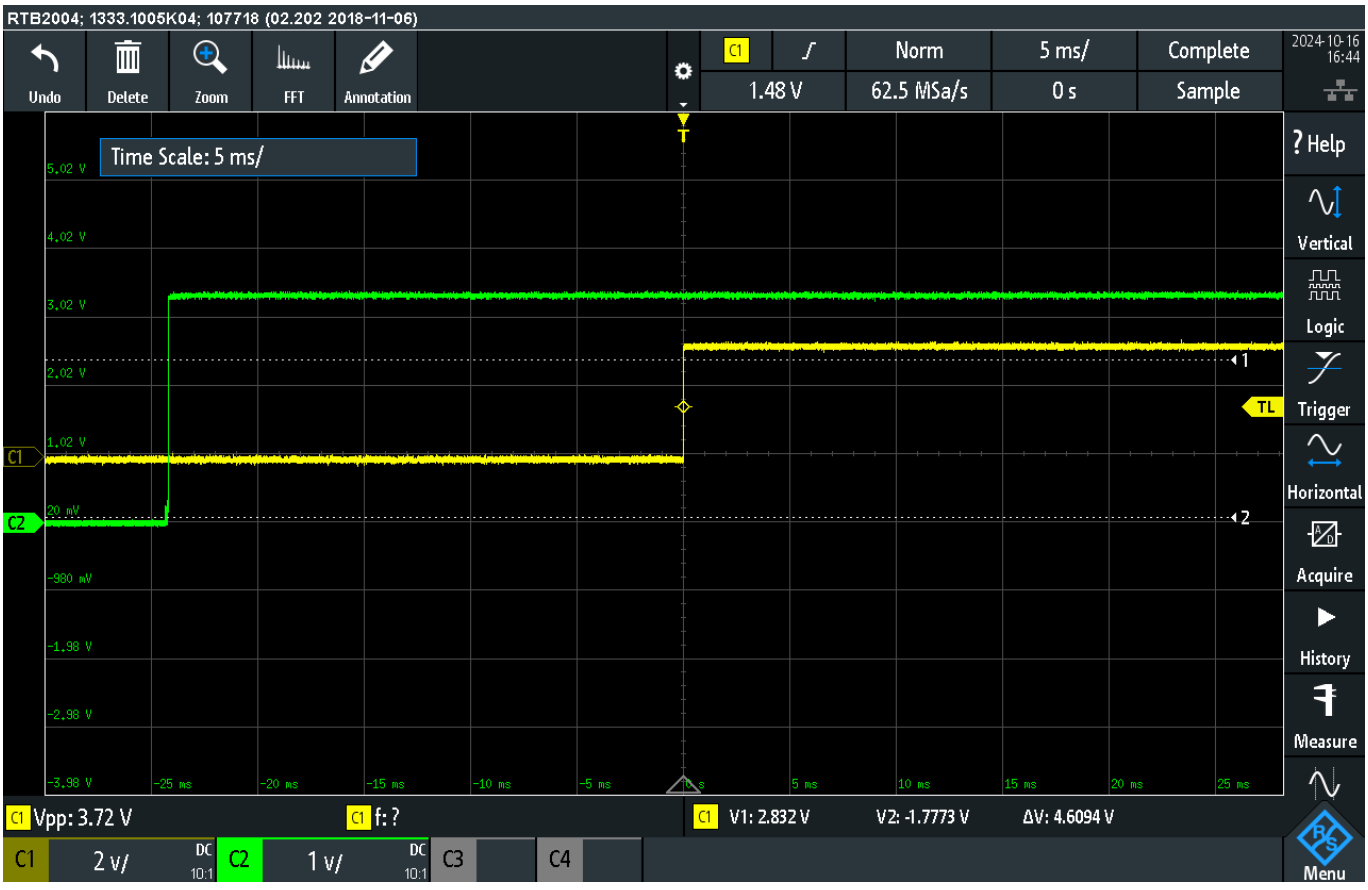
```
PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
61128 rpi-sar+  20   0    5252   2688   2560 R 100.0   0.6   0:10.30
gpioread
```



CH2: input connected to pin20

CH1: output connected to pin17

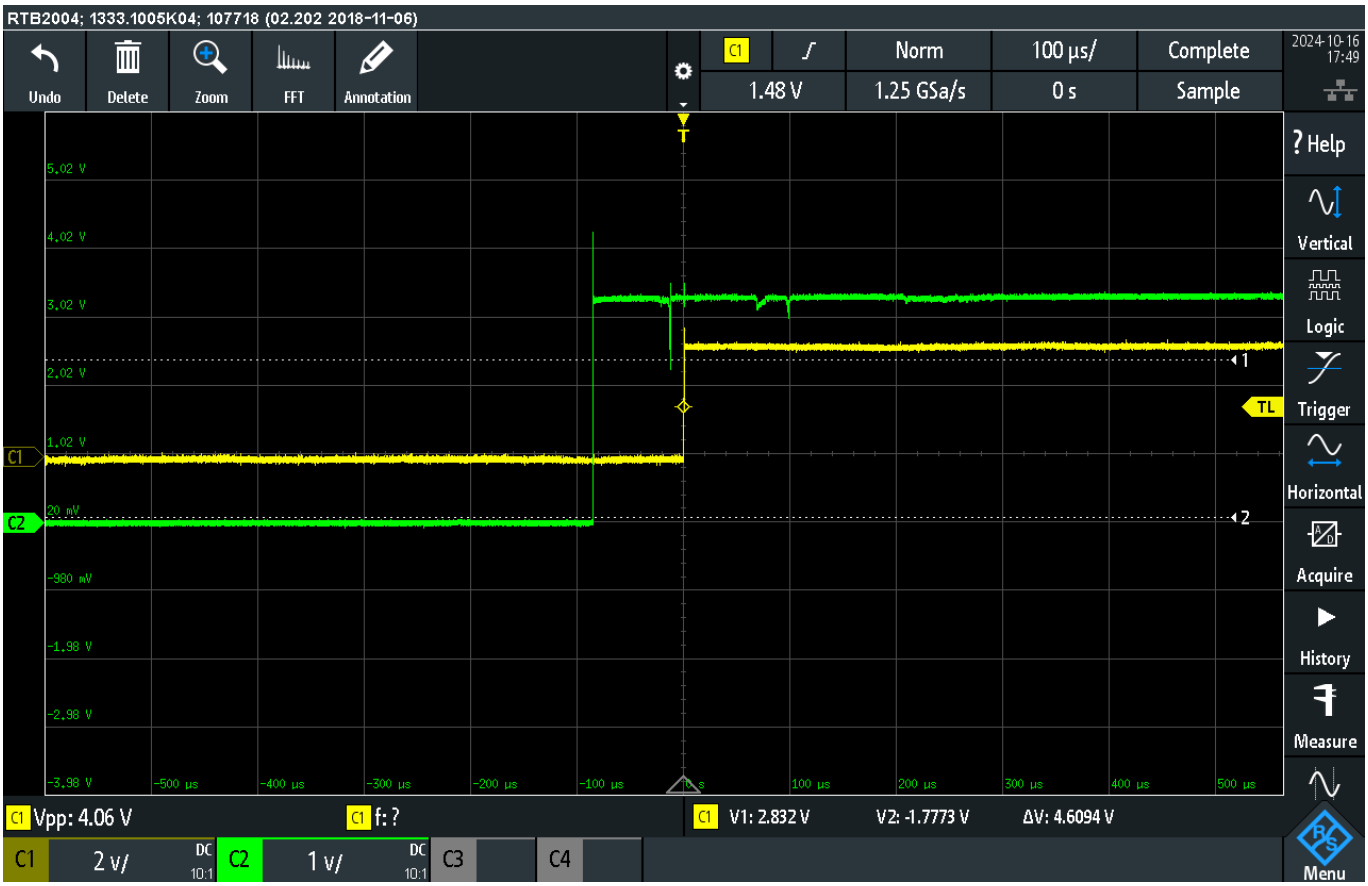
Stressed CPU: the delay gets bigger



CH2: input connected to pin20

CH1: output connected to pin17

Higher Priority: the delay gets smaller But still not as fast as if the CPU load is 0.

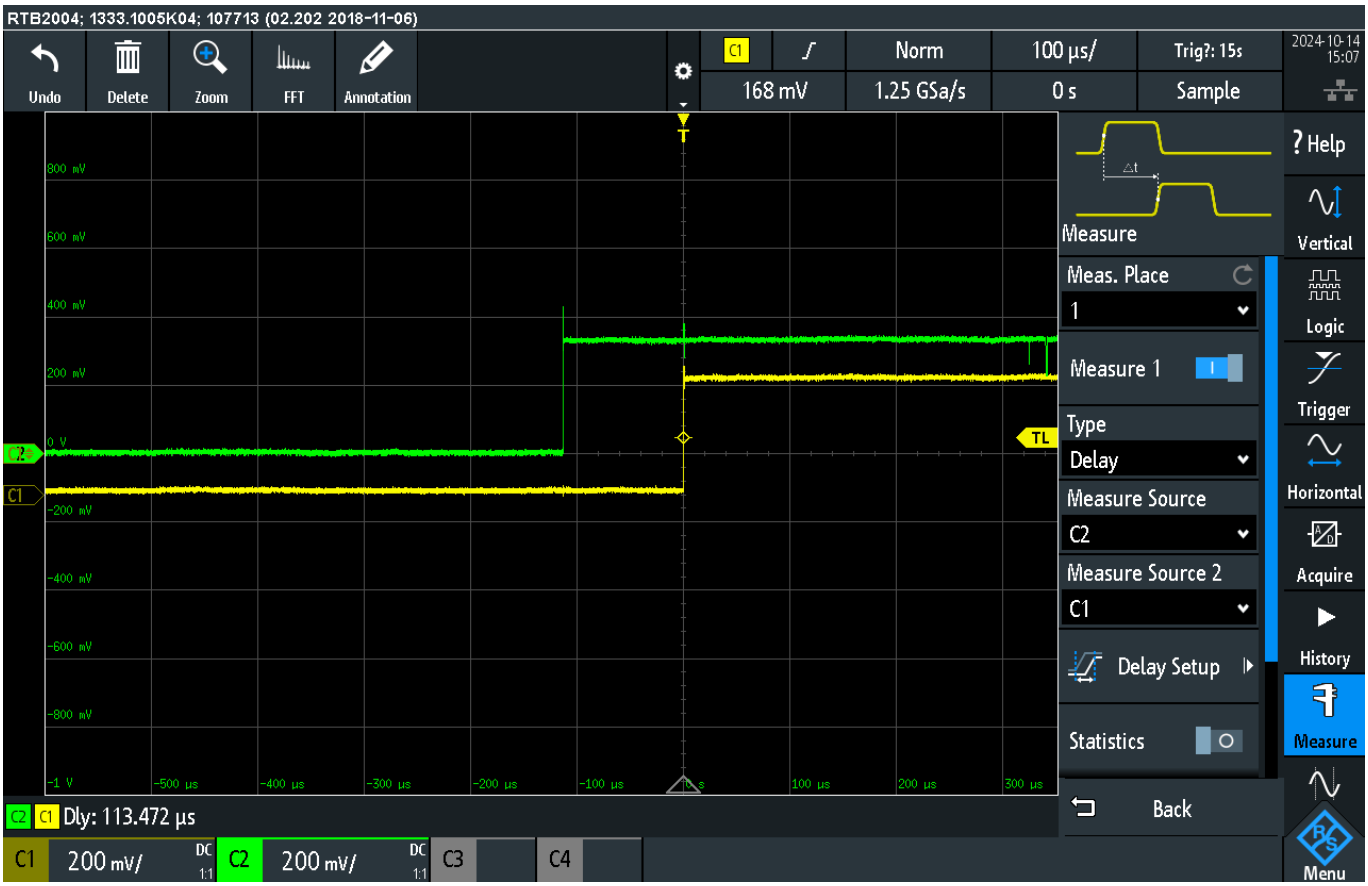


CH2: input connected to pin20
CH1: output connected to pin17

event programm

The application reacts to a rising edge event of the input pin. A blocking event is used so there is no execution until the event occurs. After a rising edge on the input, the programms continues and the output pin is set to "high".

```
PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
61132 rpi-sar+  20   0    5256   2816   2688 R  76.8   0.7   0:54.04
gpioevent
```



CH2: input connected to pin20
CH1: output connected to pin17

Stressed CPU: no difference in the delay

LKM interrupt

In a kernel application, the (super) user has access to Linux kernel functions. There is an interrupt function that allows monitoring the behavior of an input pin. The interrupt is triggered on the rising edge of the input pin, and within the interrupt service routine, the output pin is set to "high". The execution is independent of the CPU load. Thus there are no differences in the delay with various CPU conditions (stressed / not stressed). The measurement is not needed.

CH2: input connected to pin20
CH1: output connected to pin17

Evaluation

Using the Linux Kernel Module Interrupt has no consequences for the CPU load an vice versa the CPU load has no impact to the kernel module. Even if the usage of the LKM interrupt is not the fastest method, it is free from the impact of other programms/ CPU load. A real time application is defined by a maximal execution time. Just the interrupt can gurantee a fixed execution time.

Part 2

Enabling PWM capabilities with the device tree overlay, didn't work. Therefore we installed a library which does the pwm controll.

```
sudo apt install pigpio
```

The headers are included with:

```
#include <pigpio.h>
```

Running the programm requires admin rights therefore the programm is executed with

```
sudo ./speedCtrl
```

Jitter measurements

The jitter is measured with a high resolution timer and printed to the output using std::cout

Stress testing the cpu was done with the package stress

```
sudo apt install stress
```

And then using the following command:

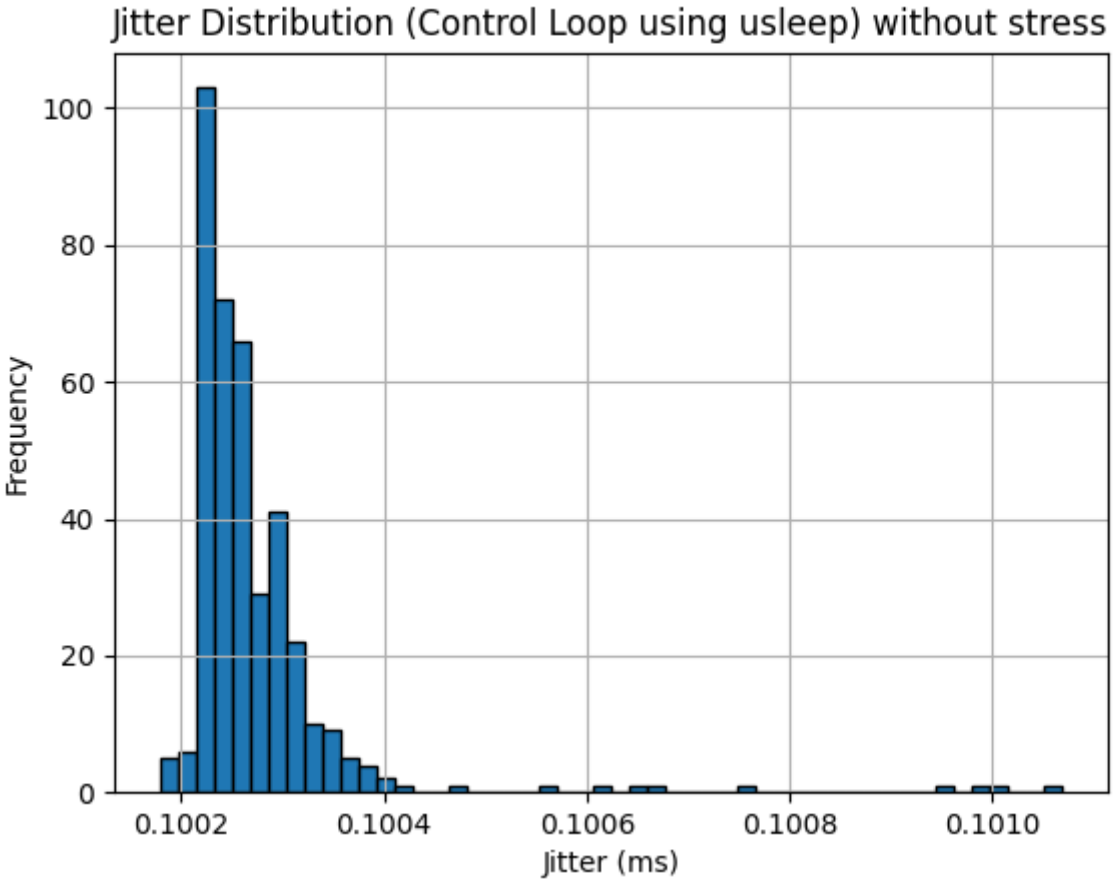
```
stress --cpu 1 --timeout 180 &
```

We evaluated two different methods for timedelay in the control loop:

- using usleep()
- using std::this_thread::sleep_for()

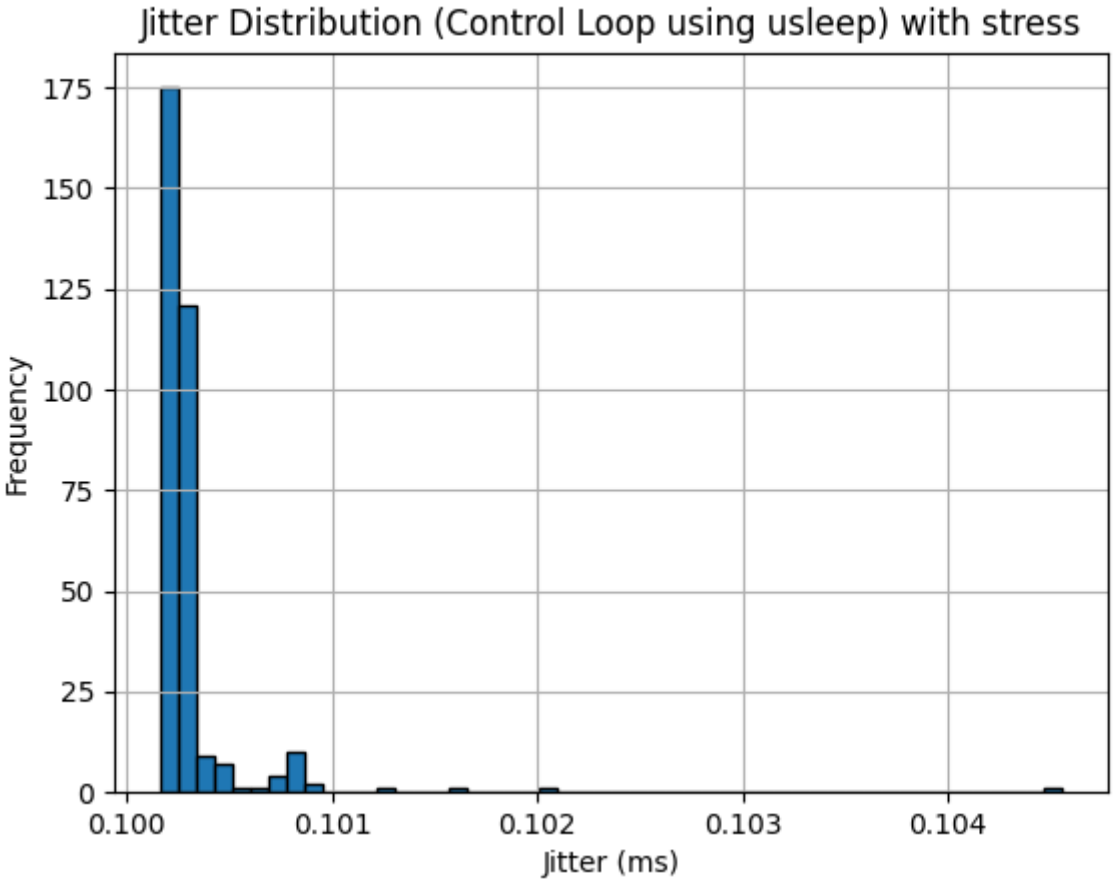
Note: The x-axis scaling is different on all histogram plots

usleep() without cpu stress



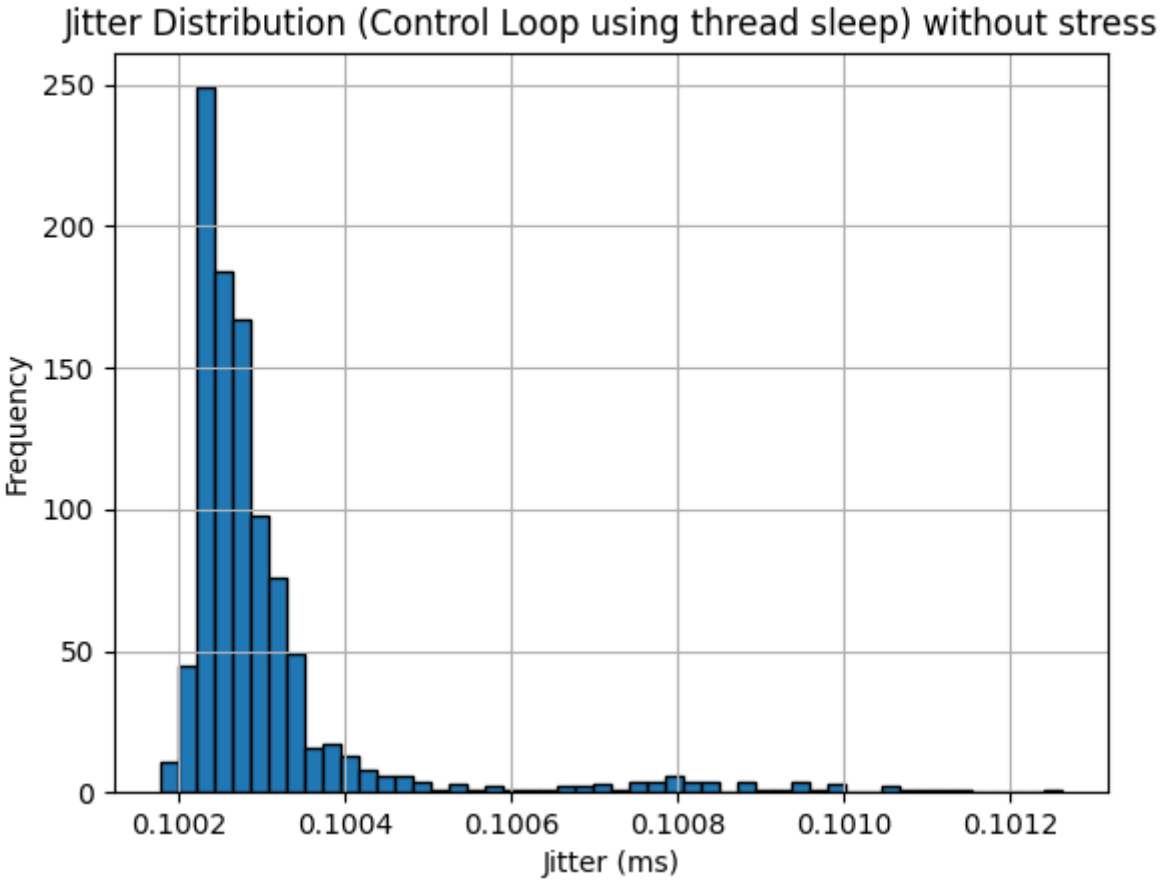
Most time measurements are close together most of them are between 200 us and 400 us, maximum time difference was around 1 ms.

usleep() with cpu stress



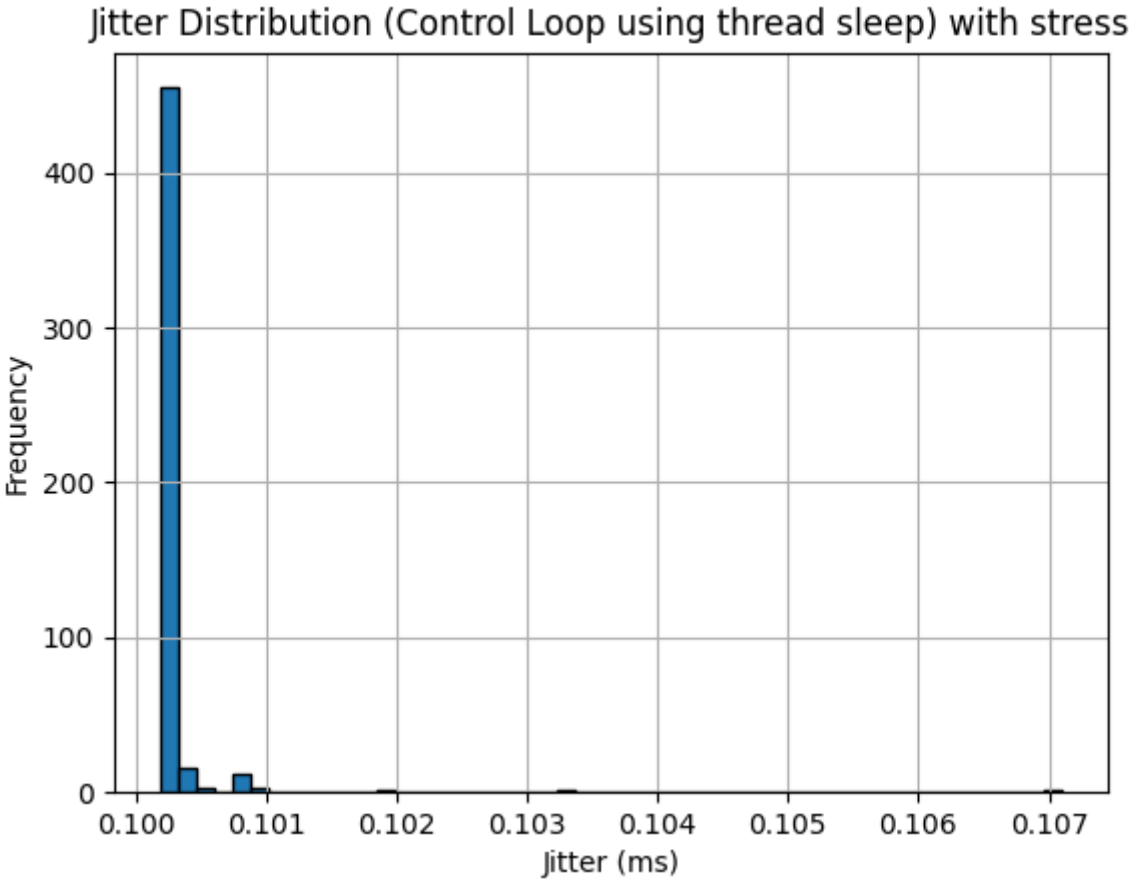
Stressing the cpu resulted in a broader time spectrum. The majority of the samples have a jitter of 1 ms. However the maximum jitter with the cpu stress is higher than 4 ms.

thread sleep without cpu stress



Most time measurements are close together most of them are between 200 us and 600 us, maximum time difference was around 1,2 ms. More values can be found between 600 us and 1 ms.

thread sleep with cpu stress

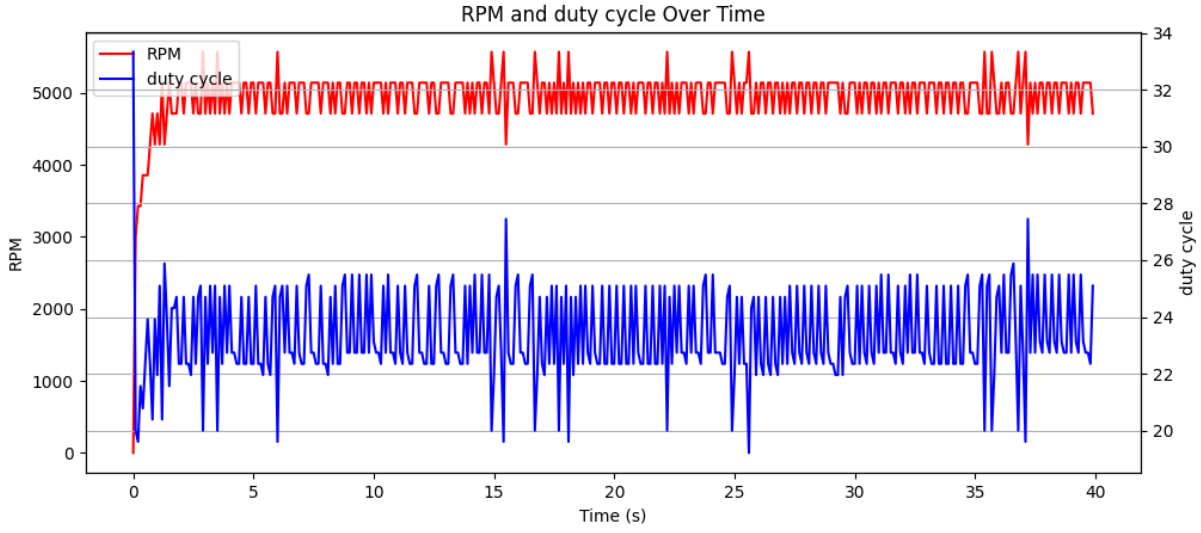


Stressing the cpu resulted in a broader time spectrum. The majority of the samples have a jitter of 1 ms. However the maximum jitter with the cpu stress is at arround 7 ms.

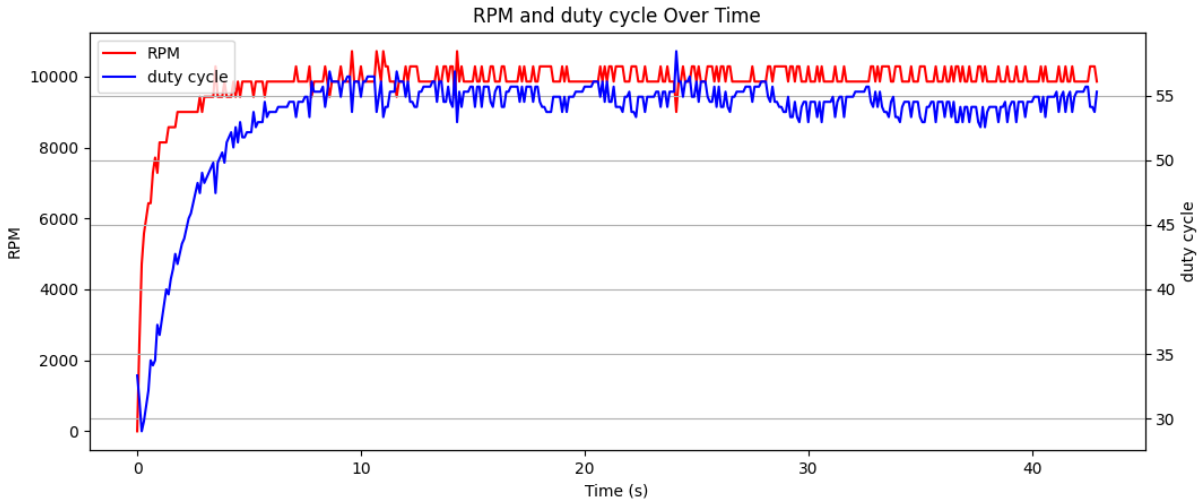
Speed

In the next two pictures, the speed is plotted in red and the duty cycle is in blue.

5000 rpm



10000 rpm



Stability of the control loop

The control loop worked very good in all test casses. More finetuning would result in even smoother rpm plots. Generally it worked better at higher speeds.
Tuning the control loop would include measuring the time difference and forwarding this measurement to the controller.

Links

Youtube: https://www.youtube.com/shorts/iH6vpbOmVDQ

Github: https://github.com/UniRoi/Linux_Motor_Encoder