Debugging realtime application with Ftrace

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Disclaimer

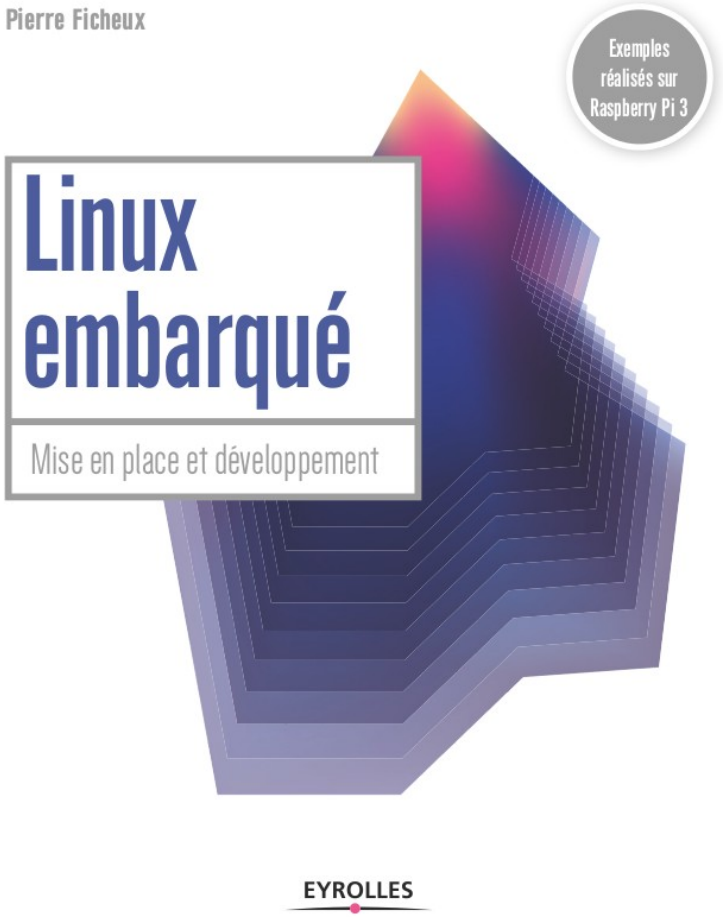
- Poor English speaker !
- But “good” French speaker and writer :-)

“Loin du français je meurs”

(Louis-Ferdinand Céline)

$ whoami

- French embedded Linux developer, writer and teacher
- CTO @ Smile ECS (Embedded & Connected Systems)
- Last book about embedded Linux (in french !)



What is Ftrace?

- The official tracer for the Linux kernel
- Added in 2009 (2.6.31)
- Mostly developed by Steven Rostedt (Red Hat, now VMware, PREEMPT_RT major designer)
- Lots of features for tracing :
  - functions
  - events
  - latency !
- Not a debugger (GDB) but a “profiler”
- Available in standard distributions
- Based on debugfs
- Activated by *Kernel hacking* > *Tracers*

Basic using

- Mount debugfs (if not mounted)

```
$ sudo mount -t debugfs debugfs /sys/kernel/debug
```

- Explore and use `/sys/kernel/debug/tracing` (as root)

```
# cd /sys/kernel/debug/tracing
# ls
available_events            max_graph_depth     stack_trace
available_filter_functions  options             stack_trace_filter
available_tracers           per_cpu             trace
...
# cat current_tracer tracing_on
nop
1
```

- Procedure / example
  - set a tracer (+ filter !) → `wakup_rt`
  - Enable tracing + run program → `hackbench`
  - disable tracing + get the result → `tracing_max_latency`

Tracing a kernel function

- Insert a test driver

```
# insmod mydriver3.ko
```

- Select “function” or “function_graph” tracer

```
# echo function_graph > current_tracer
```

- Set filter

```
# echo 'mydriver3_*' > set_ftrace_filter
# echo 1 > tracing_on
```

- Try write + read (with `strace`)

```
# echo toto > /dev/mydriver3
# strace cat /dev/mydriver3
# cat trace
```

Basic internals

- Based on gcc's profiler option `-pg`
- Adds `mcount()` function call

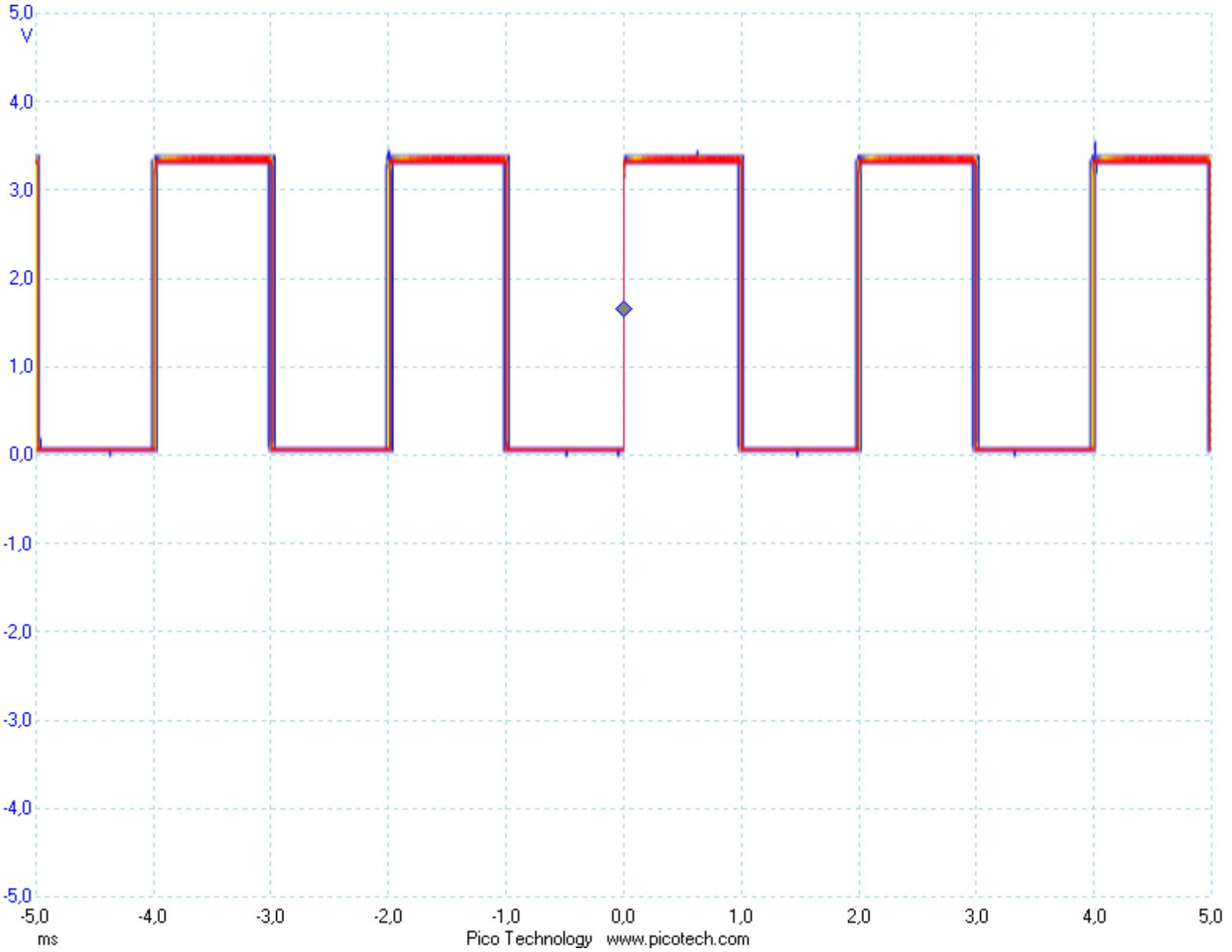
```
(gdb) disassemble my_func
Dump of assembler code for function my_func:
   0x00000000004007d1 <+0>:     push   %rbp
   0x00000000004007d2 <+1>:     mov    %rsp,%rbp
   0x00000000004007d5 <+4>:     callq  0x400630 <mcount@plt>
   0x00000000004007da <+9>:     pop    %rbp
   0x00000000004007db <+10>:    retq
```

- Too much overhead !
- Convert mcount() calls to "nop" instructions at boot time
- We need to know where they are
- Best to find them at compile time !
- Use `recordmcount` (scripts/recordmcount.c)
- Look at references for details !

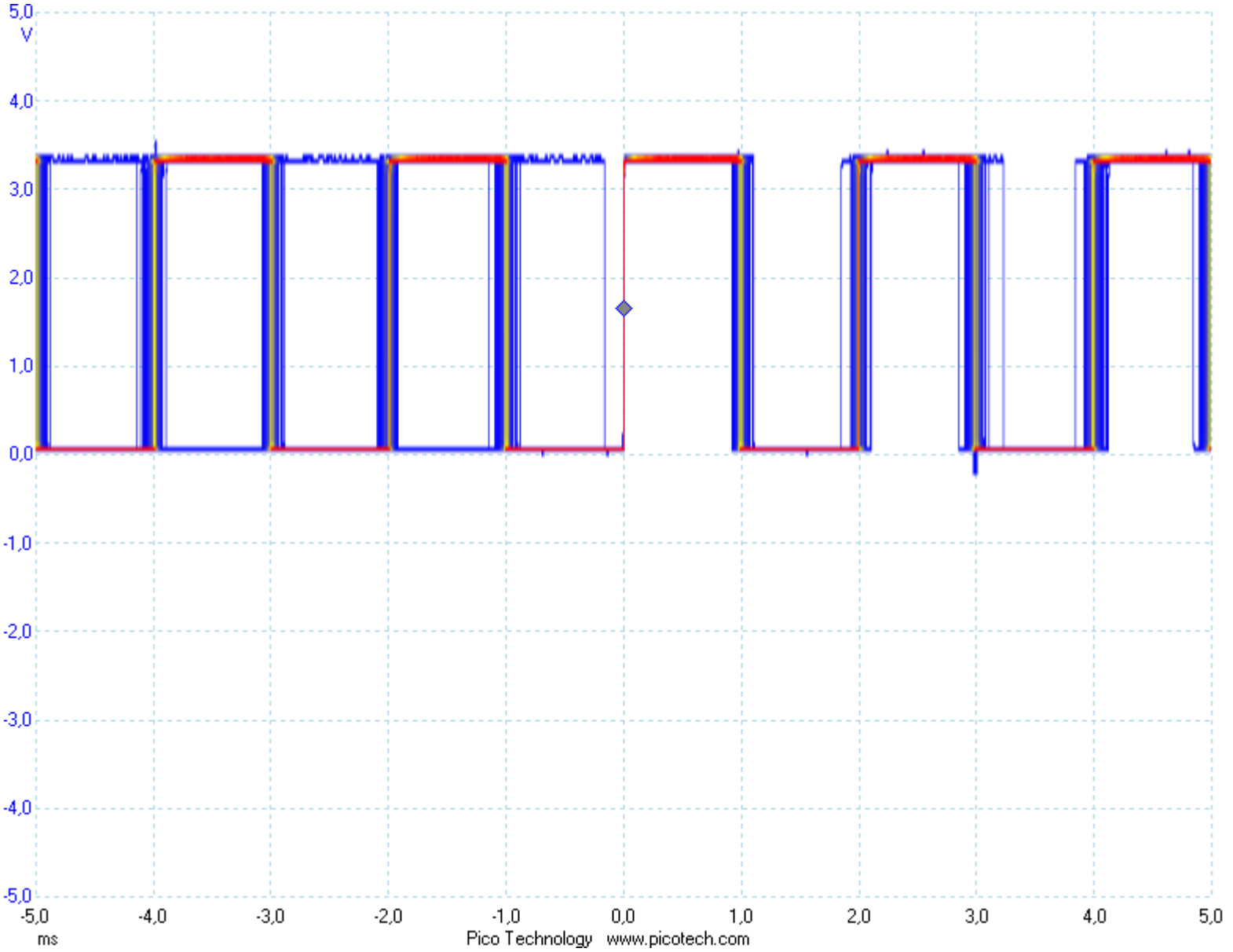
Real time programming

- Mostly periodic tasks
- Use POSIX timers for “soft” real time
  - `timer_create()`
  - `timer_settime()`
- Use `clock_nanosleep()` for “hard” real time (don’t use signal !)
- GPIO control
- Measurement without / with system load (Picoscope)
- Need to check latency

BBB, 1ms period, idle



Same with hackbench !



Testing events with Ftrace

- Periodic task → “sched_wakeup” event
- Set current tracer to nop

```
# echo nop > current_tracer
# echo sched_wakeup > set_event
```

- Start a periodic task (1 ms period by default)

```
# echo 1 > tracing_on
# cyclictest -p 99 -n
^C
# echo 0 > tracing_on
```

- Got tired of `/sys` →
  - `trace-cmd` command (text mode !)
  - Kernelshark (Gtk GUI, should be based on Qt in the future)

Text mode `trace-cmd`

- Use “record” then “report”
- Create `trace.dat` file by default
- Remote server access (“listen” mode) for embedded
- PC side

```
$ sudo trace-cmd listen -p 9999
```

- Target side

```
# ./trace-cmd record -e sched_wakeup -N <IP-addr>:9999
cyclictest -p 99 -n
```

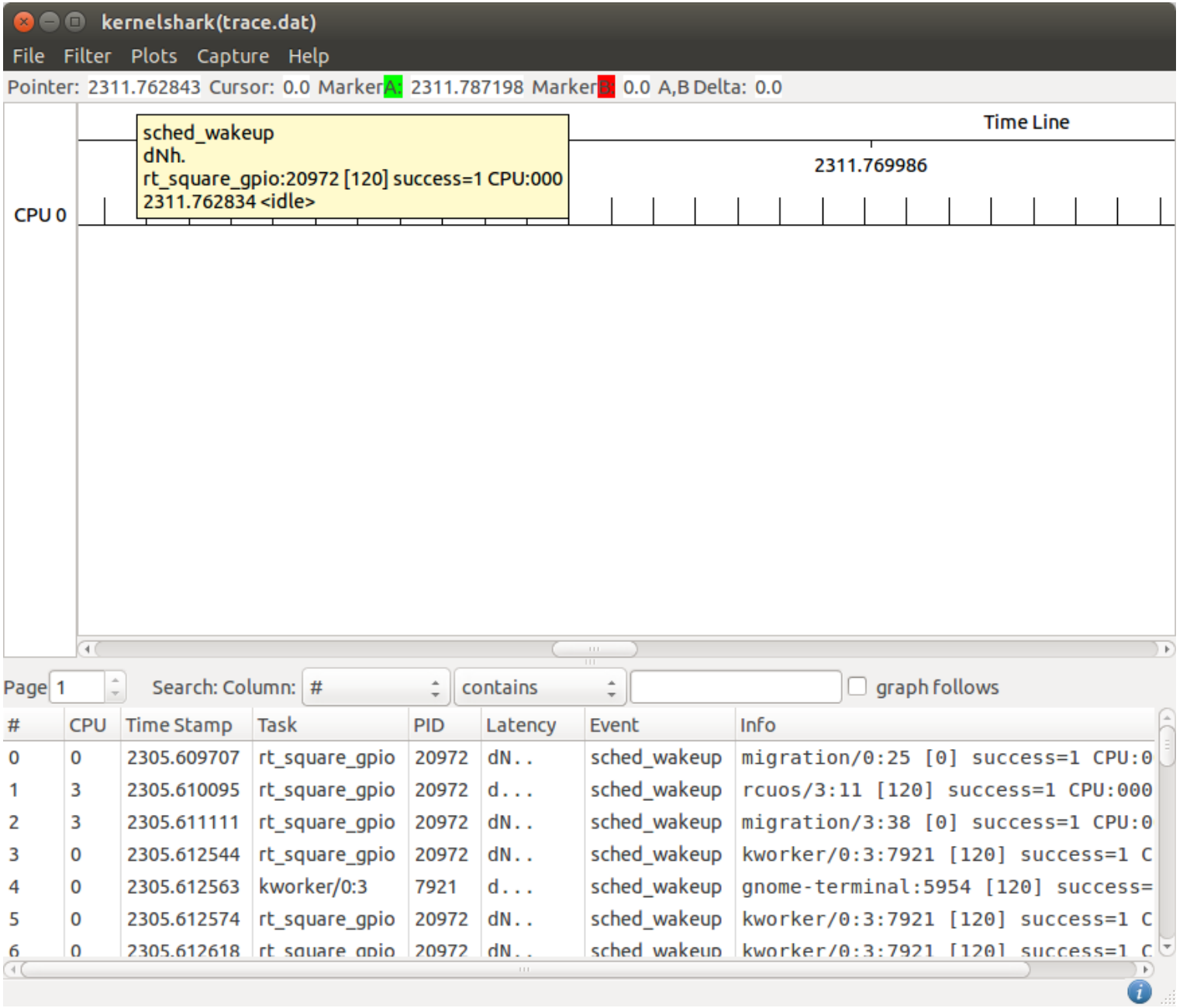
- Get report on PC

```
$ trace-cmd report -i trace.<IP-addr>\:57052.dat
<...>-126   [000]   515.726475: sched_wakeup:  comm=cyclictest pid=128
prio=0 success=1 target_cpu=000
<idle>-0    [000]   515.727475: sched_wakeup:  comm=cyclictest pid=128
prio=0 success=1 target_cpu=000
<idle>-0    [000]   515.728475: sched_wakeup:  comm=cyclictest pid=128
prio=0 success=1 target_cpu=000
<idle>-0     [000]  515.729474: sched_wakeup:  comm=cyclictest pid=128
prio=0 success=1 target_cpu=000
```

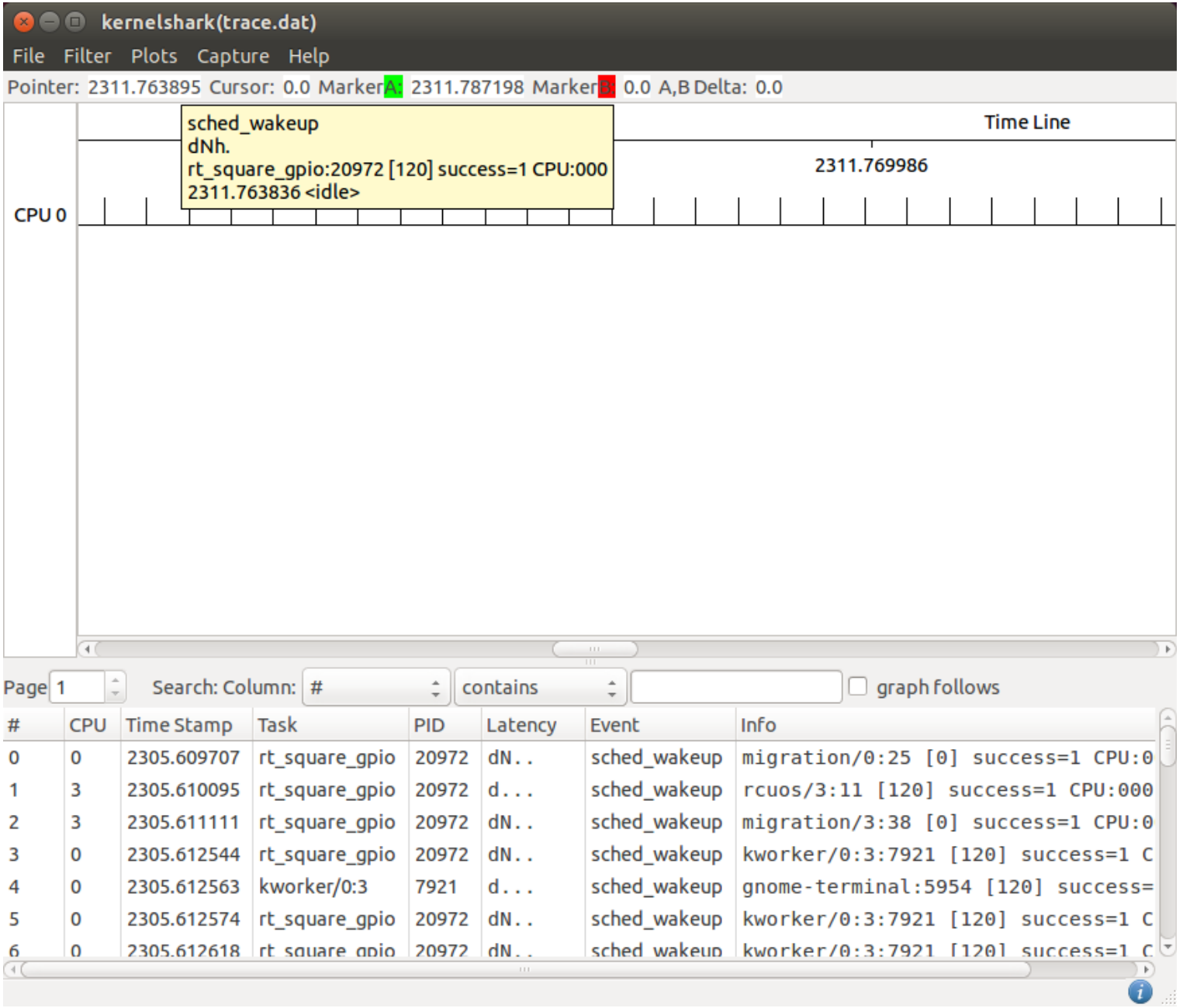
Text or GUI

- Text mode
  - extract data (script or whatever)
  - use Gnuplot
  - “static” results...
- Kernelshark is “dynamic” and interactive but
  - Is GUI :-)
  - Not that stable, should be improved by S. Rostedt at VMware (using Qt)

Periodic task (x86)



Periodic task (x86)



PREEMPT_RT on RPi

- Test on PREEMPT_RT based kernel (1 ms period)
  - `rpi_gpio` based on POSIX timer + signal (SIGALRM)
  - `rpi_gpio_ns` based on `clock_nanosleep()`
- Send flood-ping to RPi from PC
- SCHED_OTHER (no RT, p = 0)

```
# trace-cmd record -e sched_wakeup rpi_gpio_ns -p 1000000
```

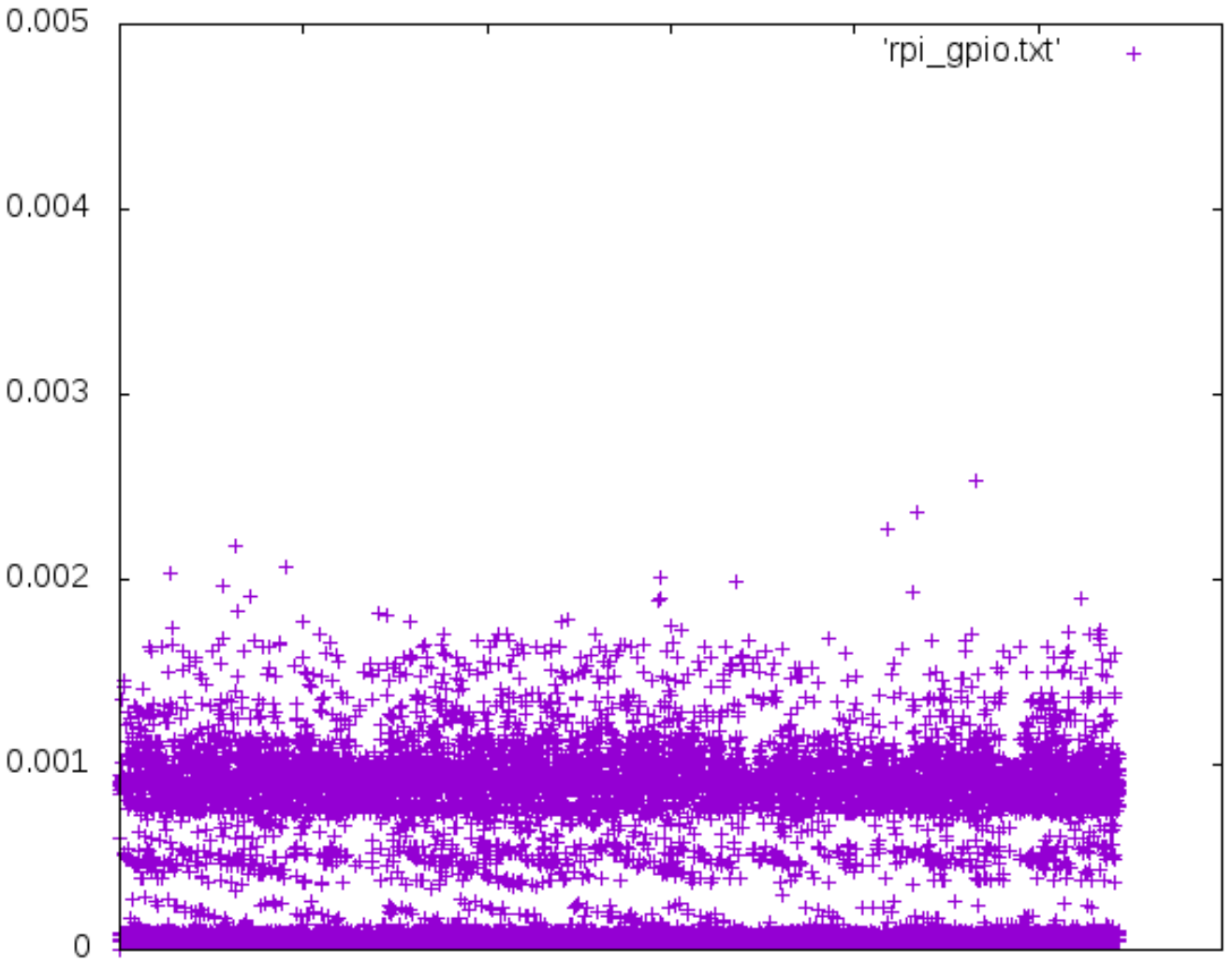
- SCHED_FIFO test (RT, p = 99)

```
# trace-cmd record -e sched_wakeup chrt -f 99 rpi_gpio -p
  1000000
# trace-cmd record -e sched_wakeup chrt -f 99 rpi_gpio_ns -p
  1000000
```

- Compare results with Gnuplot !

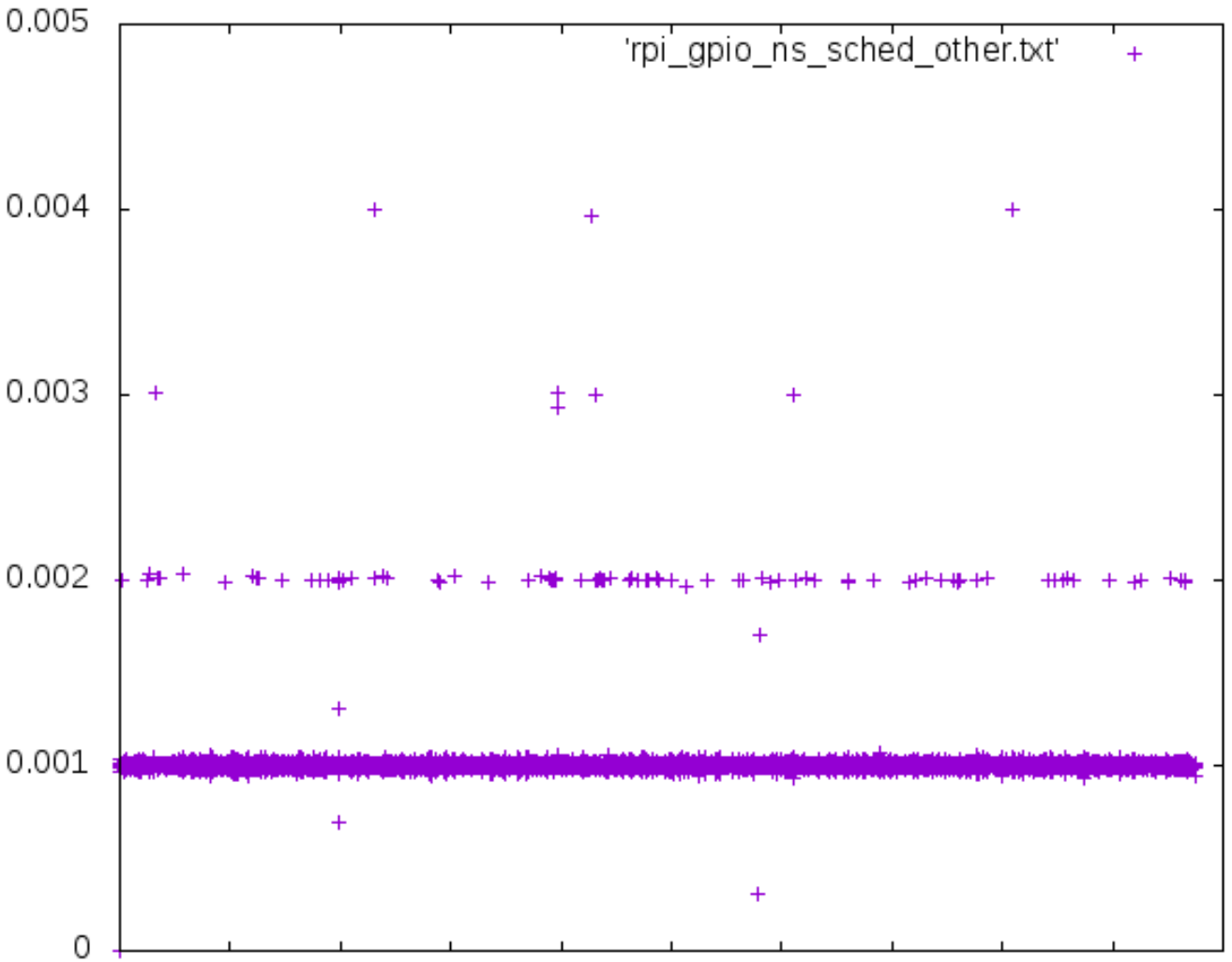
SCHED_FIFO + timer

- SCHED_FIFO + p = 99 :-)
- Program is based on SIGALRM :-(



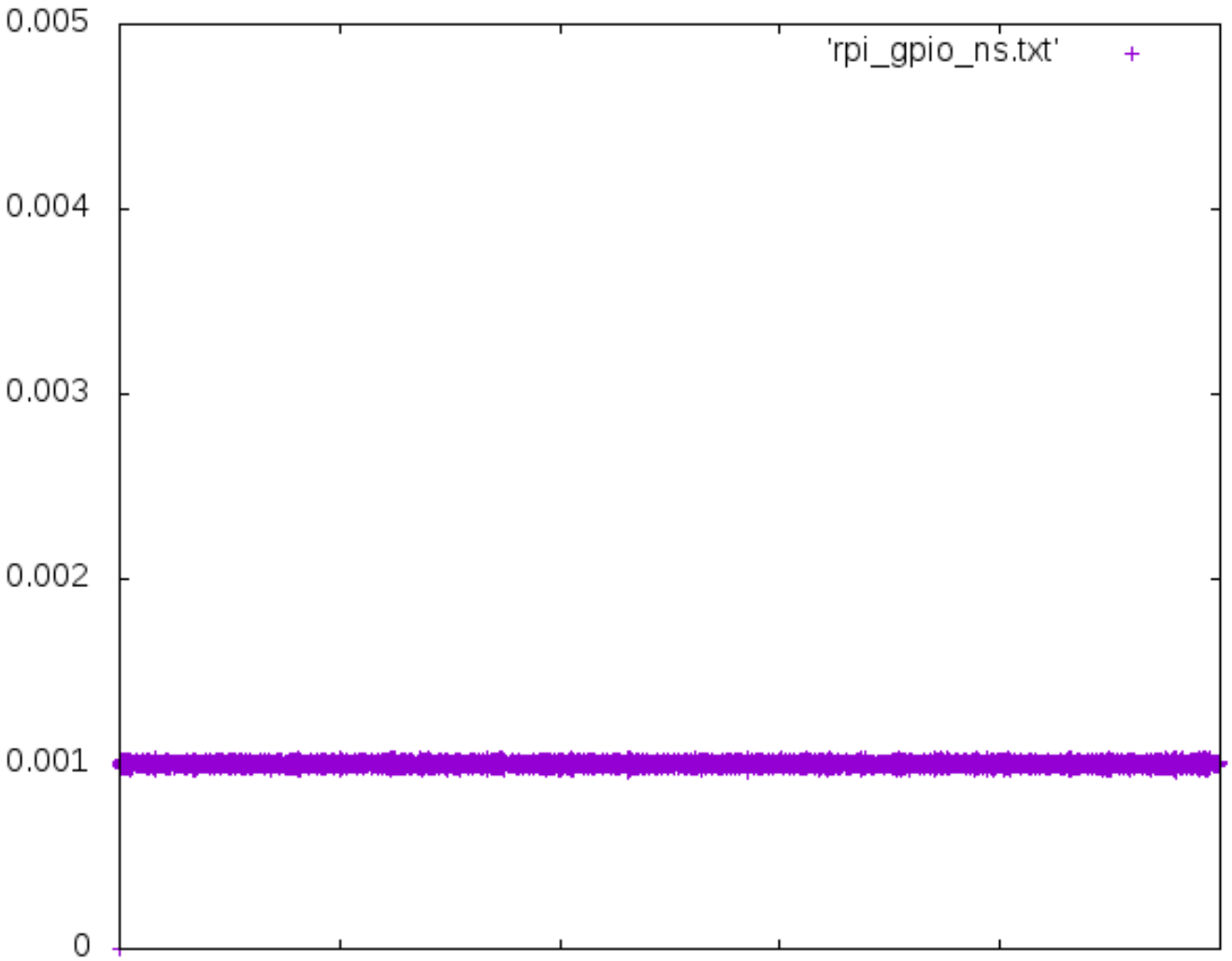
SCHED_OTHER + `clock_nanosleep()`

- SCHED_OTHER (p = 0) :-(
- No signal :-)



SCHED_FIFO + `clock_nanosleep()`

- SCHED_FIFO + p = 99 :-)
- No signal :-)



References

- Ftrace article by Christophe Blaess (Open Silicium #18)
- Ftrace doc (kernel source) https://www.kernel.org/doc/Documentation/trace/ftrace.txt
- Debugging kernel using Ftrace (#1) by S. Rostedt http://lwn.net/Articles/365835/
- Debugging kernel using Ftrace (# 2) by S. Rostedt http://lwn.net/Articles/366796
- Understanding Linux kernel via Ftrace by S. Rostedt https://www.youtube.com/watch?v=2ff-7UTg5rE (***)
- Ftrace kernel hooks by Steven Rostedt https://www.linuxplumbersconf.org/2014/ocw/system/presentations/1773/original/ftrace-kernel-hooks-2014.pdf