

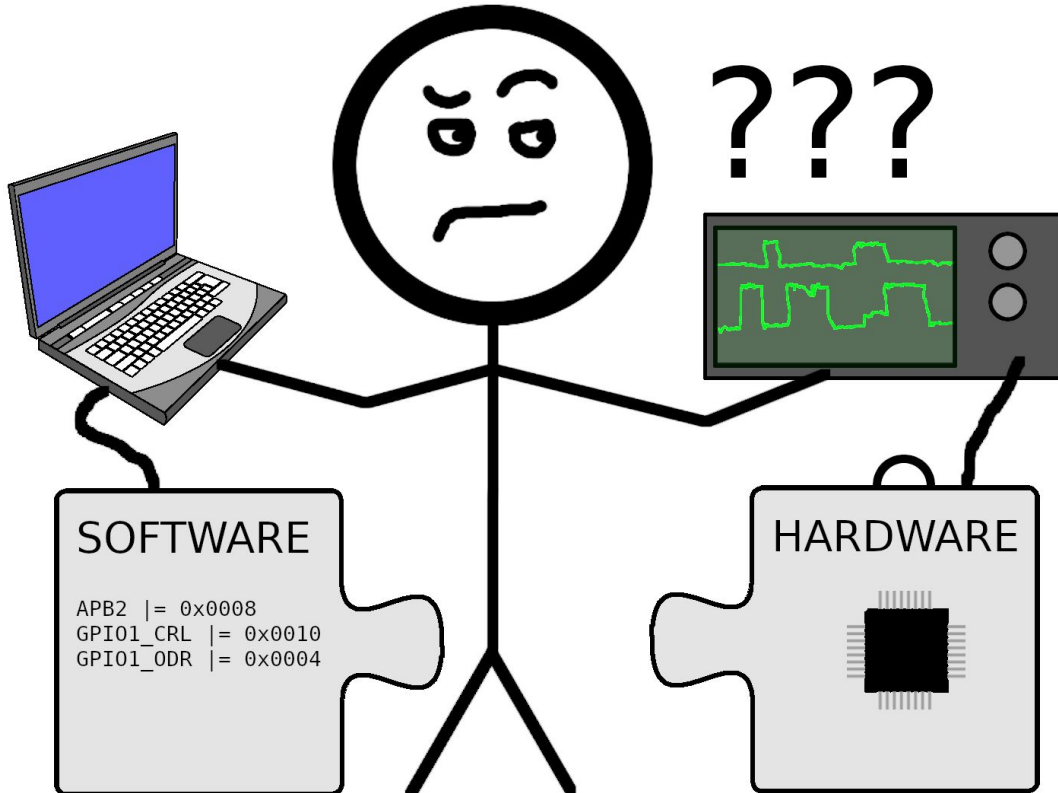
# PHiLiP on the HiL: Automated Multi-platform OS Testing with External Reference Devices

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# Embedded Development. Challenges.



## Hardware implementations vary

Improper state changes

Uninitialized registers

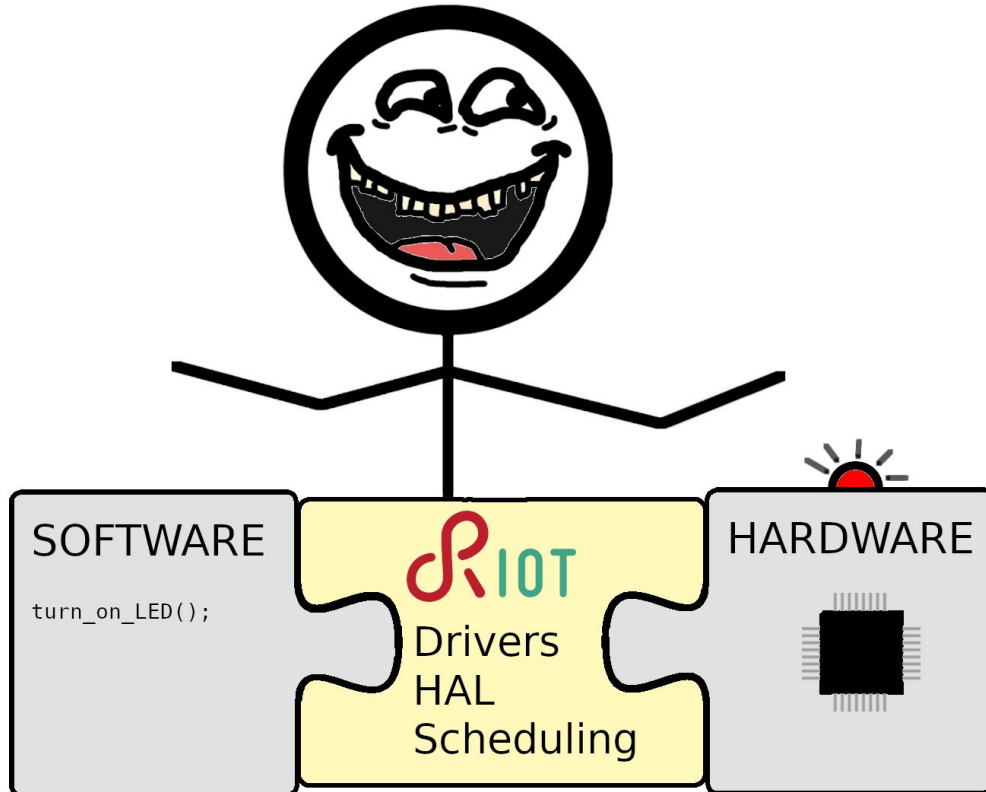
Misconfigured clocks

Incorrect component values

Broken wires

...

# Embedded Development. **Solutions.**



## Using an OS

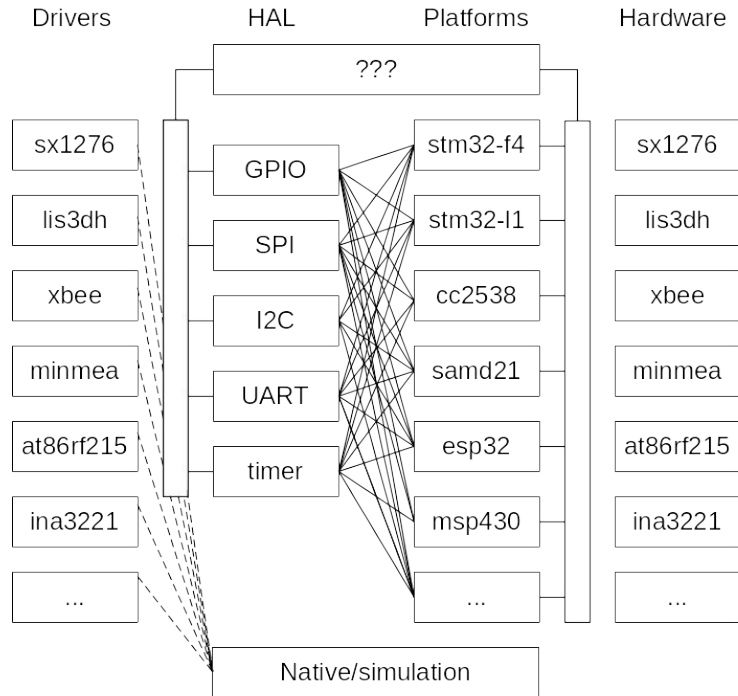
Peripheral abstraction

Device drivers

Reusable modules

Mature code that works

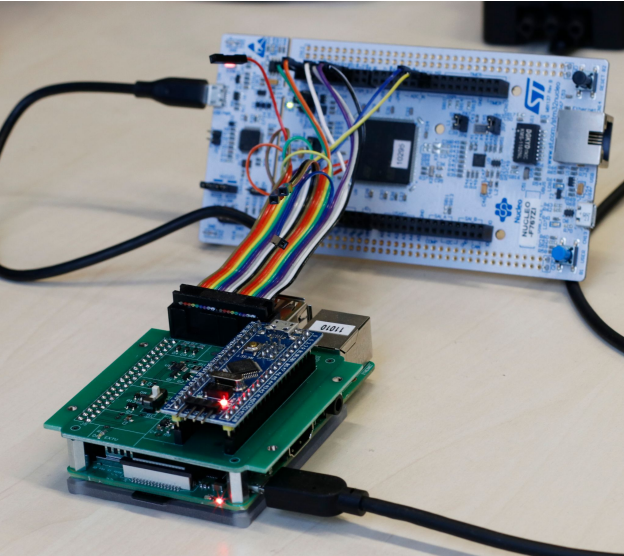
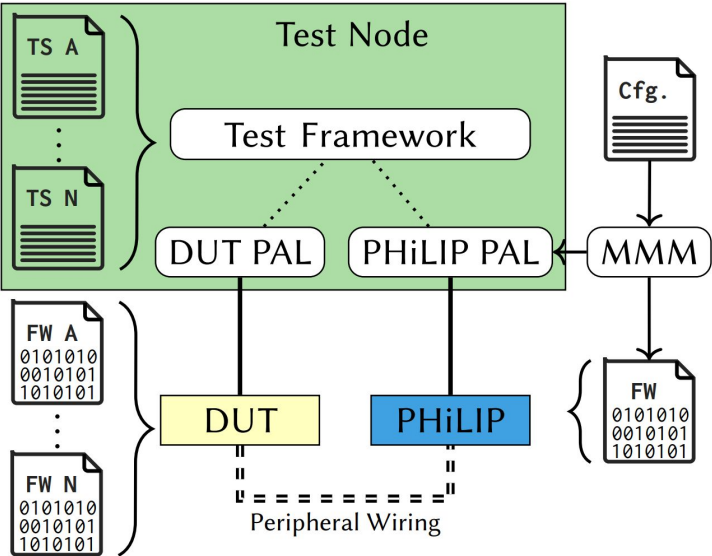
# Embedded Development. Challenges of Solutions.



Can we simplify complexity by isolating and verifying all the hardware interactions?

# PHiLiP Concept Overview

PHiLiP is qualified firmware on an inexpensive development kit  
DUT (device-under-test) runs RIOT OS test firmware and is wired to PHiLiP  
The test node coordinates the tests, interfacing to both PHiLiP and the DUT



# Deployment. **RIOT OS CI.**

- Built with open-source tools
  - Robot Framework for tests
  - Jenkins for triggering tests
  - Ansible for configuring test nodes
- 24+ unique boards
  - Various vendors
  - Heterogeneous form factors
  - 9 MCU architectures
- 96 test cases over 7 test suites
- Running for 2 years



## Deployment. **Costs.**

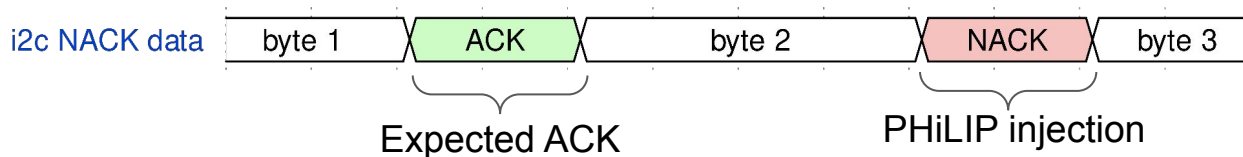
- Costs within the DUT cost range
- Affordable deployment allows community participation
- Desktop: Developer setup and run
- CI: Automated rack deployment
- DUT: Range of testing devices

	<b>Desktop</b>	<b>CI</b>	<b>DUT</b>
<b>OPEX</b>	$30 \frac{\text{mins}}{\text{run}}$	$0.05 \frac{\text{€}}{\text{run}}$	$0.01 \text{ to } 0.12 \frac{\text{€}}{\text{run}}$
<b>CAPEX</b>	10 €	80 €	7 to 136 €

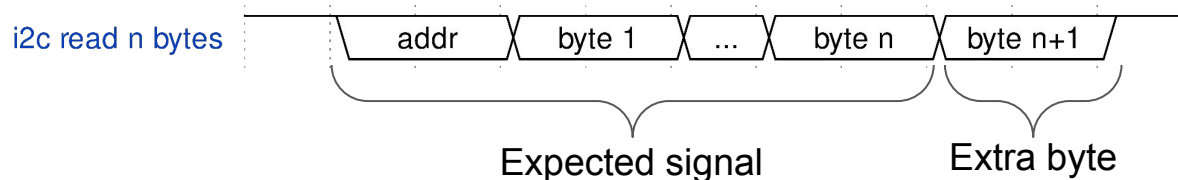
# Using PHiLIP. API Reworks.

PHiLIP was initially used during the month long I2C rework

PHiLIP can expose difficult to discover errors



PHiLIP found bugs missed with conventional tests





## Using PHiLIP. Timing.

GPIO instrumentation with 14 ns resolution

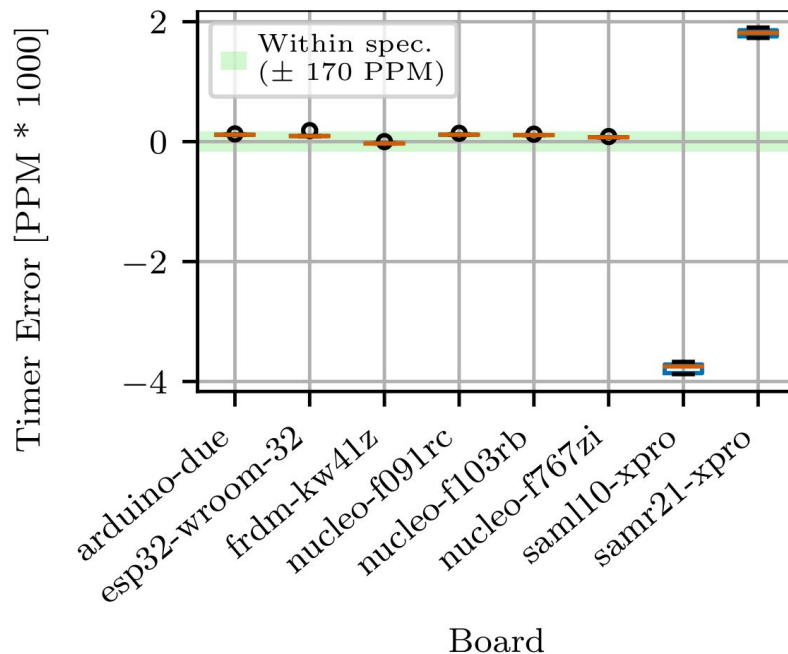
Faster results

Expose timing issues

Incorrect clock prescaler configuration

Wrong oscillator selection

Short timing deviations



# Results and Analysis. **Test Timing.**

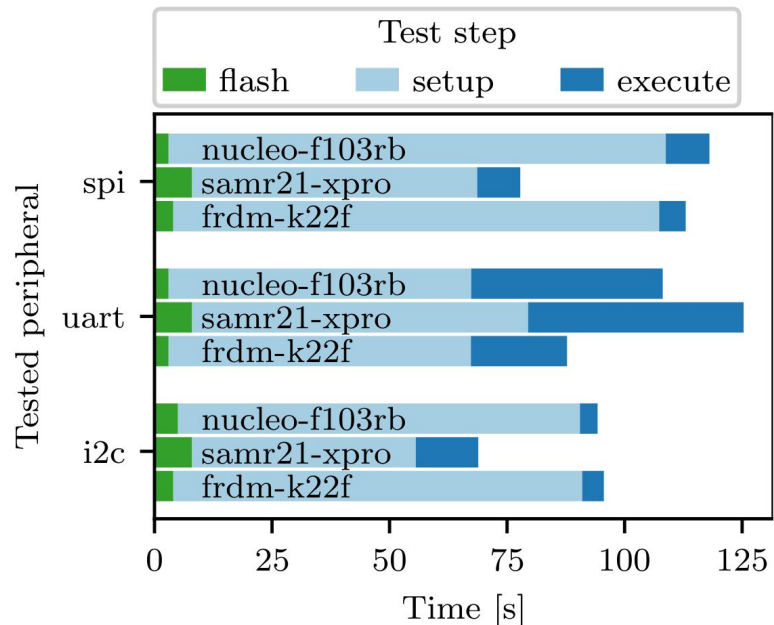
CI and test time is a limited resource

Nightlies take ~45 mins, leaving ample headroom

Test setup step is the bottleneck

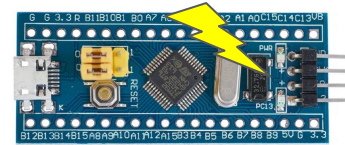
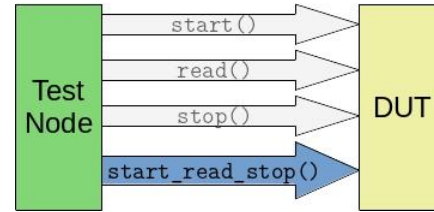
Adding boards has little effect on overall time

Scaling test cases will have the largest impact



# Lessons Learned

- Using an MCU for PHiLIP limits instrumentation capabilities
- Dedicated handling of time critical call sequences is required
- Oscillator quality on PHiLIP boards limits timing accuracy
- DUT may have communication issues
- Flashing tools can be unstable



Connecting...

Missing device  
Flash failed!

# Future Work

- Emulate PHiLIP and DUTs and use hardware to qualify emulation results (+ scalability)
- Automated selective testing (- cost)
- Adding code coverage feedback via connected debugger (+ test reliability)
- Test case generation (+ test quality)

# Thanks! Questions?

Hardware schematics and software available at <https://philip.riot-apps.net/>

Contact [Kevin.Weiss@haw-hamburg.de](mailto:Kevin.Weiss@haw-hamburg.de)

