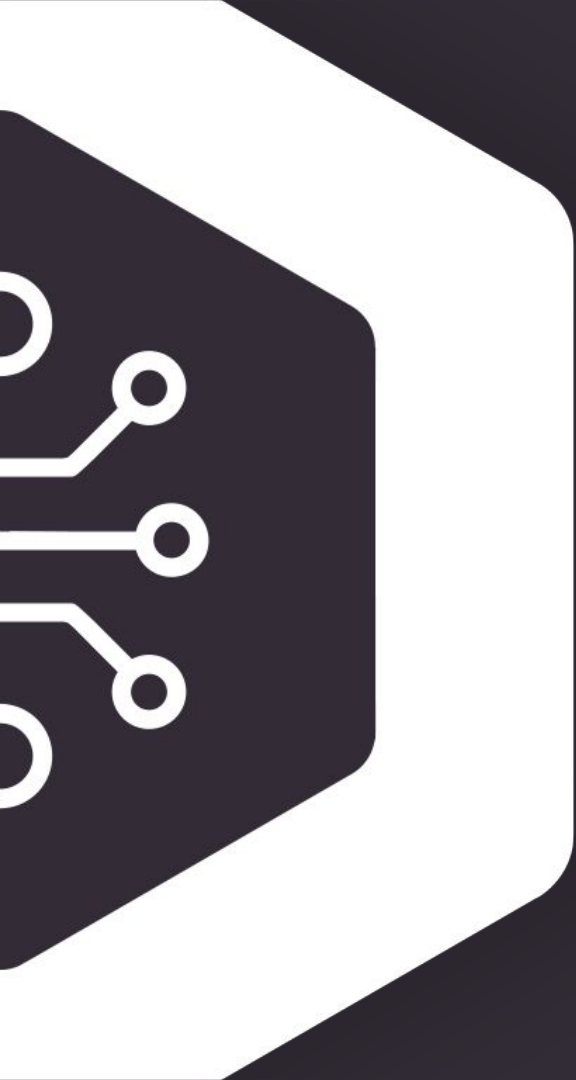




Renode - a flexible simulator for CI in complex embedded systems

Linux Plumbers Conference, 2020-08-27

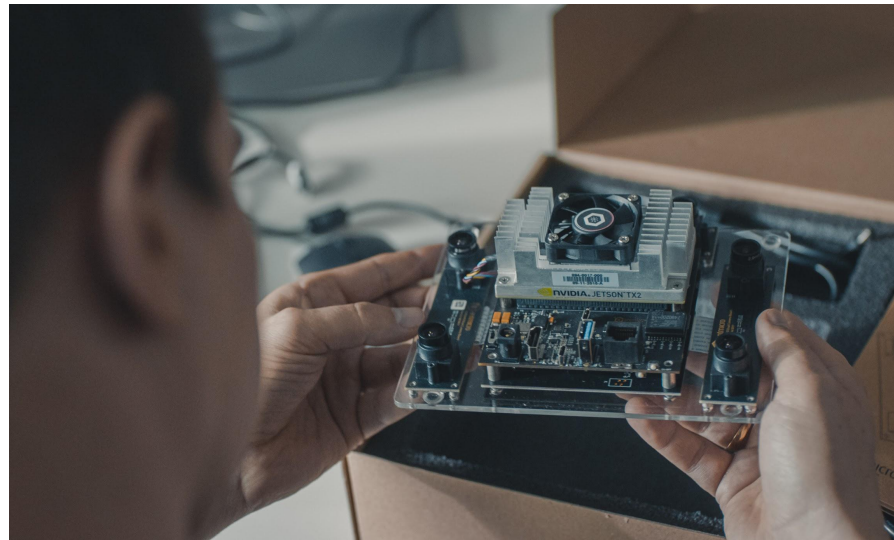
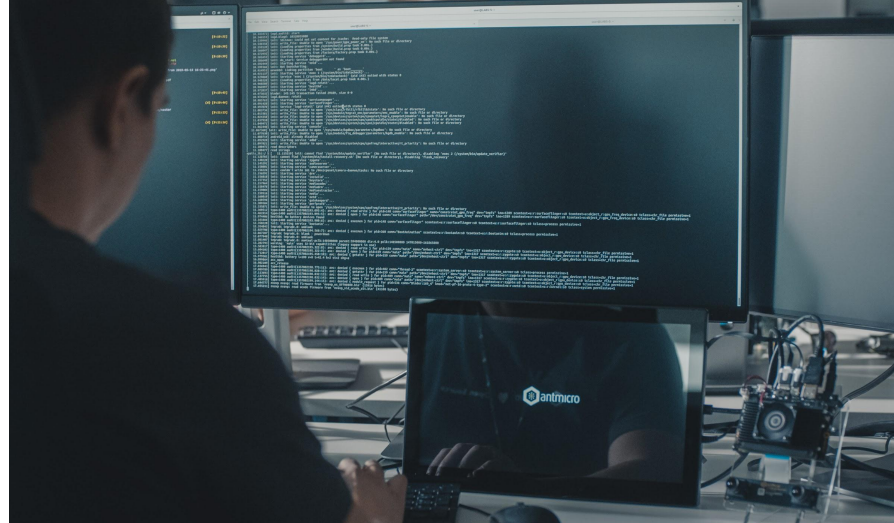
Michael Gielda, mgielda@antmicro.com



Renode - a flexible simulator for CI in complex embedded systems

ANTMICRO

- Founded 2009, developing Renode since 2010
- We use, develop, advocate open source
- Member of **Linux Foundation**, **Zephyr Project**,
Platinum Founding member of **RISC-V International** and **OpenPOWER Foundation**
- Turning ideas into software-driven products
- New design methodologies based on open source
- Embedded systems: AI/ML, autonomous vehicles, robotics, IoT, defense, aerospace, industrial automation



RENODE™

Reshape

Reload

Rethink

Remake

Regenerate

**Develop your IoT product
with Renode:**

GET STARTED

↓ SCROLL

What is Renode?

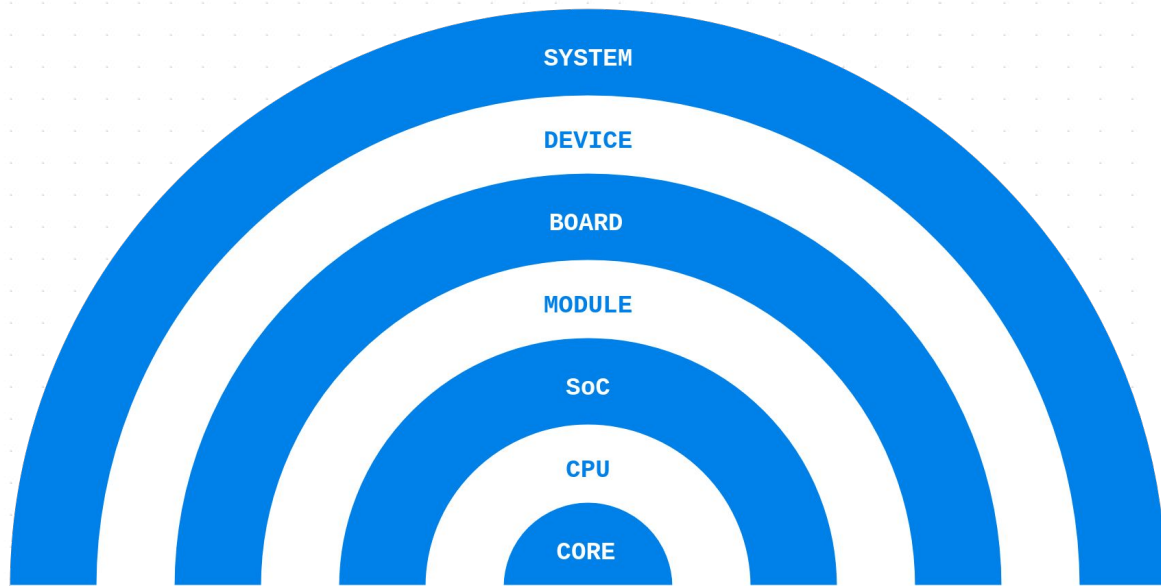
Open source hardware-simulation framework for:

- Development of complex software for embedded and IoT systems
- Architectural exploration and research
- Pre-silicon prototyping and HW-SW co-development

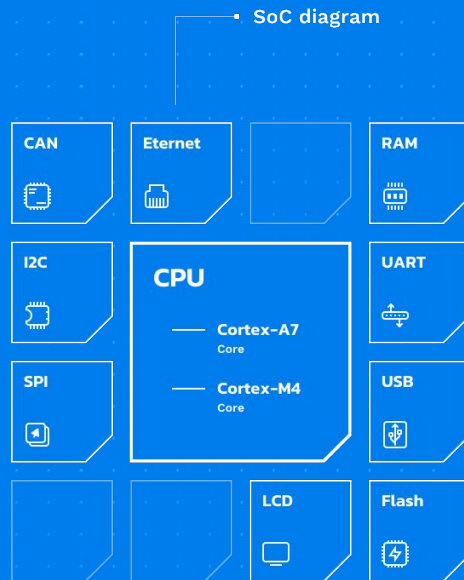
Features in brief:

- Plug-and-play building blocks
- Simulates system on many levels - CPUs, SoCs, peripherals, sensors, wired/wireless connection
- Flexible, deterministic and software-agnostic
- Continuous Integration-oriented
- “Batteries included” - lots of demos and binaries

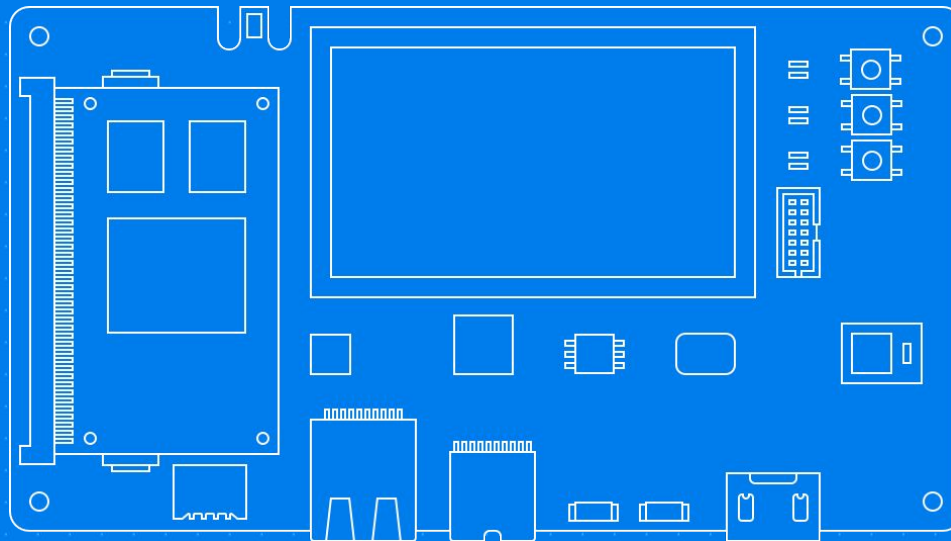
Simulate your system on many levels



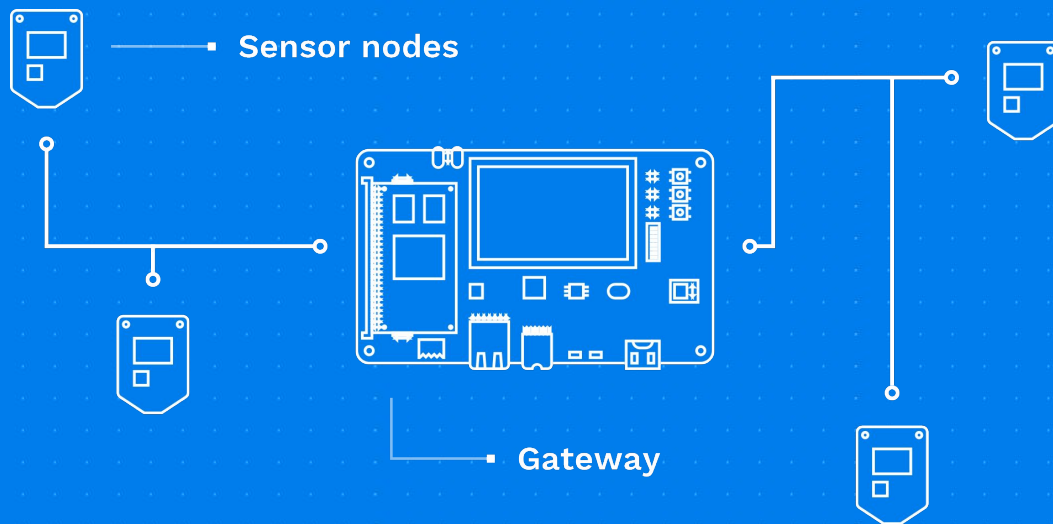
Layer #1: System-on-Chip



Layer #2: The device



Layer #3: Complex system



Supported platforms/vendors

LEON3	 life.augmented	 QuickLogic
 NORDIC SEMICONDUCTOR	 MICROCHIP	
 SILICON LABS	 TEXAS INSTRUMENTS	
 SiFive	 RISC-V	 OpenPOWER™

Supported boards



Platform description format

- human readable
- modular
- extendible
- enable new boards /
platforms w/o coding

```
uart: UART.MiV_CoreUART @ sysbus 0x70001000  
    clockFrequency: 66000000
```

```
cpu: CPU.RiscV @ sysbus  
    cpuType: "rv32g"
```

```
plic: Interrupts.PlatformLevelInterruptController @ sysbus 0x40000000  
    IRQ -> cpu@1  
    numberOfSources: 31 //based on release notes
```

Various integrations



GitLab



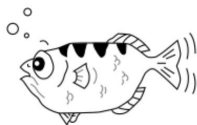
Wireshark



Robot



Jenkins



GDB



Verilator



USB/IP

Various integrations

- Verilator for HW-SW co-development ([note](#) with Google on our blog)
- PlatformIO integration ([note](#) on Linux Foundation blog)
- TensorFlow Lite support ([note](#) with Google on TF Lite blog)
- Robot Framework, Jenkins, GitLab CI, GitHub Actions (e.g. [blog note](#) by Memfault)
- protocol / stack testing: OPC-UA, TSN, 6lowpan, Thread etc.

Renode & Linux

Renode enables Linux development through supported architectures:



Renode framework Retweeted

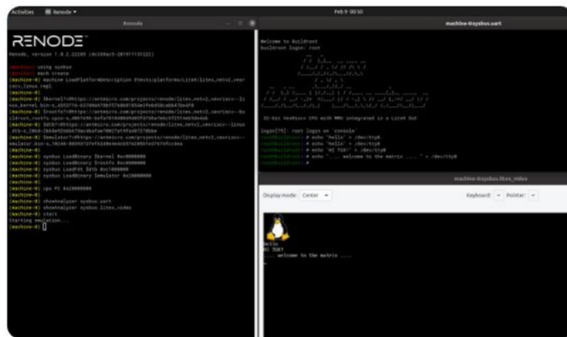


Drew Fustini @pdp7

Pretty neat that with [@renodeio](https://renode.io) on my laptop, I can emulate Linux running on a RISC-V processor including a framebuffer to show that adorable Tux



[github.com/renode/renode/...](https://github.com/renode/renode/)



1:45 AM · Feb 9, 2020 · Twitter Web App

7 Retweets 30 Likes

Renode's Linux-Capable Platforms and Demos

- Kendryte (Linux-nommu)
- LiteX/VexRiscv
- HiFive Unleashed (buildroot)
- PolarFire SoC Icicle Kit (Yocto/buildroot)
- Zedboard
- Vybrid
- Versatile
- Versatile Express
- Nvidia Tegra 3

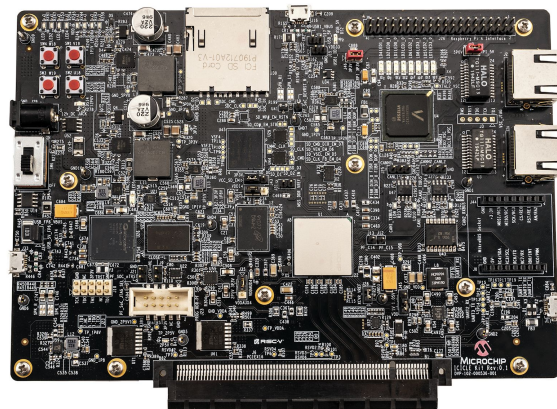
VexRiscv

- VexRiscv - best performing soft (FPGA) RISC-V implementation
- super scalable, from Lattice iCE40 to big FPGAs
- winner of 2018 RISC-V soft CPU contest
- multi-core, Linux-capable platform ([blog note](#)), lots of I/O & features supported in Renode

PolarFire SoC

- 1st mass-produced Linux-capable RISC-V implementation
- Early adopters of the platform
- Pre-silicon access to it in Renode
- All peripherals supported
- Affordable and powerful
- Already generating lots of interest and expected to be very successful

PolarFire Icicle kit



RENODE™

Renode, version 1.10.1.23438 (466d0236-202008201352)

(monitor) s @scripts/single-node/icicle-kit.resc

(machine-0) █

```
[ 1.239813] mmc0: unrecognised CSD structure version 0
[ 1.239922] mmc0: error -22 whilst initialising MMC card
[ 1.283132] mmc0: unrecognised CSD structure version 0
[ 1.283242] mmc0: error -22 whilst initialising MMC card
```

Starting syslogd: OK

Starting klogd: OK

Running sysctl: OK

Starting mdev... OK

modprobe: can't change directory to '/5.6.16': No such file or directory

Starting network: [3.190022] macb 20112000.ethernet eth0: validation of sgmi w
ith support 000,00000000,00006280 and advertisement 000,00000000,00004280 failed: -
22

[3.190527] macb 20112000.ethernet eth0: Could not attach PHY (-22)

ip: SIOCSIFFLAGS: Invalid argument

FAIL

Starting dropbear sshd: FAIL

Welcome! Login with root/root

buildroot login: root

Password:

█

machine-0:sysbus.mmuart0

- □ ×

```
[ 1.074000] RunStateMachine(): boot_service(u54_3)::Download -> boot_service(u54_3)::Idle
[1.375000] RunStateMachine(): boot_service(u54_3)::Download -> boot_service(u54_3)::Idle
[1.375100] RunStateMachine(): boot_service(u54_4)::Download -> boot_service(u54_4)::Idle
[1.375100] RunStateMachine(): boot_service(u54_4)::Download -> boot_service(u54_4)::Idle
[1.378100] RunStateMachine(): boot_service(u54_1)::Download -> boot_service(u54_1)::Wait
[1.378300] boot_download_chunks_onExit(): boot_service(u54_1)::u54_2:sbi_init 80200
000
[1.378500] boot_download_chunks_onExit(): boot_service(u54_1)::u54_3:sbi_init 80200
000
[1.380200] boot_download_chunks_onExit(): boot_service(u54_1)::u54_4:sbi_init 80200
000
[1.380300] boot_download_chunks_onExit(): boot_service(u54_1)::u54_1:sbi_init 80200
000
[1.380500] boot_wait_onEntry(): boot_service(u54_1)::Checking for IPI ACKs: - -
[1.380700] boot_wait_handler(): boot_service(u54_1)::Checking for IPI ACKs: ACK/IDL
E ACK
[1.380900] RunStateMachine(): boot_service(u54_1)::Wait -> boot_service(u54_1)::Idle
e
█
```



Supported boards

Renode supports a wide array of hardware platforms, covering multiple architectures, CPU families and providing various I/O capabilities.

This chapter contains an (incomplete) list of selected supported hardware targets - all of these include sample software binaries that run both on real hardware and in Renode.

To run example software on any of the below boards, simply run Renode and use:

```
s @scripts/PATH/TO/SCRIPT-NAME.resc
```

Tab completion is available also for filenames, so be sure to explore the available demos.

The ultimate goal of Renode is to run any binary-compatible software targeted for any of those hardware platforms without modification, although of course your specific use case may require extending the provided hardware description / models.

Supported boards include:



QuickFeather Development
Kit



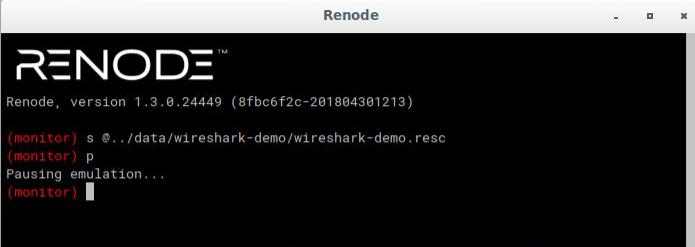
OpenPOWER Microwatt on
Digilent Nexys Video



Microchip PolarFire SoC
Icicle Kit

Renode and networking

- multi-node capability & determinism
open up IoT testing use cases
- simple networking medium
simulation (e.g. distance-based
packet loss)
- enables testing protocols and stacks
(OPC-UA, Zephyr)
- integrate with regular network
testing tools



```
13:41:24.1211 [DEBUG] client/radio: Sending frame 0x61 0xDC 0xB 0xCD 0xAB 0x1 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0 0x0  
0xC5 0x66 0x4 0x0 0x0 0x0 0x40 0xA4. (2)  
13:41:24.1311 [WARNING] server/sysbus: [CPU0: 0x20B5D8] (tag: ADC) ReadDoubleWord from non existing peripheral  
13:41:24.1312 [WARNING] server/sysbus: [CPU0: 0x20B5D8] (tag: ADC) WriteDoubleWord to non existing peripheral  
13:41:24.1312 [WARNING] server/sysbus: [CPU0: 0x20B5D8] (tag: ADC) ReadDoubleWord from non existing peripheral  
13:41:24.1312 [WARNING] server/sysbus: [CPU0: 0x20B5D8] (tag: ADC) WriteDoubleWord to non existing peripheral  
13:41:24.1312 [WARNING] server/sysbus: [CPU0: 0x20B5D8] (tag: ADC) ReadDoubleWord from non existing peripheral
```

```

13:41 Sending response 0 to fd00::200:0:0:2
13:41 Received request 1 from fd00::200:0:0:2
13:41 Sending response 1 to fd00::200:0:0:2
13:41 Received request 2 from fd00::200:0:0:2
13:41 Sending response 2 to fd00::200:0:0:2
0xC5 Received request 3 from fd00::200:0:0:2
13:41 Sending response 3 to fd00::200:0:0:2
0x0 0 Received request 4 from fd00::200:0:0:2
0x0 0 Sending response 4 to fd00::200:0:0:2
13:41 Received request 5 from fd00::200:0:0:2
13:41 Sending response 5 to fd00::200:0:0:2
13:41

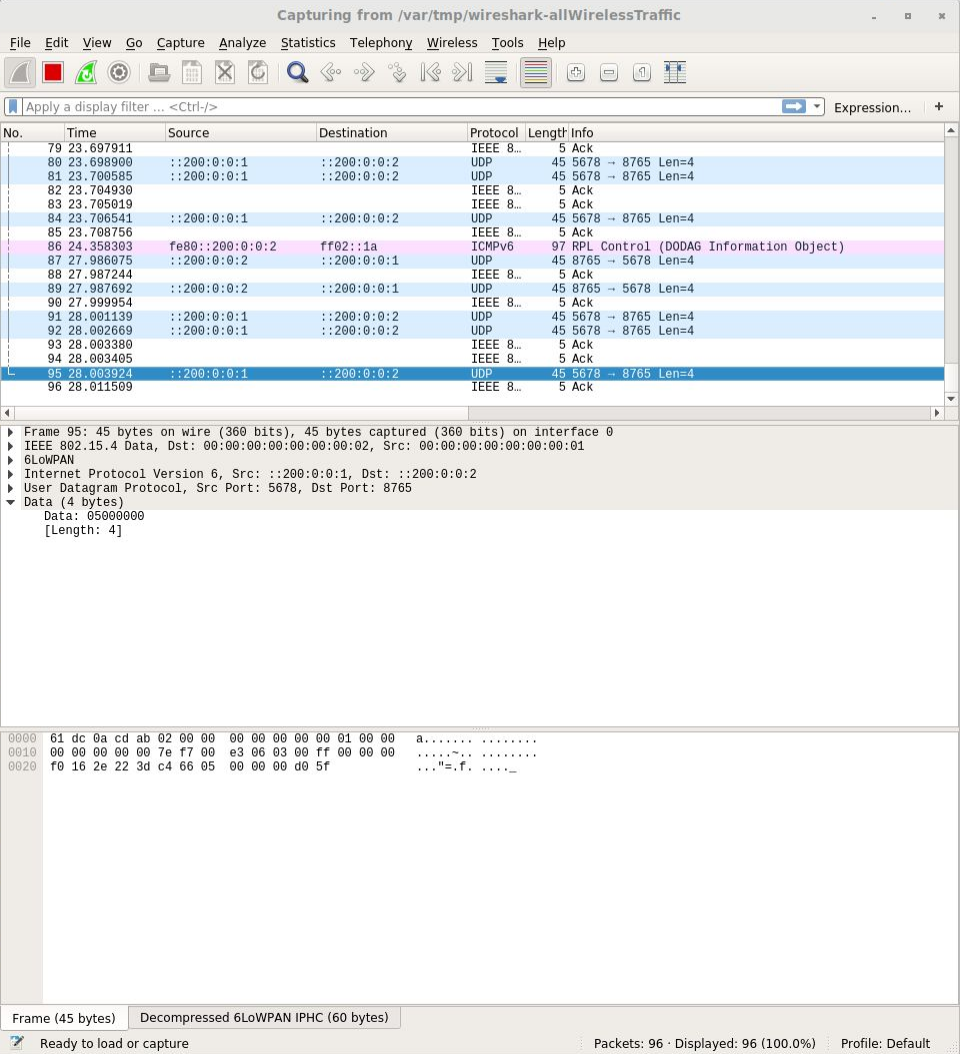
```

```
13:41:27.2544 [WARNING] client/sysbus: [CPU0: 0x203E24] (tag: 'ADC') ReadDoubleWord from non existing peripheral
13:41:27.2544 [WARNING] client/sysbus: [CPU0: 0x203E24] (tag: 'ADC') WriteDoubleWord to non existing peripheral
13:41:27.2545 [WARNING] client/sysbus: [CPU0: 0x203E24] (tag: 'ADC') ReadDoubleWord from non existing peripheral
13:41:27.2545 [WARNING] client/sysbus: [CPU0: 0x203E24] (tag: 'ADC') ReadDoubleWord from non existing peripheral
13:41:28.4190 [WARNING] client/sysbus: [CPU0: 0x203E24] (tag: 'ADC') ReadDoubleWord from non existing peripheral
13:41:28.4191 [WARNING] client/sysbus: [CPU0: 0x203E24] (tag: 'ADC') WriteDoubleWord to non existing peripheral
```

```

13:41:28.4191
13:41:28.4201
13:41:28.4221
client:sysbus.uart0
Sending request 0 to fd00::200:0:0:1
0xC4 0x66 0x5
Received response 0 from fd00::200:0:0:1
13:41:28.4349
Sending request 1 to fd00::200:0:0:1
13:41:28.4350
Received response 1 from fd00::200:0:0:1
13:41:28.4350
Sending request 2 to fd00::200:0:0:1
13:41:28.4350
Received response 2 from fd00::200:0:0:1
13:41:28.4383
Sending request 3 to fd00::200:0:0:1
0xC4 0x66 0x5
Received response 3 from fd00::200:0:0:1
13:41:29.0983
Sending request 4 to fd00::200:0:0:1
13:41:29.0983
Received response 4 from fd00::200:0:0:1
13:41:29.0984
Sending request 5 to fd00::200:0:0:1
13:41:29.0984
Received response 5 from fd00::200:0:0:1
13:41:29.1094
13:41:29.1095

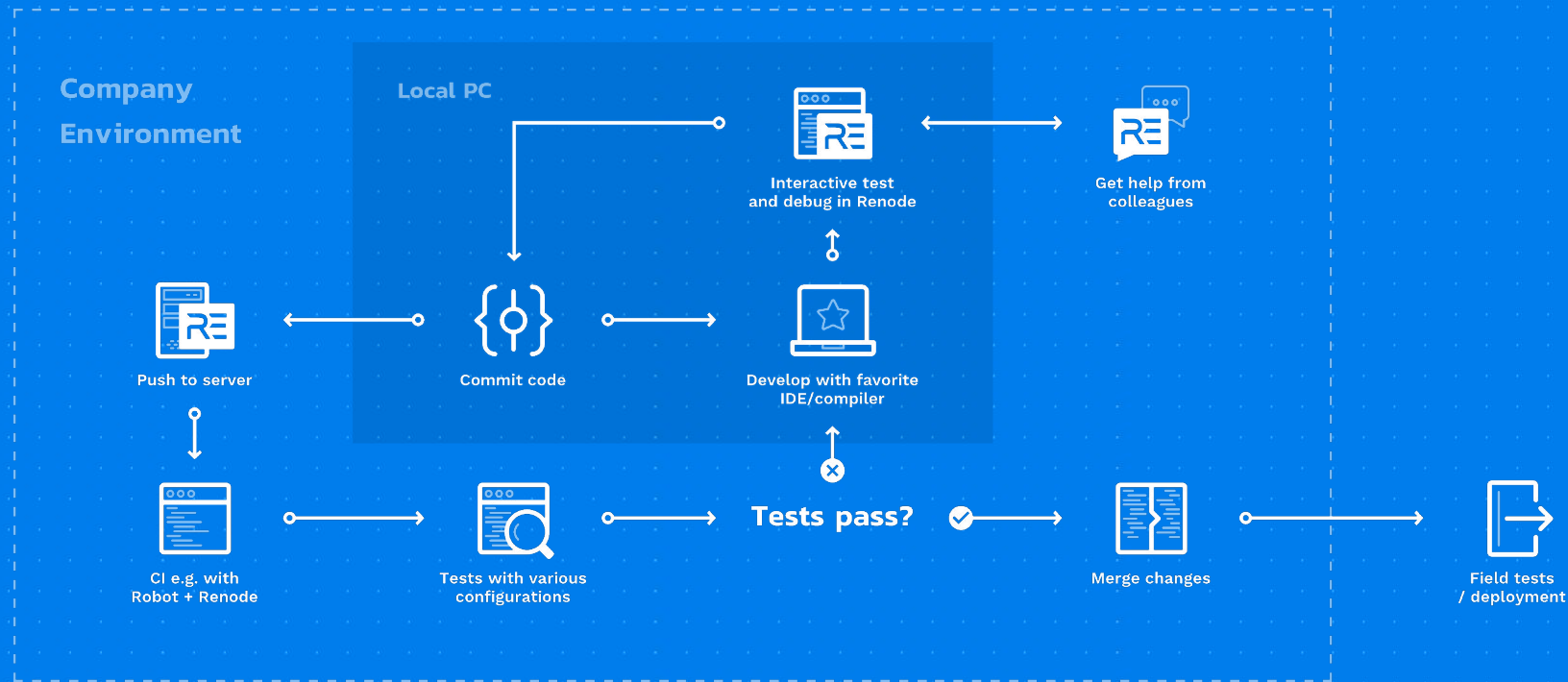
```



Continuous Integration

- CI is used extensively at Antmicro and our customers
- SW building, testing and deploying using isolated reproducible containerized environments, such as Docker and Singularity
- Automated build pipelines that can be executed by multiple parties
- Gives reproducible and traceable result
- Simplifies testing new changes
- Eliminates points of failure while working on multiple devices in different locations
- Can be used to build multiple product variants, entire product lines

Renode-based Continuous Integration workflow for IoT systems



Testing / CI

- Easy to create new test cases in Renode thanks to Robot Framework integration
- Tested software includes:
 - Linux
 - FreeRTOS
 - Zephyr
 - RIOT
 - TensorFlow Lite
 - Mbed
 - NuttX
 - Tock
 - micropython
 - Android
 - Bare Metal software
 - Contiki
 - Wolfboot
 - eCos
 - Redboot
 - and more!



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2786b68 8 days ago

 [History](#)

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 LiteX_I2C_Zephyr.cs	Reduce verbosity of the demo	3 months ago
 angle.data	Add Renode section	9 months ago
 circle.data	Add Renode section	9 months ago
 litex-vexriscv-tflite.repl	Add Renode section	9 months ago
 litex-vexriscv-tflite.resc	README: Use locally-built binaries when running Renode	8 days ago
 litex-vexriscv-tflite.robot	Remove redundant ADXL345 model	3 months ago

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```
antmicro@renode-dell: ~/renode-hq-master/renode
File Edit View Search Terminal Help
21
20 Execute Command sysbus.gpioInputs.user_switch_1 Toggle
19 Test If Uart Is Idle 5
18
17 Should Generate Interrupts On Gpio Both Edges
16 Create Machine riscv-interrupt-blinky-gpio_interrupts-edge_both.elf-s_134928-d90257bf
15 Create Terminal Tester ${UART}
14
13 Start Emulation
12
11 Wait For Line On Uart CoreTIMER and external Interrupt Example.
10 Wait For Line On Uart Observe the LEDs blinking on the board. The LED patterns changes every
9
8 Test If Uart Is Idle 5
7
6 Execute Command sysbus.gpioInputs.user_switch_0 Toggle
5 Wait For Line On Uart GPIO1
4
3 Execute Command sysbus.gpioInputs.user_switch_0 Toggle
2 Wait For Line On Uart GPIO1
1
157 Execute Command sysbus.gpioInputs.user_switch_1 Toggle
MiV.robot 157,17 62%
```

```
antmicro@renode-dell: ~/renode-hq-master/renode
File Edit View Search Terminal Help
antmicro@renode-dell:~/renode-hq-master/renode$ ./test.sh tests/platforms/MiV/MiV.robot
Preparing suites
Starting suites
Running tests/platforms/MiV/MiV.robot
=====
MiV
=====
Should Blink Led Using Systick | PASS |
-----
Should Blink Led Using CoreTimer | PASS |
-----
Should Run FreeRTOS Sample | PASS |
-----
Should Run LiteOS Port Sample | PASS |
-----
Should Generate Interrupts On Gpio Rising Edge | PASS |
-----
Should Generate Interrupts On Gpio Falling Edge | PASS |
-----
Should Generate Interrupts On Gpio Both Edges | PASS |
-----
Should Generate Interrupts On Gpio High Level | PASS |
-----
Should Generate Interrupts On Gpio Low Level | PASS |
-----
MiV | PASS |
9 critical tests, 9 passed, 0 failed
```

TEST SUITE TEST LOG

20190729 13:31:14 GMT+02:00 | 1 day 5 hours ago

REPORT

Log level: TRACE

Test Statistics

Total Statistics	Total	Pass	Fail	Elapsed	Pass / Fail
Critical Tests	6	6	0	00:02:39	
All Tests	6	6	0	00:02:39	

Statistics by Tag

Total	Pass	Fail	Elapsed	Pass / Fail
No Tags				

Statistics by Suite

Total	Pass	Fail	Elapsed	Pass / Fail	
Test Suite	6	6	0	00:02:42	

Test Execution Log

SUITE	Test Suite	00:02:42.304
Full Name:	Test Suite	
HotSpot Action:	-	
Source:	/tmp/45-pipeline/SAME70.robot	
Start / End / Elapsed:	20190729 13:28:32.325 / 20190729 13:31:14.629 / 00:02:42.304	
Status:	6 critical test, 6 passed, 0 failed 6 test total, 6 passed, 0 failed	
+ SETUP	renode-keywords: Setup	00:00:03.419
+ TEARDOWN	renode-keywords: Teardown	00:00:00.003
+ TEST	Single Node Should Send A PDelay Request Packet	00:00:05.597
+ TEST	Slave Should Call The Phase Dis Callback	00:00:18.705
- TEST	Master Should Send Announce Packets With The Expected Parameters	00:00:07.651
Full Name:	Test Suite.Master Should Send Announce Packets With The Expected Parameters	
Start / End / Elapsed:	20190729 13:29:00.115 / 20190729 13:29:07.766 / 00:00:07.651	

LINUX-LITEX-VEXRISCV-PIPELINE

A Linux build running on the LiteX soft SoC



[CONTAINER](#)
[FULL HISTORY](#) →

Last launch: **Pass**

07/13/2019, 10:24 | e5314db | 00:01:49

[DETAILS](#) →

RIOT-CC2538DK-PIPELINE



[CONTAINER](#)
[FULL HISTORY](#) →

Last launch: **Pass**

07/13/2019, 10:42 | cea907d | 00:00:32

[DETAILS](#) →

RPL UDP IN CONTIKI-NG ON CC2538DK

Two **CC2538** nodes running Contiki-NG connected with RPL-UDP



[CONTAINER](#)
[FULL HISTORY](#) →

Last launch: **Pass**

07/13/2019, 10:24 | 7f6d340 | 00:05:34

[DETAILS](#) →

ZEPHYR TSN/GPTP ON SAM E70



[CONTAINER](#)
[FULL HISTORY](#) →

Last launch: **Pass**

07/04/2019, 11:03 | 9ecc6cd | 00:10:06

[DETAILS](#) →

Interesting?

Get Renode™ for:

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macOS  Download	Windows  Download	

Renode 1.10 – latest news

- Renode 1.10 recently released
- portable Renode installation option - no dependencies required
- New CPUs, SoCs, platform and boards, e.g:
 - NXP K64F
 - Nordic NRF52-DK (32-bit Arm Cortex-M4 CPU)
 - Microwatt
 - 4-core VexRiscv
 - PolarFire peripherals
 - Enhanced QuickLogic EOS S3 support

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THANK YOU
FOR YOUR ATTENTION!

