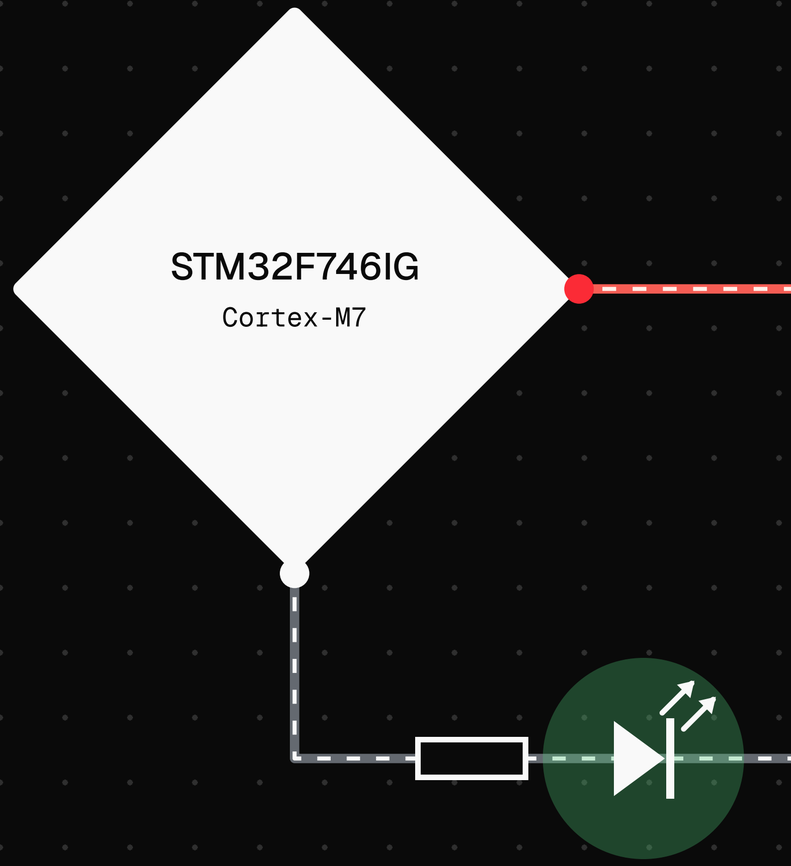
εmul

FOSS 2026 · EDUCATION TRACK

An open browser-based co-simulator of STM32 firmware and electrical circuits as a free alternative to Proteus



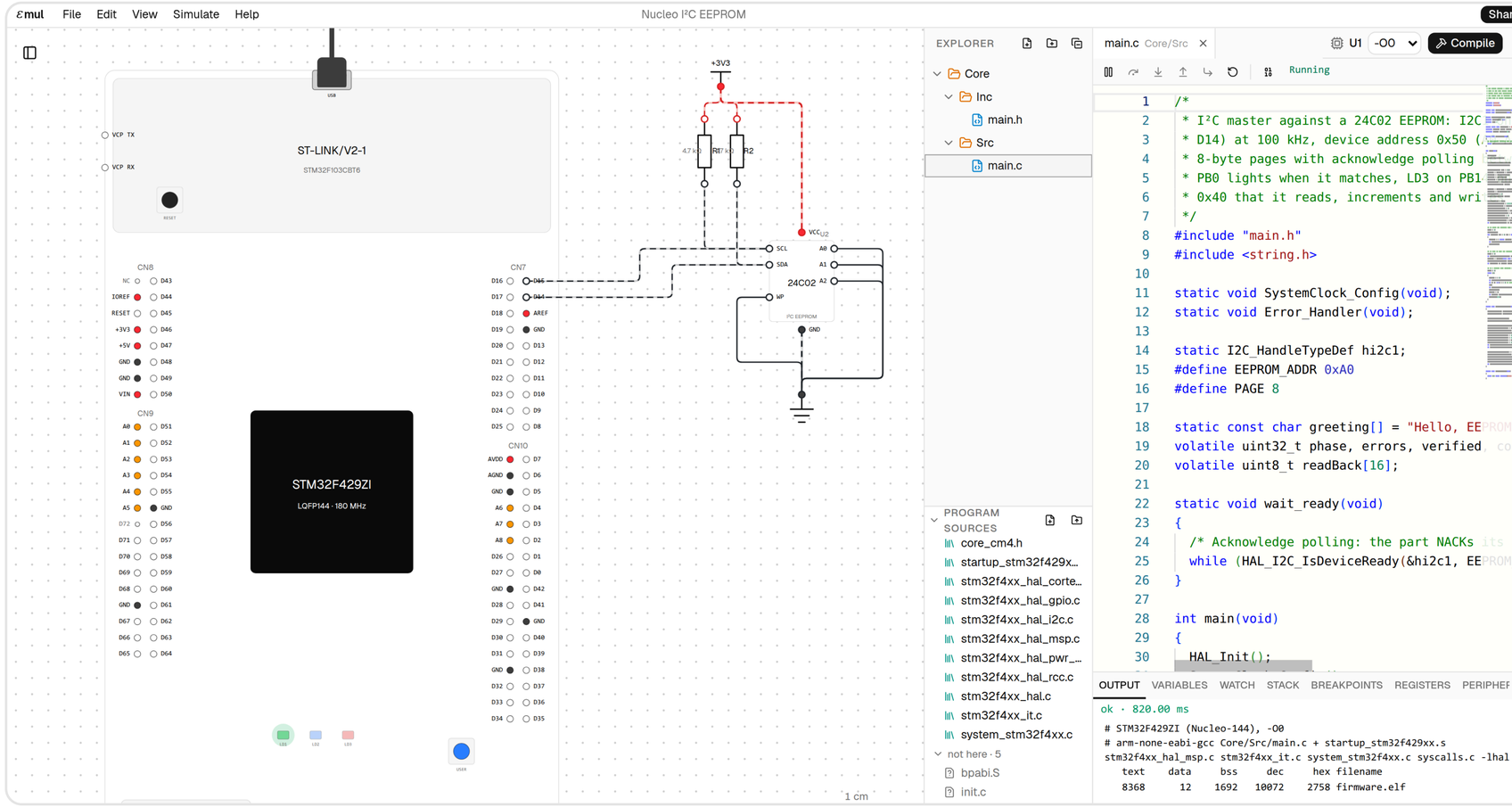
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Chernihiv Polytechnic National University, Department of Information and Computer Systems

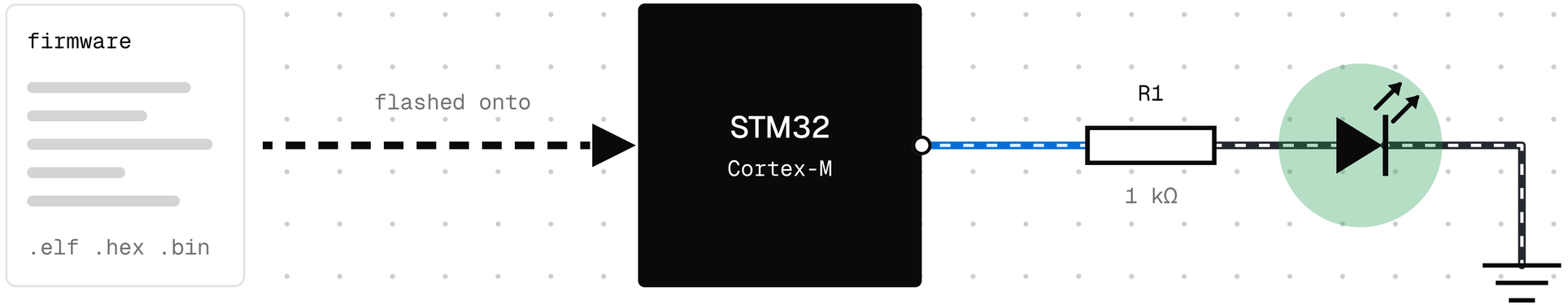
εmul runs unmodified STM32 firmware against a simulated circuit, in a browser tab.

Load the firmware from STM32CubeIDE, or write it in the browser. Wire the parts, press Run.

- Apache-2.0
- emul.digituni.org, nothing to install



In a microcontroller lab, the code and the circuit only work together.



Firmware
C/C++ code compiled for the chip

Microcontroller
a small computer that drives pins

Circuit
what the pins drive and read

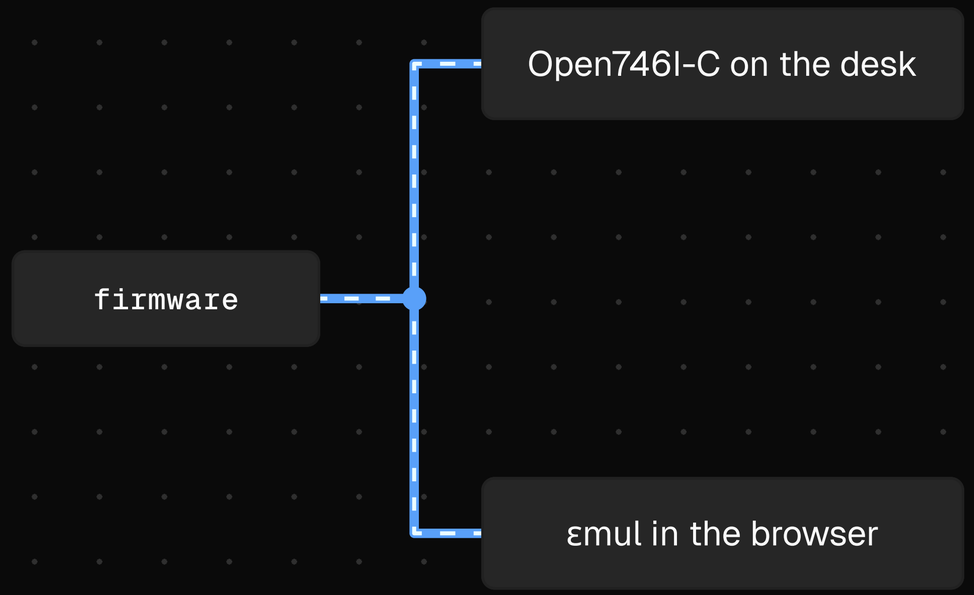
With no board on every desk, the course needs a simulator that runs the firmware and the circuit at once.

Proteus runs firmware against a circuit but is closed; each free tool covers one side.

	Runs STM32 Cortex-M4/M7 firmware	Simulates the circuit	Free software	
Proteus VSM	◐	●	○	paid, Windows only
Wokwi (hosted, free tier)	○	○	○	digital, up to Cortex-M3
SimulIDE	○	●	●	desktop, no ARM yet
QEMU	◐	○	●	CPU only, no GPIO model
ngspice	○	●	●	no MCU emulation
εmul	●	●	●	in the browser, Apache-2.0

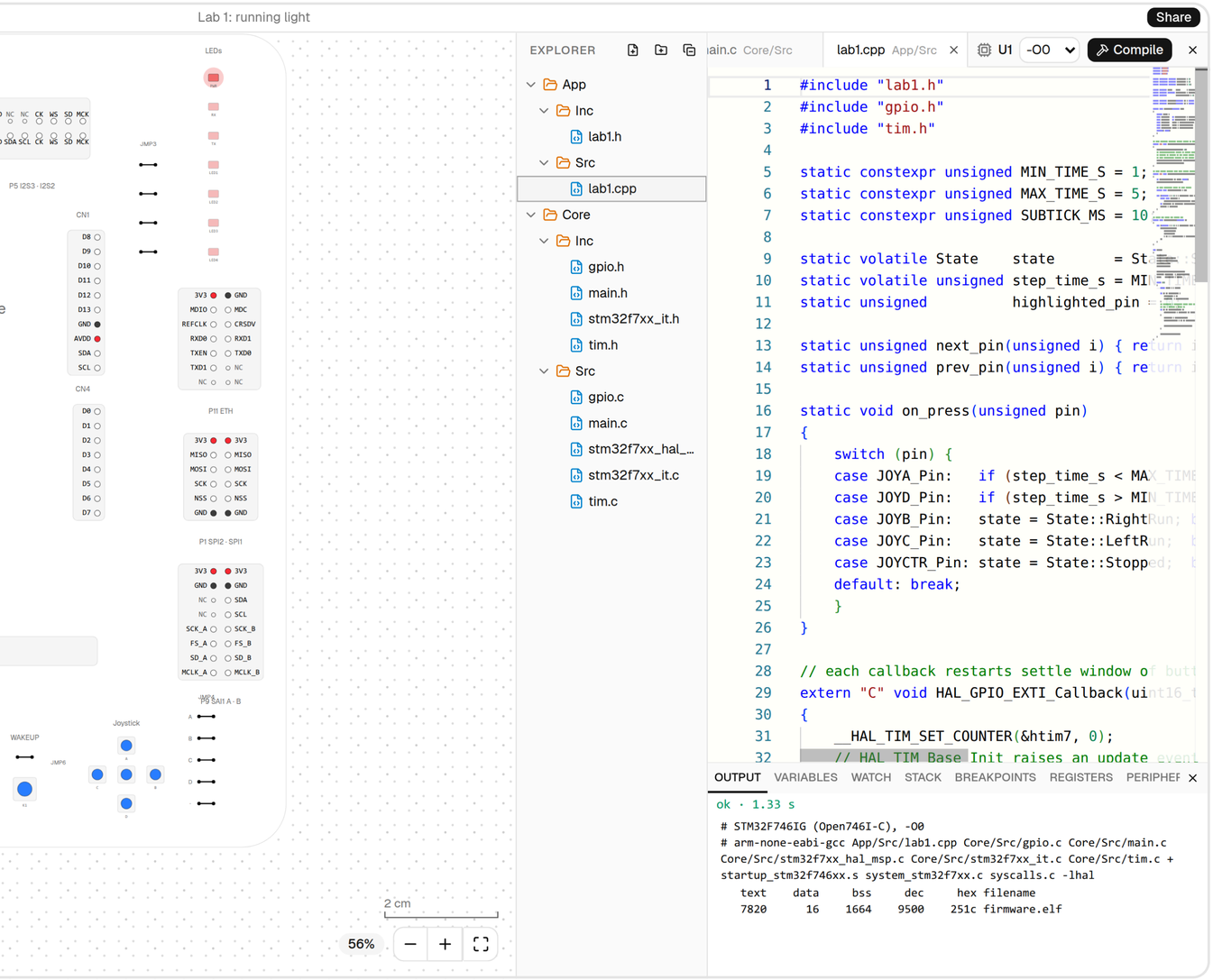
Virtual and physical labs together teach more than either alone.

de Jong, Linn & Zacharia, Science 340 (2013), 305-308



So the firmware has to be the same on the board and in the simulator.

From a link to a running bench in five steps.



01 Open emul.digituni.org

02 Place a board

03 Wire the parts

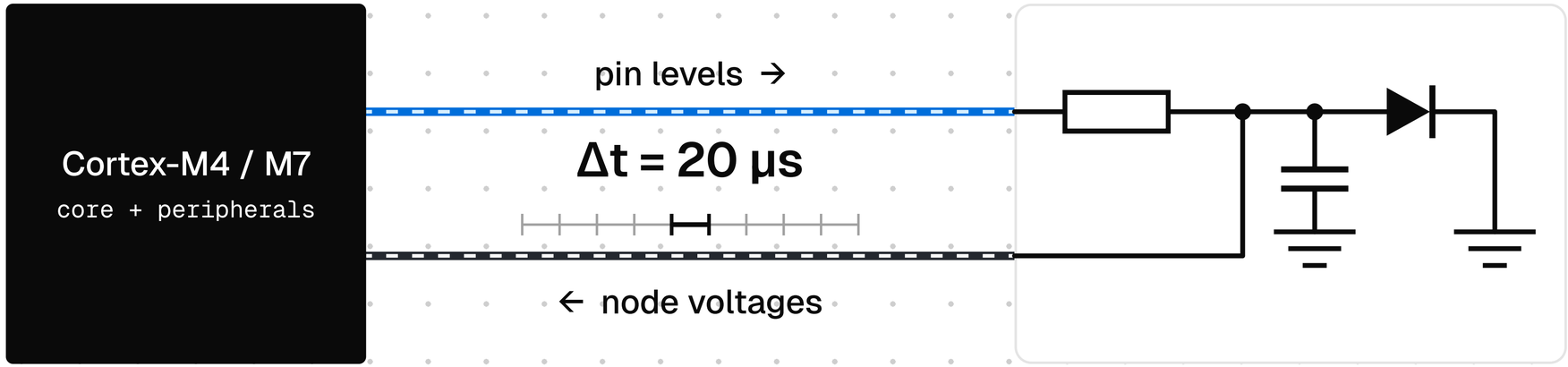
04 Load an .elf, .hex or .bin, or write the code here

05 Press Run

The editor is also a debugger: breakpoints, stepping, registers.

Share a bench as a link, or edit it together live.

The firmware and the circuit advance together, 20 µs at a time.



CPU emulator

discrete-event, one step ahead

Circuit solver

continuous: transient MNA, θ = 0.52

SERIAL BUSES

Time-exact edges: a 115 200-baud bit is shorter than Δt.

DATASHEET LIMITS

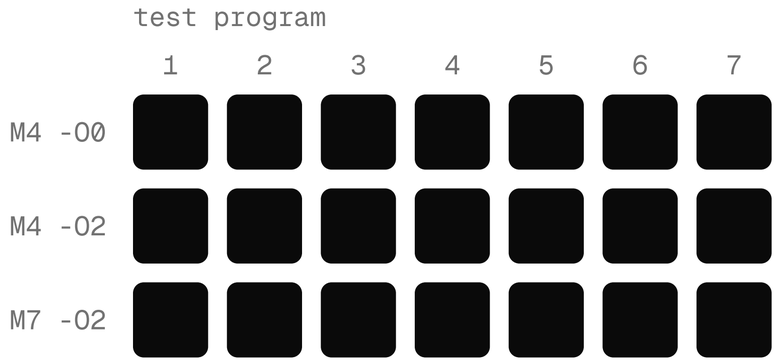
12 V on a GPIO does what it does on the desk.

Every check value from the emulated core matched a host build of the same programs.

1 074

check values, all equal to the host build

seven C test programs, three builds of each



21 images, no discrepancies

506.6 M

instructions where the compiled blocks and the interpreter agree

the block compiler turns Thumb-2 code into JavaScript; the interpreter is the reference

The solver agrees with ngspice on the same models.

0.016 %

median deviation, 22 quantities

ngspice 36, same models

Zener: load voltage

Amplifier: collector voltage

Amplifier: gain

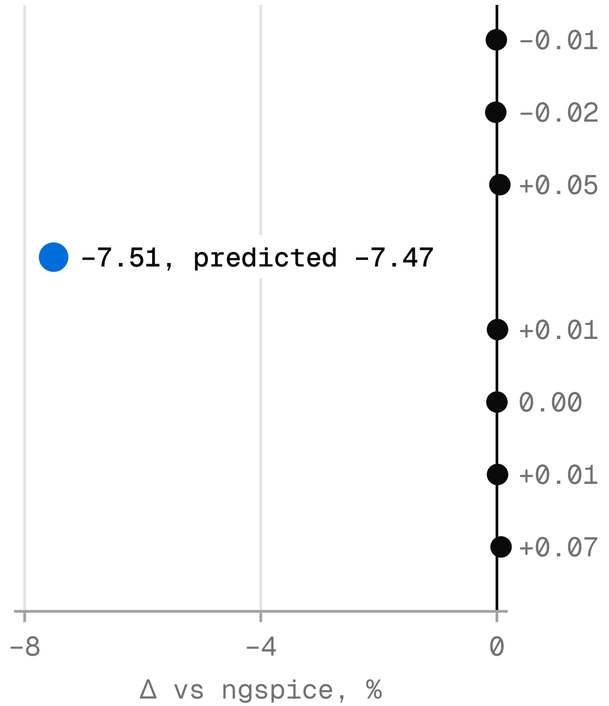
RLC at resonance: current

Rectifier: peak

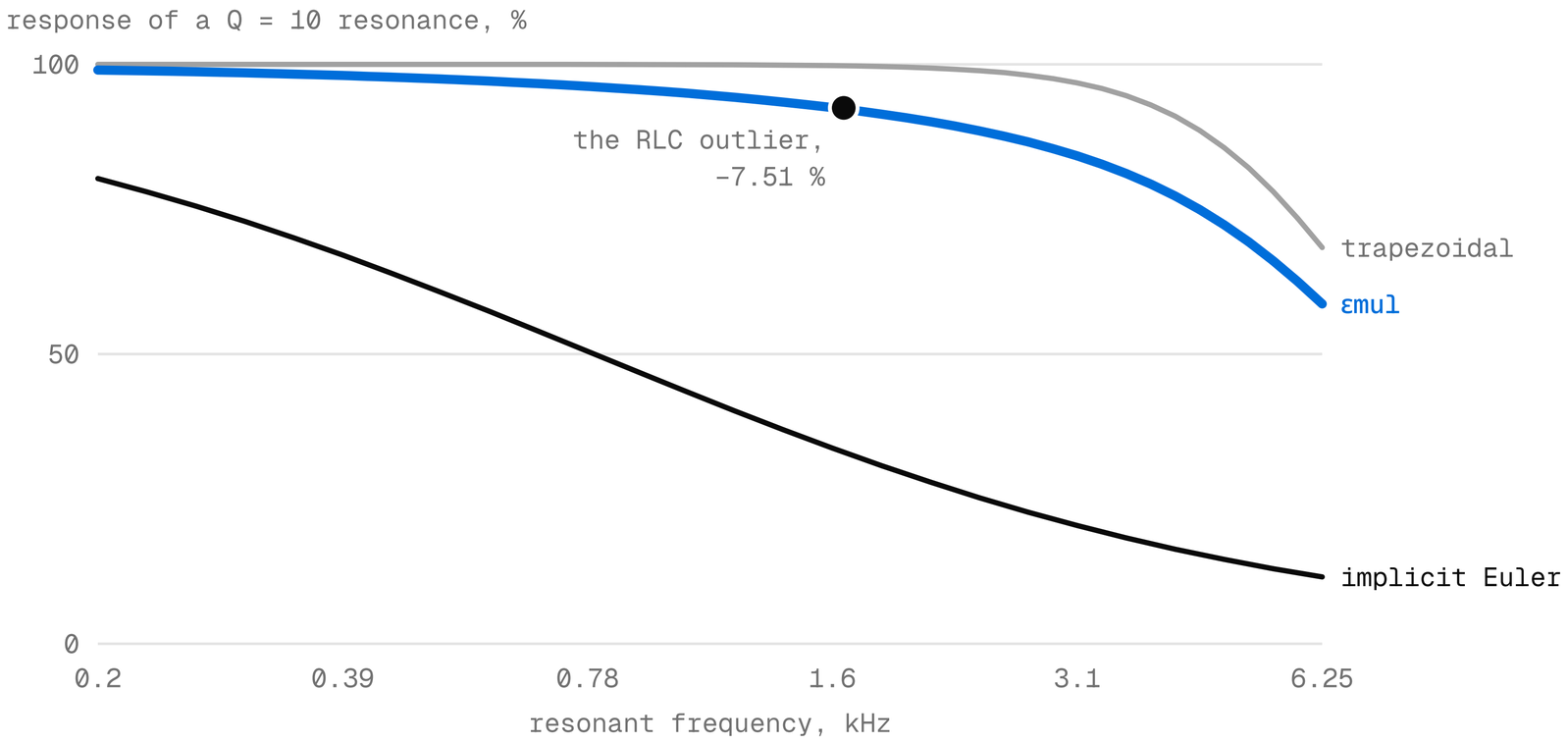
Rectifier: ripple

Current mirror: output

MOSFET: drain–source voltage



The 20 µs step damps fast resonances, predictably.



What εmul loses

2 % at 0.4 kHz

7.5 % at 1.6 kHz

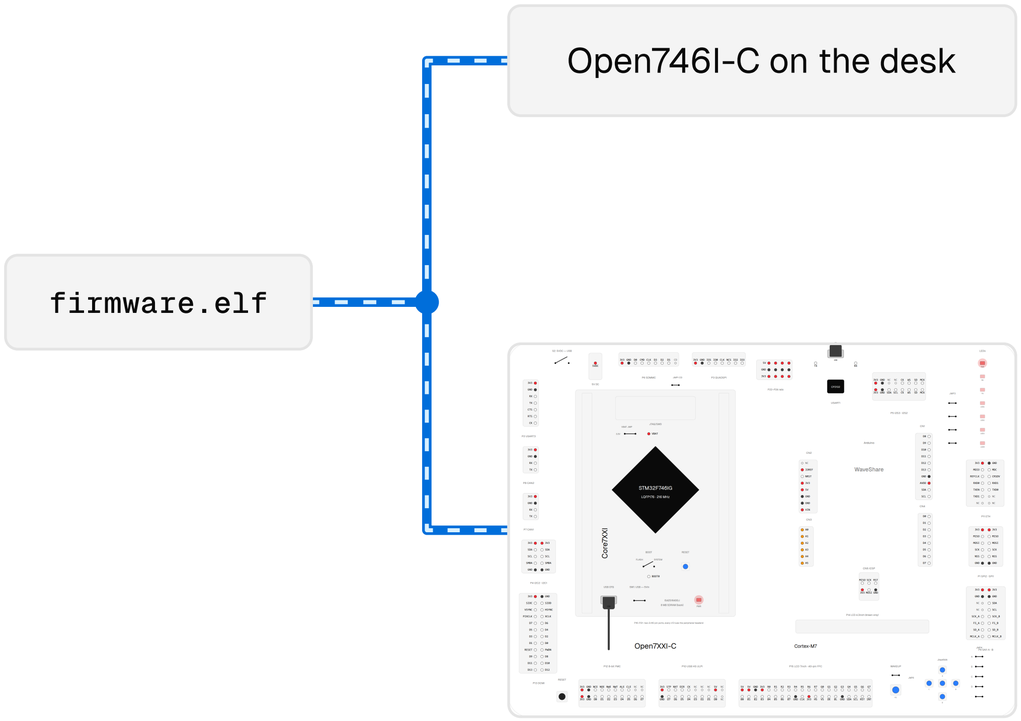
41 % at 6.25 kHz

Predicted by the θ-method:

$$s \to \frac{1 - z^{-1}}{\Delta t \left(\theta + (1 - \theta)\, z^{-1}\right)}, \qquad z = e^{\,j\omega\Delta t}$$

55 measured points fall on the predicted curves, median 0.05 %.

The same lab .elf behaved identically on the physical board and in ɛmul.



ɛmul in the browser

LAB 1 TASK

- a running light on four LEDs
- joystick C and B set the direction
- A and D change the dwell, 1–5 s
- the centre stops it; debounced in software

1.000 s

dwell in ɛmul for a set 1 s

5.000 s

at the 5 s cap

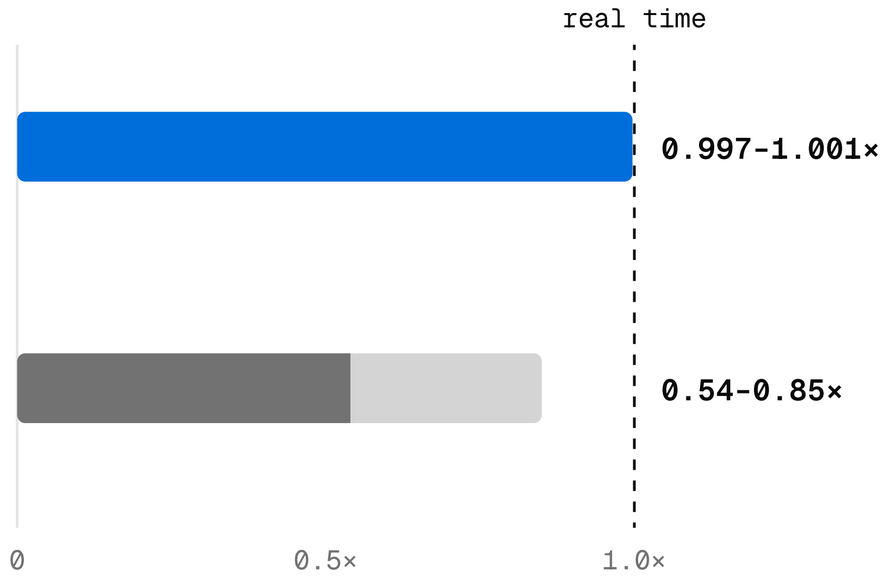
IN CLASS

Two more students defended this lab on ɛmul, and the lecturer accepted their work.

Lab benches run in real time, in the browser.

Lab bench, F746 at 50 MHz
and two LCD demos at 200 MHz

Firmware with an idle loop
at 180 MHz



The solver keeps real time up to ~40 linear or ~15–20 nonlinear unknowns; slower benches give the same results, only later.

99.9 %

of solver steps skipped as settled in a blink firmware

so the emulated core sets the speed

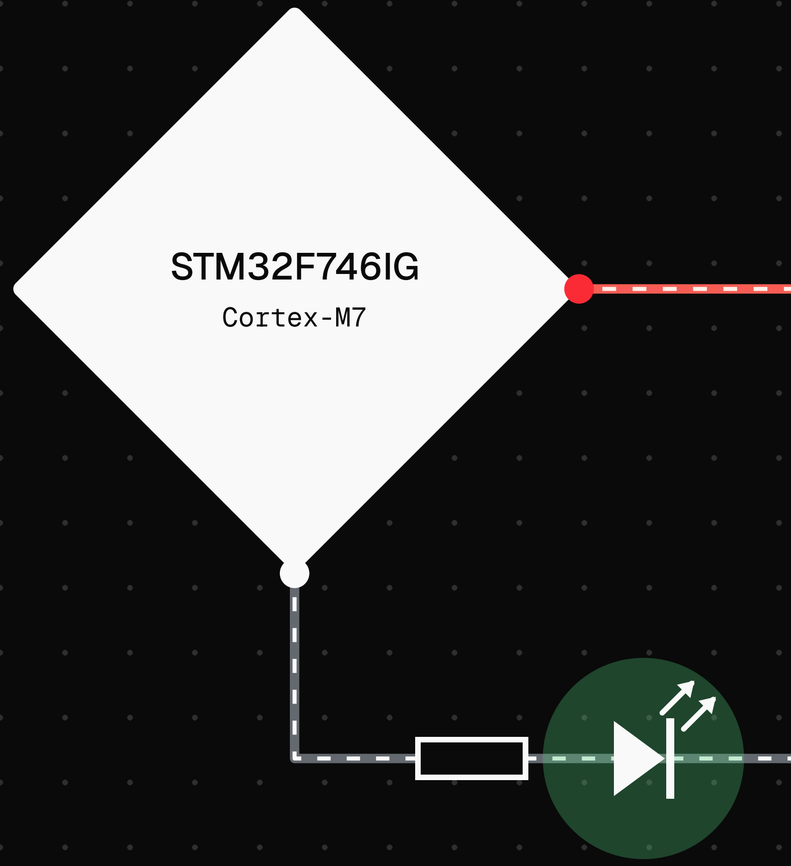
Production build · Chromium 151 · Intel Core i5-10400 · 10 s window

We know four limits and have a next step for each.

LIMIT TODAY		NEXT
20 µs step damps resonances above ~2 kHz	→	adaptive step
Board timing observed, not measured	→	measure UART, PWM, wake-from-Stop
Only informal classroom use	→	a structured study in the course
No ready-made logic ICs, character LCDs, sensors	→	74xx ICs; HDL parts work today

εmul

A circuit simulator for microcontroller labs that runs your real STM32 firmware.



emul.digituni.org

github.com/ChernihivPolytechnicNationalUniversity/emul

Apache-2.0 · release v1.22.1

Thank you. Questions?

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