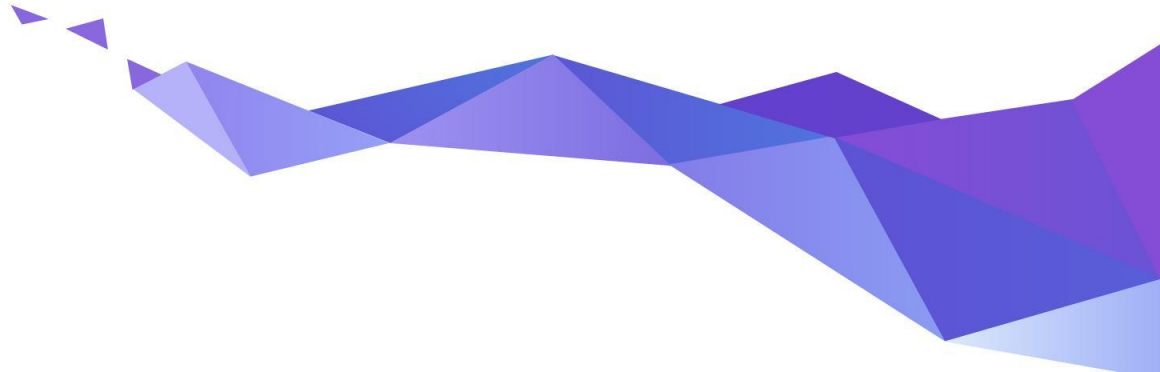# Zephyr in Education

Zephyr usage in ZHAW labs

David Lorenz <lorv@zhaw.ch>, Johannes Neyer <neye@zhaw.ch>

Team IoT, InES, ZHAW

- **Zephyr in research projects since 2019 (v1.14)**

  - Evaluation of the Zephyr RTOS in a Master's thesis
  - Wide adoption of Zephyr in research and development projects

Team IoT, InES, ZHAW

- **Now also in education**

    - Zephyr is used in laboratories of several lectures
        - Microcomputing Systems 1 (Bachelor)
        - Embedded Real-Time Software (Master)
        - Embedded Security (WBK)
    - Firmware of student projects (Bachelor/Master theses)

Embedded Real-Time Software (Master)

- **Threads and Scheduling Concepts**
- **Resource Locks (Mutexes, Semaphores) (Dining Philosophers Problem)**
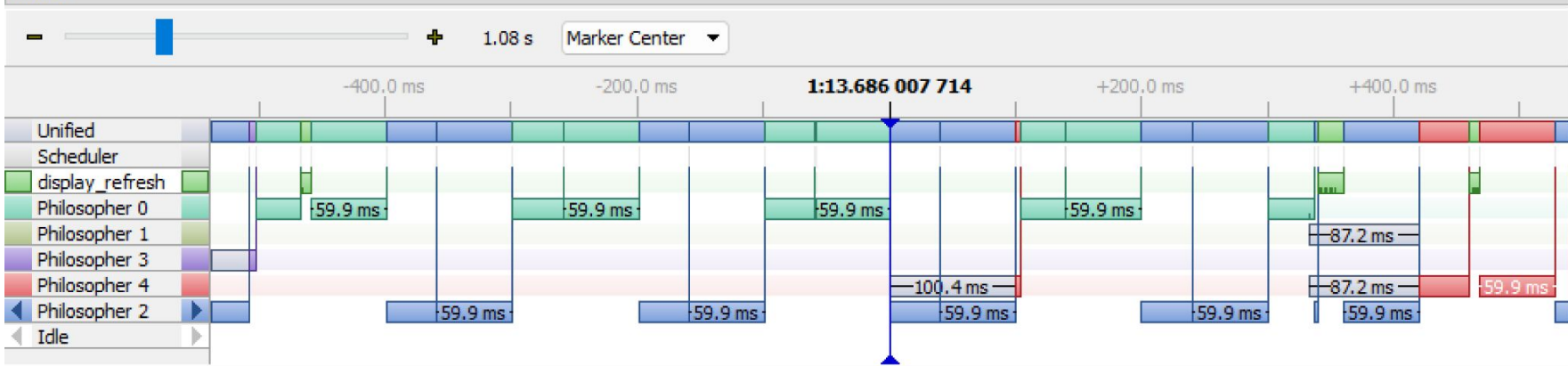- **Debugging (SEGGER Ozone, SEGGER SystemView)**
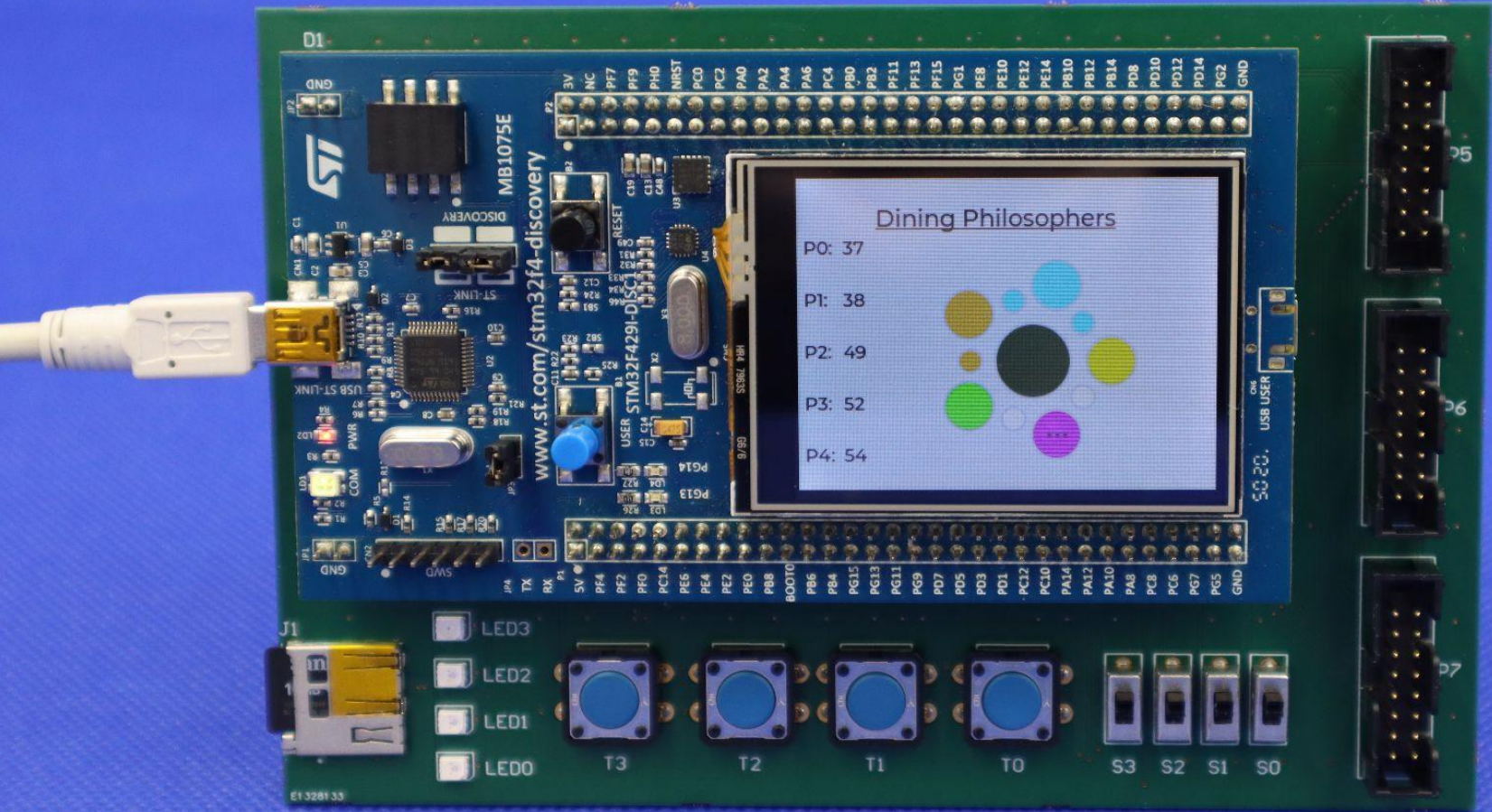
Dining Philosophers

P0: 37

P1: 38

P2: 49

P3: 52

P4: 54

File   View   Go   Target   Tool   Window   Help

#	Time	Context	Event	Resource	Detail
24370	1:13.626 047 744	Scheduler	Task Stop		
24371	1:13.626 052 304	Philosopher 0	Task Run		Runs for 59.950 ms
24372	1:13.685 697 452	Philosopher 0	Task Ready		Philosopher 4, runs after 100.411 ms
24373	1:13.686 002 768	Philosopher 0	Task Stop		
24374	1:13.686 007 714	Philosopher 2	Task Run		Runs for 40.098 ms
24375	1:13.726 097 405	Philosopher 2	Task Ready		display_refresh, runs after 13.464 us
24376	1:13.726 106 018	Philosopher 2	Task Stop		
24377	1:13.726 110 869	display_refresh	Task Run		Runs for 35.798 us
24378	1:13.726 116 107	display_refresh	Function #95		Returns 0x0 after 100.079 ms
24379	1:13.726 119 583	display_refresh	k_mutex_lock	0x20000488	mutex=0x20000488, FOREVER
24380	1:13.726 122 155	display_refresh	k_mutex_lock		Returns ESUCCESS after 2.571 us
24381	1:13.726 131 542	display_refresh	k_mutex_unlock	0x20000488	mutex=0x20000488

Timeline

1.08 s   Marker Center

-400.0 ms   -200.0 ms   **1:13.686 007 714**   +200.0 ms   +400.0 ms

Unified
Scheduler
display_refresh
Philosopher 0   59.9 ms   59.9 ms   59.9 ms   59.9 ms
Philosopher 1   87.2 ms
Philosopher 3
Philosopher 4   100.4 ms   87.2 ms   59.9 ms
Philosopher 2   59.9 ms   59.9 ms   59.9 ms   59.9 ms   59.9 ms
Idle

26 738 Events   01:19.963 200   Loaded

Embedded Security (WBK)

- **3 Labs based on Zephyr RTOS on a nRF52840 dev-kit**

  - Certificate based authentication to a server with the addition of a secure-element
  - Secure boot with MCUBoot and Sysbuild
  - Secure OTA update with MCUBoot and Sysbuild

Embedded Security (WBK)

- **Authentication with secure-element**

    - What is a secure-element?
        - Crypto acceleration
        - Secure storage
        - Public-/private-key management
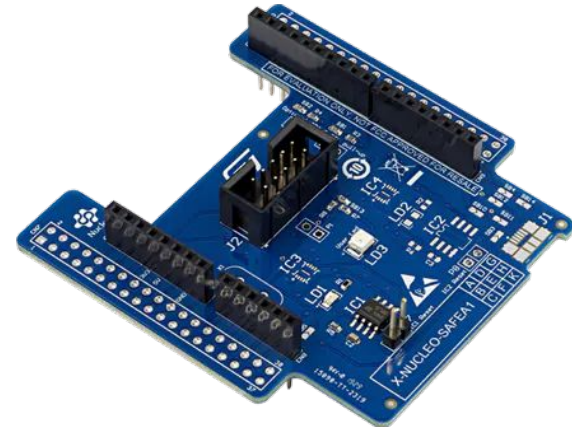
Embedded Security (WBK)

- **Authentication with secure-element**

  - Transform secure-element SDK into a proper Zephyr module
    - Provide necessary hardware abstractions and data structures
    - CMakeLists.txt
    - Kconfig
    - module.yaml

Embedded Security (WBK)

- **Secure boot/update with MCUBoot and Sysbuild**

  - MCUBoot bootloader
    - Default bootloader in Zephyr
    - Not part of the Zephyr-project

Embedded Security (WBK)

- **Secure boot/update with MCUBoot and Sysbuild**

  - Sysbuild
    - Higher-level build system written in CMake
    - Introduced in Zephyr 3.2.0
    - Used to build several applications in one run (e.g. bootloader and main application)

Problems with Zephyr in Education

- **Time in the labs is limited**

    - Focus is on lab content and not development environment
    - Maximizing time for students to work on the problem while minimizing debugging the development environment

Problems with Zephyr in Education

- **Zephyr is new for students**
- **Every student has a different setup**
- **Lab supervisor must be able to provide help efficiently**

Development Environment for Students

- **Goal:**
  - Uniform
  - Reproducible
  - Easy and quick to set up
  - Easy to maintain

Development Environment for Students

- **Initial solution: Ubuntu Desktop VM** (~10 GiB)
  - Not reproducible
  - Time consuming to set up and maintain
  - Uses a lot of resources (storage, RAM, CPU)
  - Forces students to work inside of VM
  - Unreliable file sharing
  - Reliable hardware access
  - Works on Windows/MacOS/Linux

Development Environment for Students

- **Current solution: container / WSL image**
  (~ 2 GiB / ~ .5 GiB compressed)
    - Sufficiently reproducible
    - Lean resource usage
    - Reliable file sharing
    - Students can use familiar environment
    - Works on Windows/MacOS/Linux
    - WSL: hardware is not accessible out of the box
      SEGGER tools (J-Flash Lite, J-Link scripts) are used
      on host for flashing the board

Development Environment for Students

```
FROM debian:12-slim

# Install apt packages
# Install pip packages
# Install Zephyr SDK
# Clone Zephyr

WORKDIR /root/dev
CMD ["bash"]
```

Development Environment for Students

```
docker build \
    --build-arg="ZEPHYR_VERSION=4.0.0" \
    --build-arg="SDK_VERSION=0.17.0" \
    --build-arg="MODULES=cmsis hal_stm32 segger" \
    . -t zephyr_v4.0.0
```

Development Environment for Students

```
cid=$(docker create zephyr_v4.0.0)

docker export $cid > zephyr_v4.0.0_wsl.tar
```

Development Environment for Students

```
cid=$(docker create zephyr_v4.0.0)

docker export $cid > zephyr_v4.0.0_wsl.tar


wsl --import zephyr_v4.0.0 `

    \path\to\wslDistroStorage\zephyr_v4.0.0 `

    zephyr_v4.0.0_wsl.tar
```

Organize ·   New folder

   «   tmp   >   build   >   zephyr

Search zephyr

Name	Date modified	Type	Size
lib	10/10/2024 11:36 AM	File folder	
misc	10/10/2024 11:36 AM	File folder	
soc	10/10/2024 11:36 AM	File folder	
subsys	10/10/2024 11:36 AM	File folder	
isrList.bin	10/10/2024 11:36 AM	BIN File	1 KB
zephyr.bin	10/10/2024 11:36 AM	BIN File	242 KB
zephyr.hex	10/10/2024 11:36 AM	HEX File	680 KB

This PC

Network

Linux

embreal_zephyr_v3.1.0

File name: zephyr.hex

Data files (*.bin *.hex *.mot *.sre)

Open   Cancel

Development Environment for Students

- **Challenges / Outlook**
  - Some people new to shell / containers / WSL
  - Container future proof
- **Successfully conducted two iterations with container**
  - Pleasant setup experience
  - Could cope with heterogeneity
  - All students had a working setup
  - Positive students feedback