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DIAC
Framework for Distributed Industrial Automation and Control

Scheduling IEC 61499 Function Block based models on resource constrained platforms (MCUs)

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Outline

- Introduction
  - Background about industrial control systems and IoT devices
- Proposed development
  - IEC 61499 extension
- run-time system and mapping
  - RTFM-kernel, SRP, and RTFM-4-FUN mapping
- 4DIAC extension and code generation
  - model definition, export filters, and executable compilation
- example and conclusions
  - software based PWM generator

Background about Industrial Control

- Industrial control systems implemented using PLCs
  - Real-time operating system
  - Software run-time environments
- Standards to improve the portability
  - IEC 61131-3
  - IEC 61499
- Industrial control systems design modularized by
  - Function Blocks diagrams (IEC 61131): to graphically structure the control system into interconnected components
  - Event based communication (IEC 61499) onto a network of devices

IoT: Internet of Things

- Embedded sensors and controllers integrated into control systems
- Problems to develop lightweight IoT devices
  - Generally, high resource demands
  - Lack of real-time support for resource limited devices

Key ideas

Extend IEC 61499 based 4DIAC tool

- Real-time execution of Function Block based design
- Light-weight controllers (MCUs) with limited resources (memory and CPU).
- Synchronous and asynchronous events
  - Extension of the IEC 61499 model
- Mapping onto the minimalistic RTFM-kernel

Proposed development

IEC 61499 extension

- Extension of model to distinguish between synchronous and asynchronous events
- A synchronous event is immediately executed on behalf of the sender (does not break compliance to the IEC 61499 standard)
- Synchronous event chains must never cause a cycle (would render a deadlock)
- An asynchronous event is the head of a synchronous event chain and can be given a static priority

RTFM-kernel

- Hardware assisted scheduling
- Exploits the underlying interrupt hardware for preemptive (static priority based) execution under the Stack Resource Policy
- General approach to preemptive scheduling under shared resources
- Guarantees deadlock-free execution on single stack (single core systems)

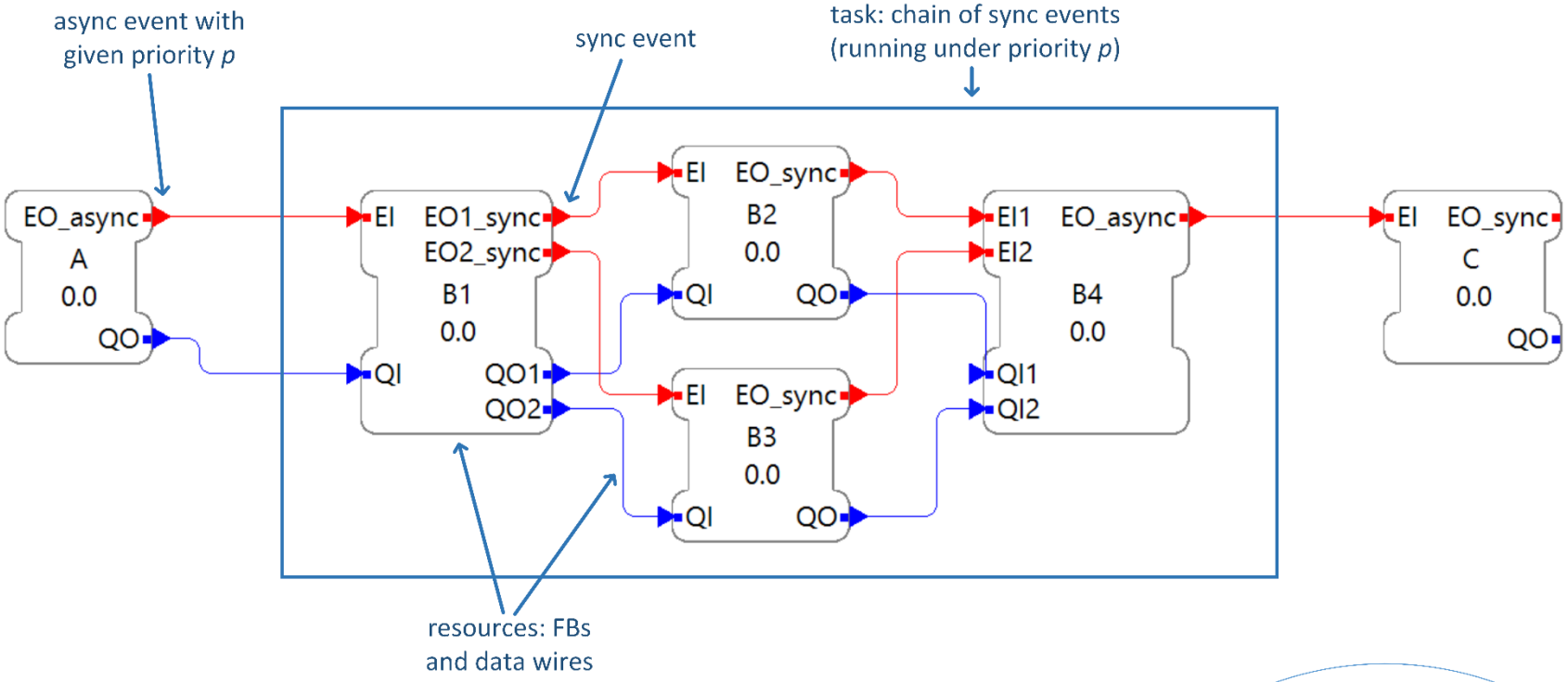
Stack Resource Policy (SRP)

- A task preempts, if
  - it has the highest priority of all enabled tasks
  - its priority is higher than system ceiling
- System ceiling is also based on ceiling levels of currently claimed resources (maximum priority of all tasks that access a resource)

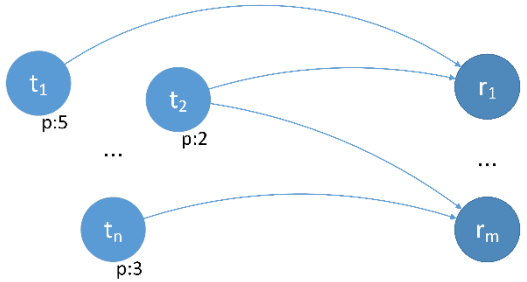
- If a task needs an already claimed resource it is blocked **before** its preemption attempt (not at the resource claiming attempt) → deadlock-free

IEC 61499 mapping onto RTFM-kernel

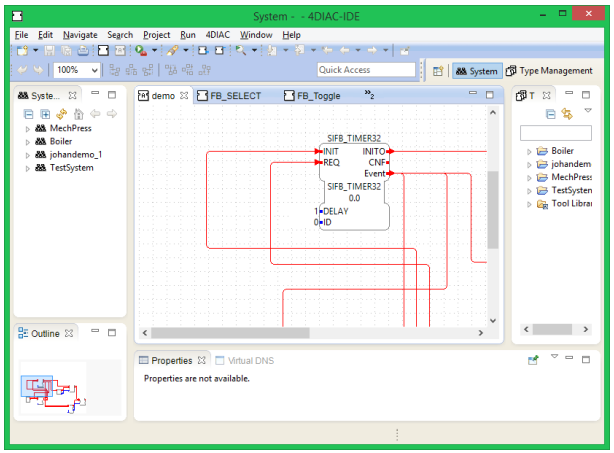
RTFM-4-FUN



RTFM-kernel:



4DIAC extension



definition of extended IEC 61499 models

FB network exported to C code

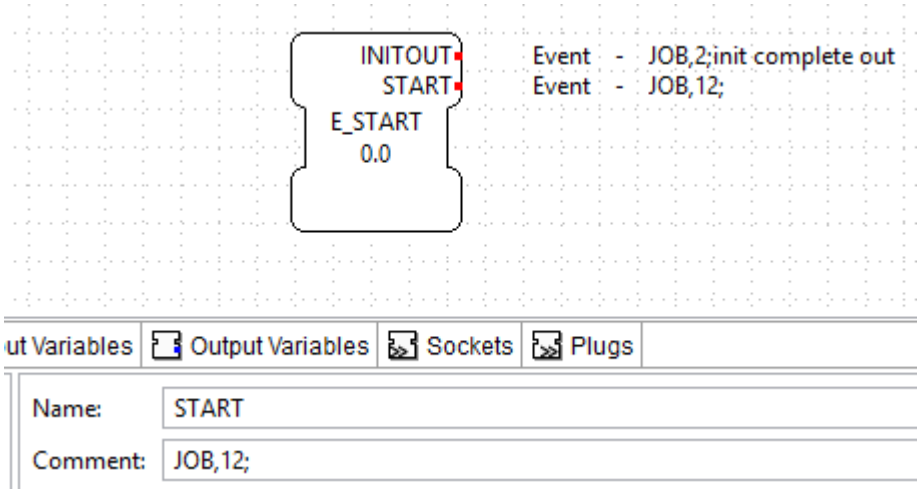
+

RTFM-kernel primitives

RTFM-kernel based executable (bare metal MCU)

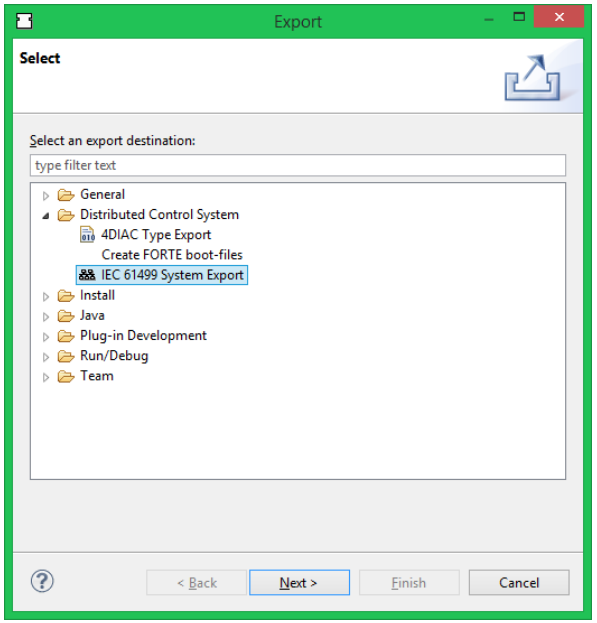
Extended model definition

- FB description with output event annotations
- either synchronous or asynchronous events
- optional priority for asynchronous events



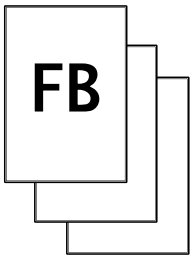
Export filters

- two export filters
- FB definitions exported to .cpp and .hpp files
- system description (system.xml) exported to C program (RTFM-4-FUN mapped model)



code generation

RTFM-kernel based executable



.cpp file for each FB definition

calls functions

FB network (system.xml)

C program

uses

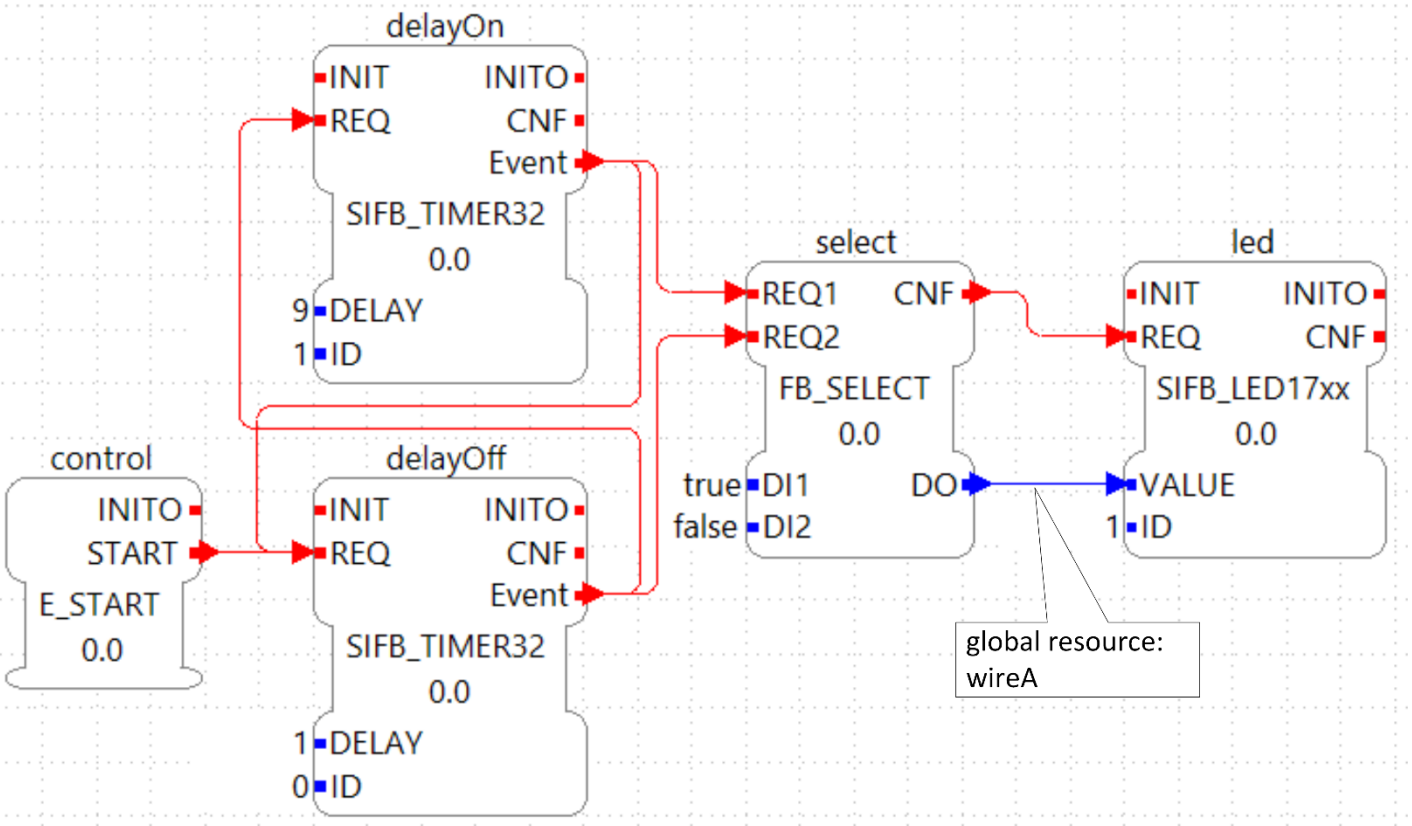
RTFM-kernel primitives

compiled

executable

PWM generator

- software based PWM generator built as FB network



example

PWM generator

- … demo

PWM generator: results

- generated executable analyzed
- critical path has approximately 200 cycles (including the overhead of the scheduler)
- allows to run the PWM generator at frequencies up to 500 kHz on a cheap low-end MCU running at 100 MHz
- implies 2µs scan period for a scan based system which is not feasible with resource demanding run-time environments as used in common PLCs

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Thanks for your attention

Questions and suggestions

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