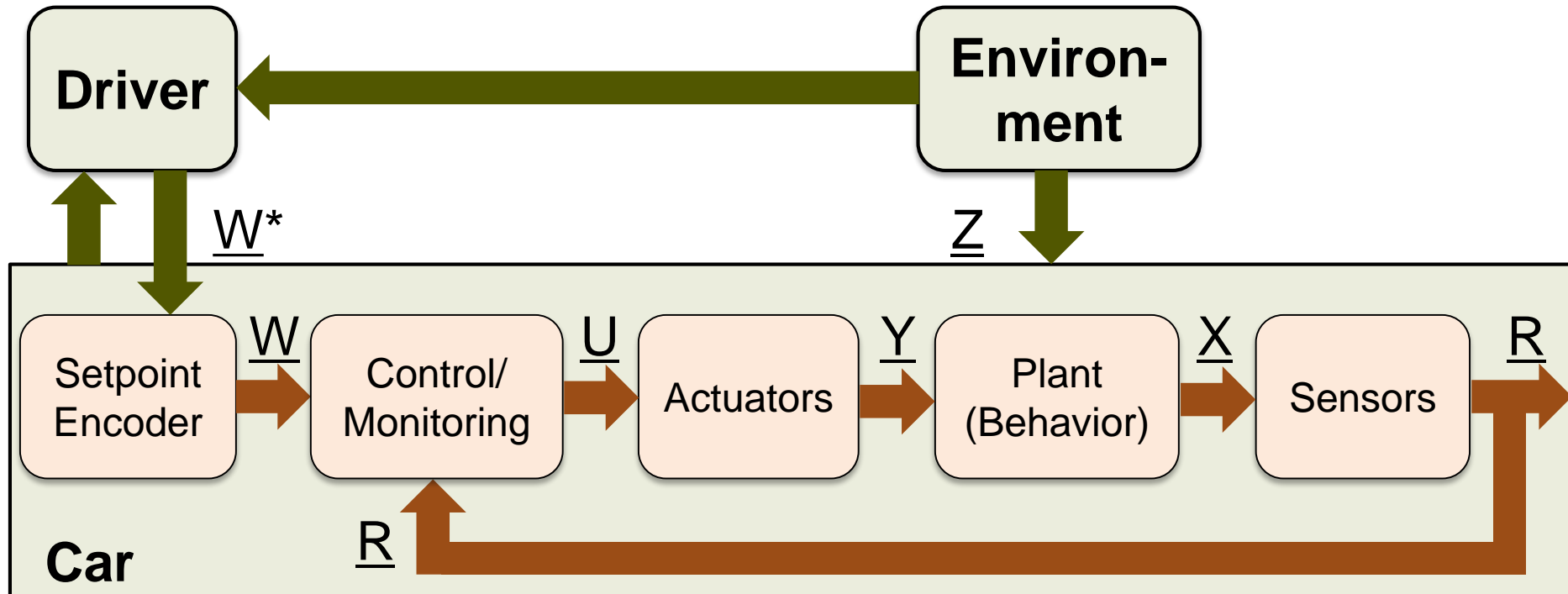

Software Platforms for Automotive Systems

Lecture 2: Basic Concepts

Alejandro Masrur

22th October 2015, TU Chemnitz

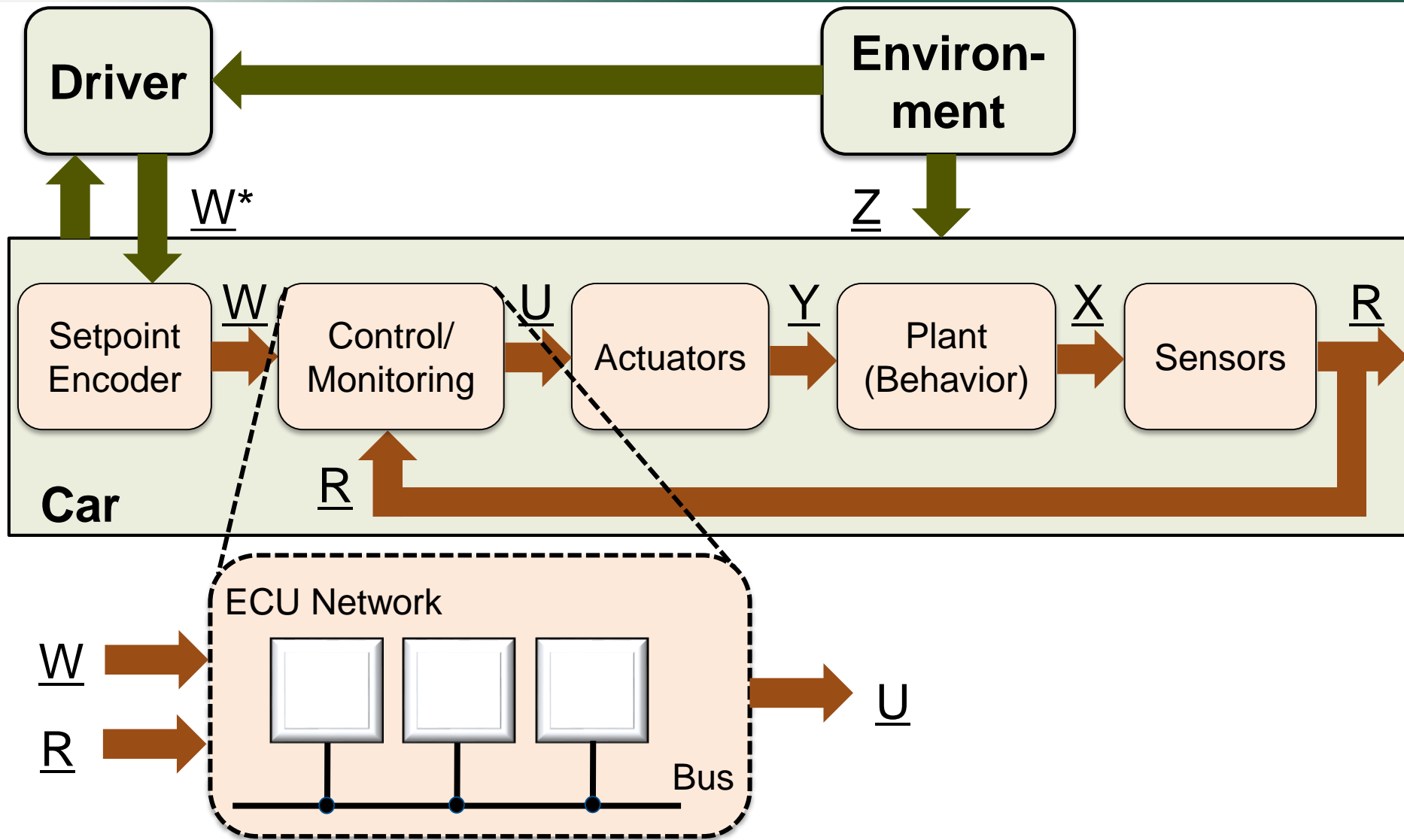
Automotive Control Systems



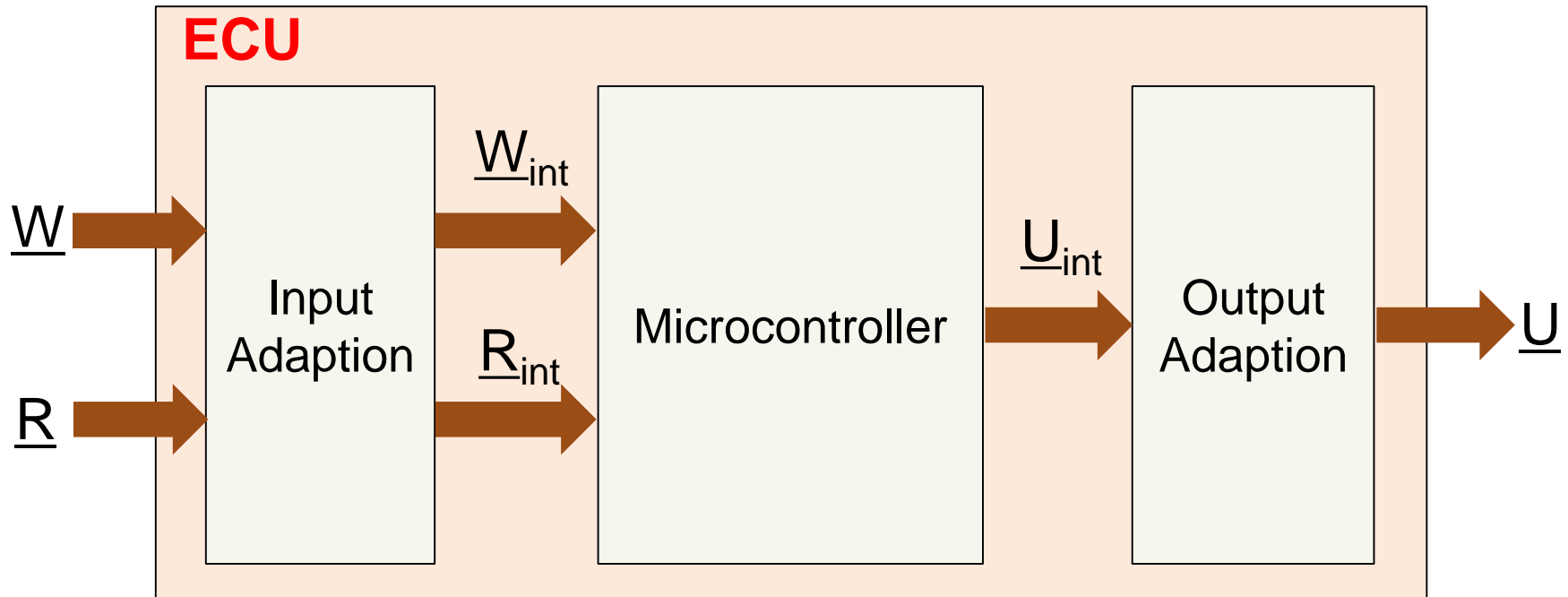
- \underline{R} : Feedback
- \underline{U} : Controller output
- \underline{W} : Reference
- \underline{W}^* : Input by the driver

- \underline{R} : Sensed values
- \underline{X} : Controlled signals
- \underline{Y} : Actuation values
- \underline{Z} : Disturbance

ECU Network = Control Tasks

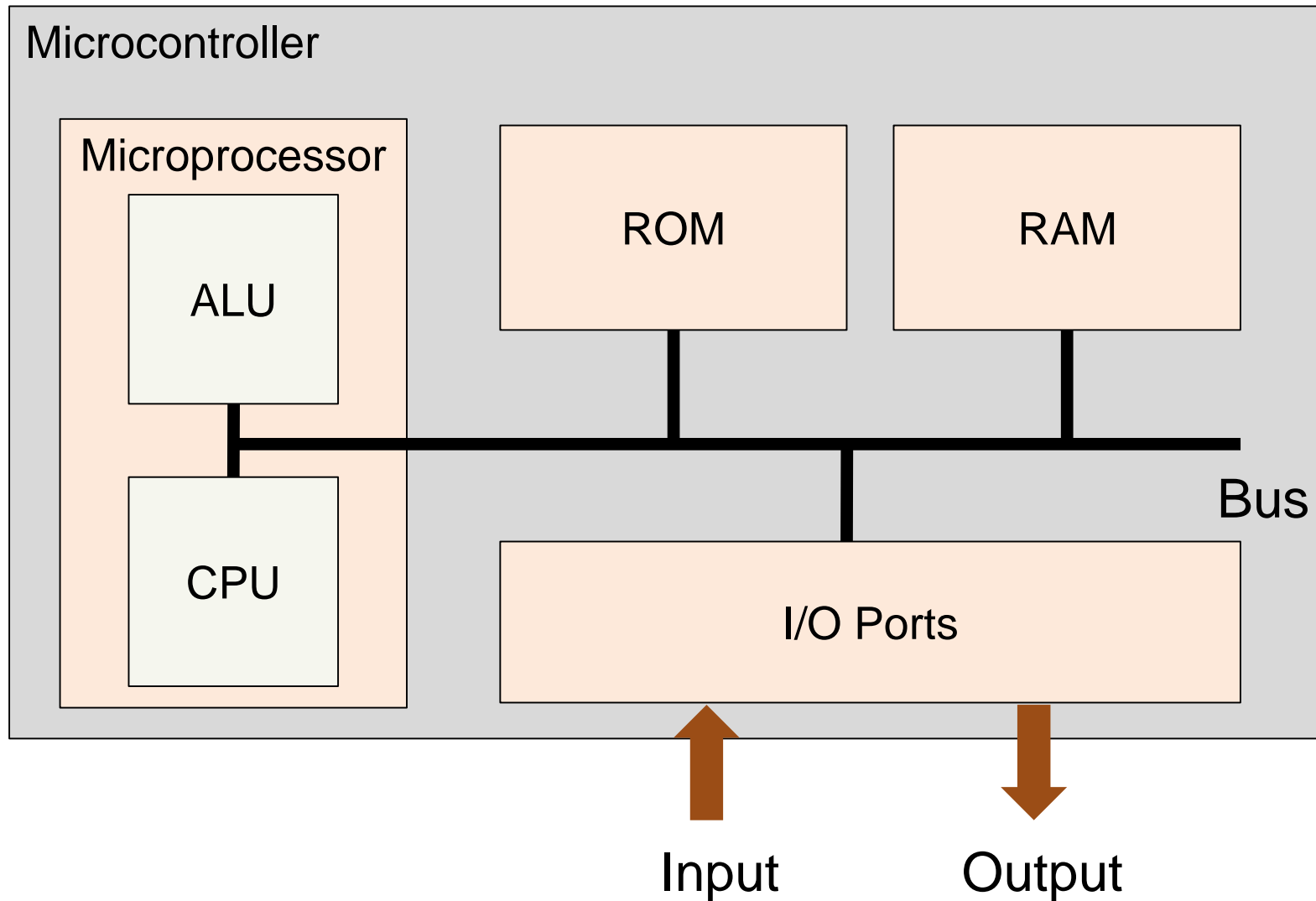


Block Diagram of an ECU



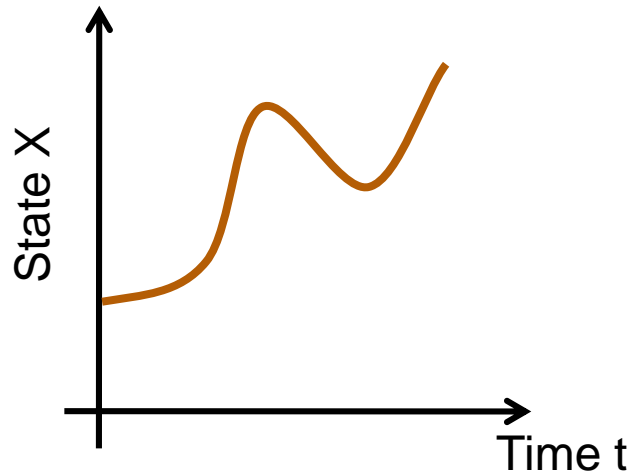
- Input/output adaption
 - Translate voltage and current levels

Block Diagram of a Microcontroller

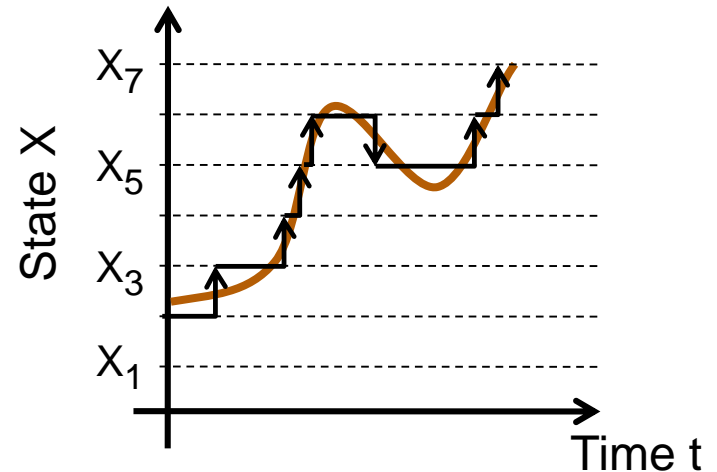


Sampling Signals

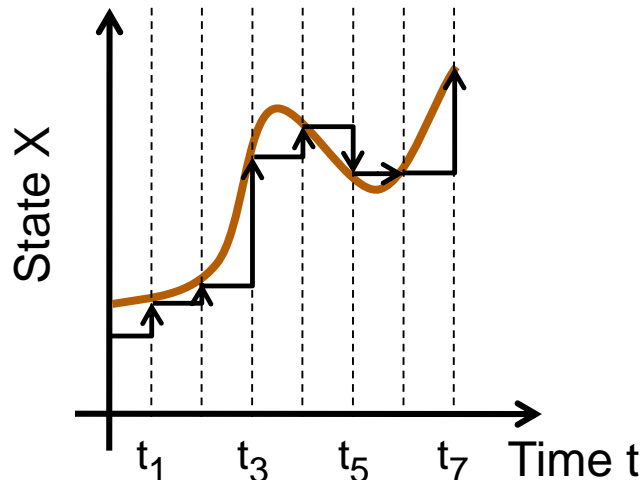
Continuous time and values



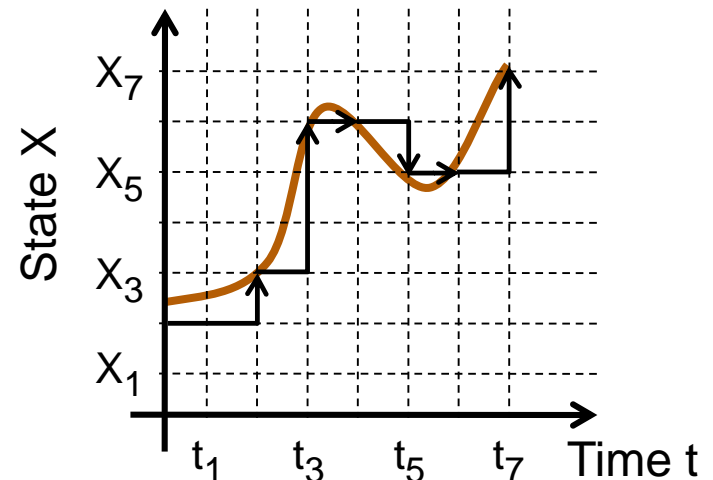
Continuous time and discrete values



Continuous values and discrete time



Discrete time and values



Light Indicator for Fuel Level

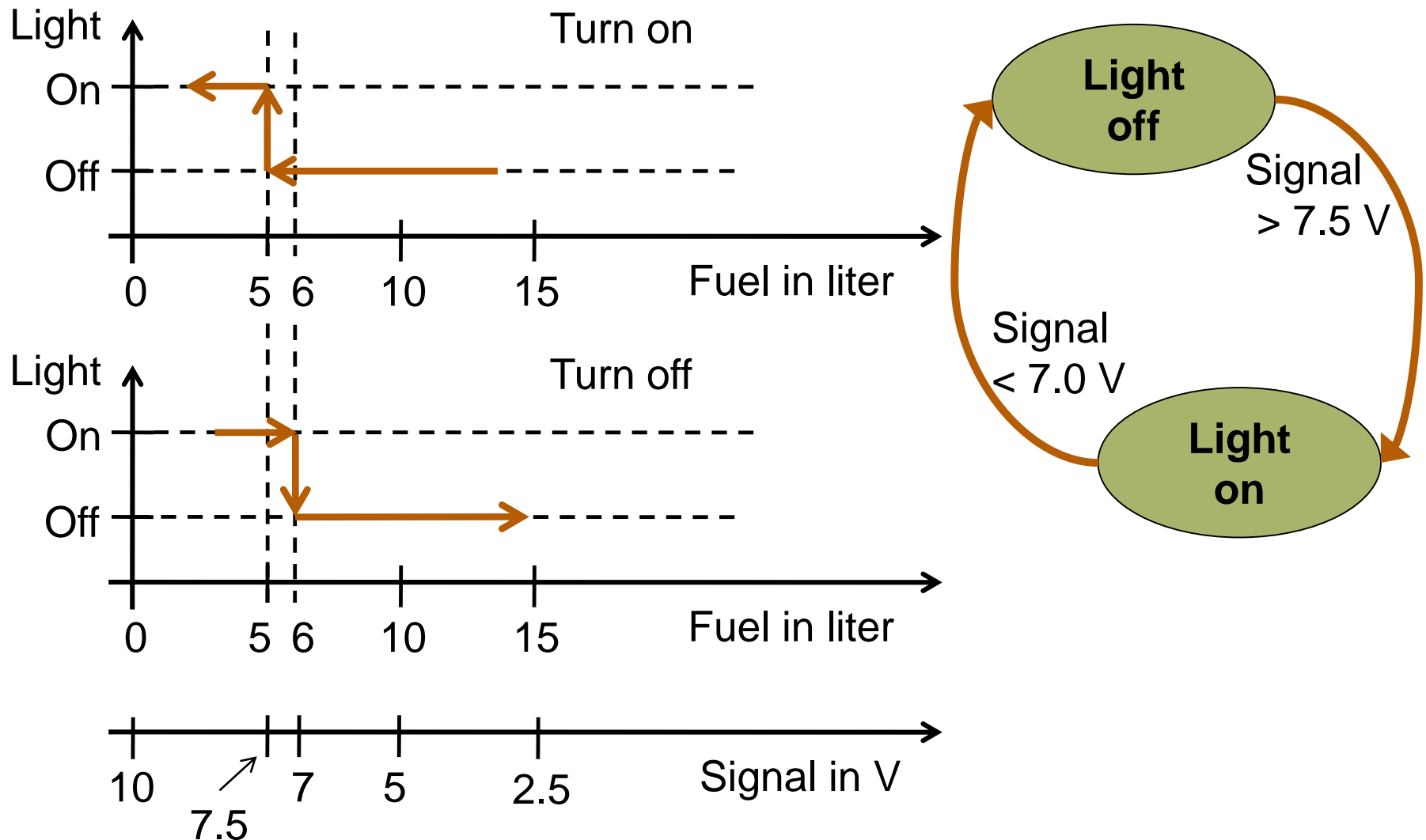
- **Design requirements:**

- Indicate when critical level is reached
 - Critical level is 5 liters
- Turn off indication when fuel is above critical level
- Avoid fluctuations

- **Design constraints**

- Fuel level sensor returns voltage value
 - Linearly dependent on fuel level
 - 10 V = zero liters, decrements by 0.5 V with every liter
 - Saturates at 0 V from 20 liters onwards

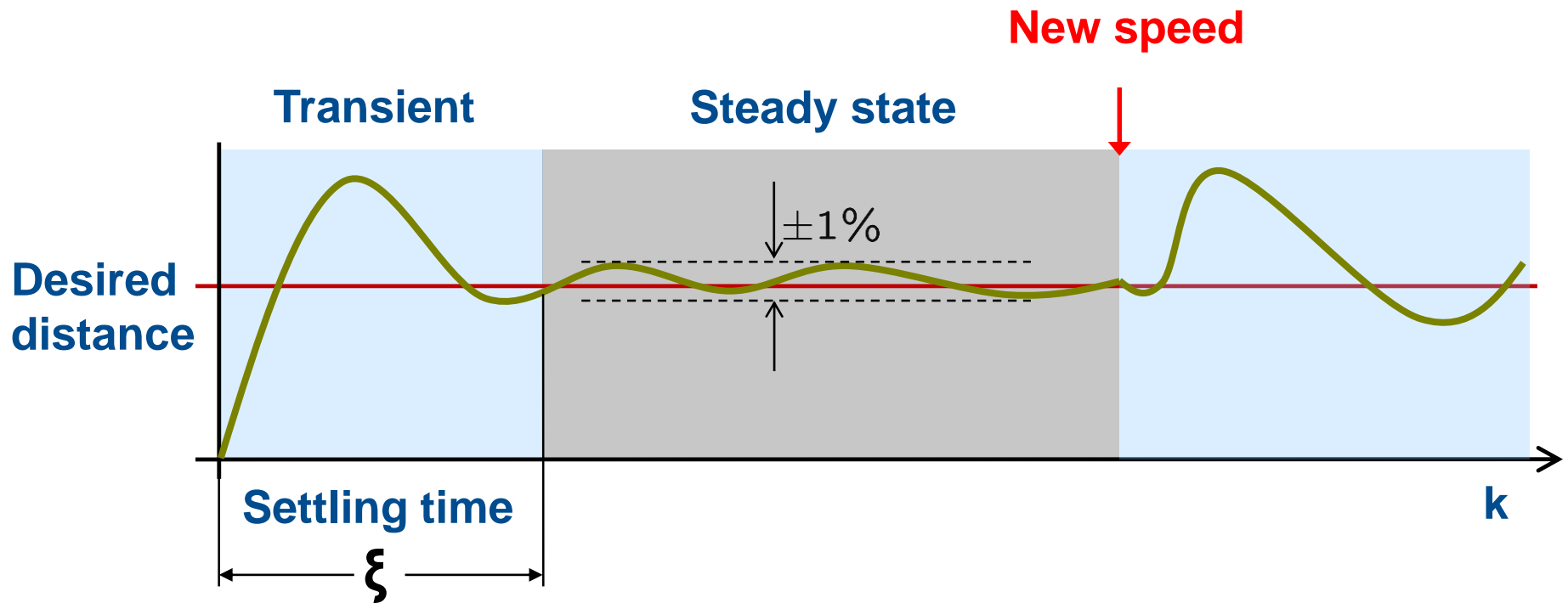
State Automata: Fuel Level



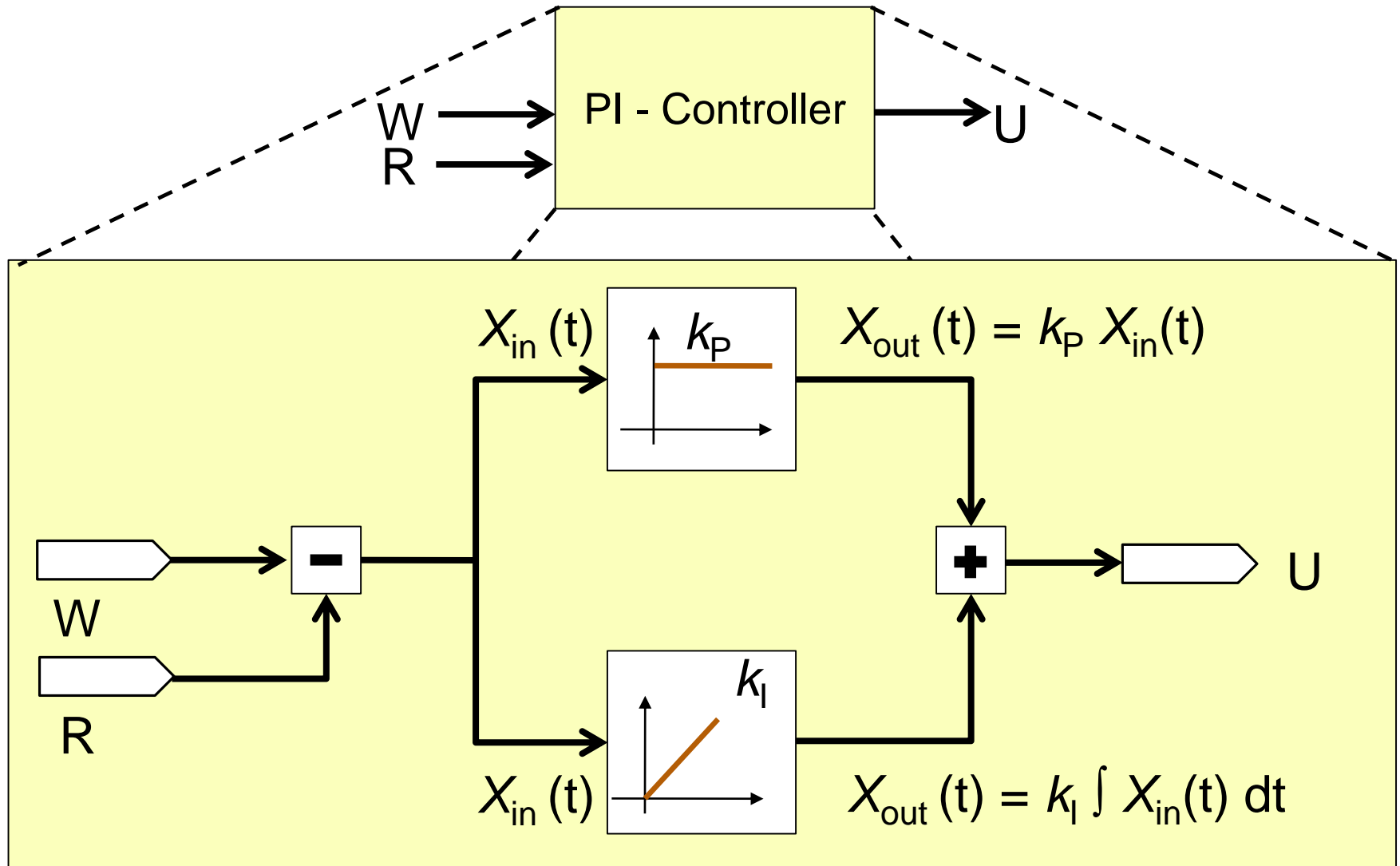
Distance Control

- This is a subsystem of ACC
- Design requirements:
 - A desired distance is given (by another subsystem, etc.)
 - Keep desired distance to leading car
 - Independent of its speed
 - (Sudden) changes in speed should be considered
 - Independent of steepness
- Design constraints
 - Distance sensor measures up to 300 meters ahead

Distance Control



Control Algorithm

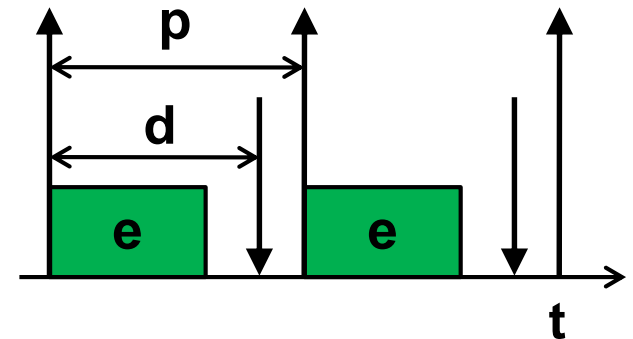


Real-Time Behavior

- **Tasks need to be executed on time**
- **Tasks are associated with deadlines**
 - **Deadline misses may cause damage**
 - **Human lives in danger = hard real-time**
 - **Brakes in a car, steer by wire, etc.**
 - **Quality of service goes down = soft real-time**
 - **Multimedia systems, MMI, etc.**
 - **Require a schedulability/feasibility analysis**

Task Model and Scheduling

- Model for real-time tasks
 - Periodic/sporadic with inter-release time: p
 - Relative deadline: d
 - Worst-case execution time: e
- The case $d = p$ is more usual
 - Rate Monotonic (RM)
- The case of $d \leq p$ is harder to handle
 - Deadline Monotonic (DM)



Constant-Time Tests

- “Utilizations bounds” from the literature
 - The Liu and Layland test:

$$\sum_{i=1}^n \frac{e_i}{p_i} \leq n \cdot \left(2^{1/n} - 1 \right)$$

RM

- The hyperbolic bound:

$$\prod_{i=1}^n \left(1 + \frac{e_i}{p_i} \right) \leq 2$$

RM

Constant-Time Tests

- “Utilizations bounds” from the literature
 - The Liu and Layland test:

$$\sum_{i=1}^n \frac{e_i}{p_i} \leq n \cdot \left(2^{1/n} - 1\right) \quad \Longrightarrow \quad \sum_{i=1}^n \frac{e_i}{\underbrace{d_i}_{\text{DM}}} \leq n \cdot \left(2^{1/n} - 1\right)$$

- The hyperbolic bound:

$$\prod_{i=1}^n \left(1 + \frac{e_i}{p_i}\right) \leq 2 \quad \Longrightarrow \quad \prod_{i=1}^n \left(1 + \frac{e_i}{\underbrace{d_i}_{\text{DM}}}\right) \leq 2$$

- These are sufficient but not necessary conditions

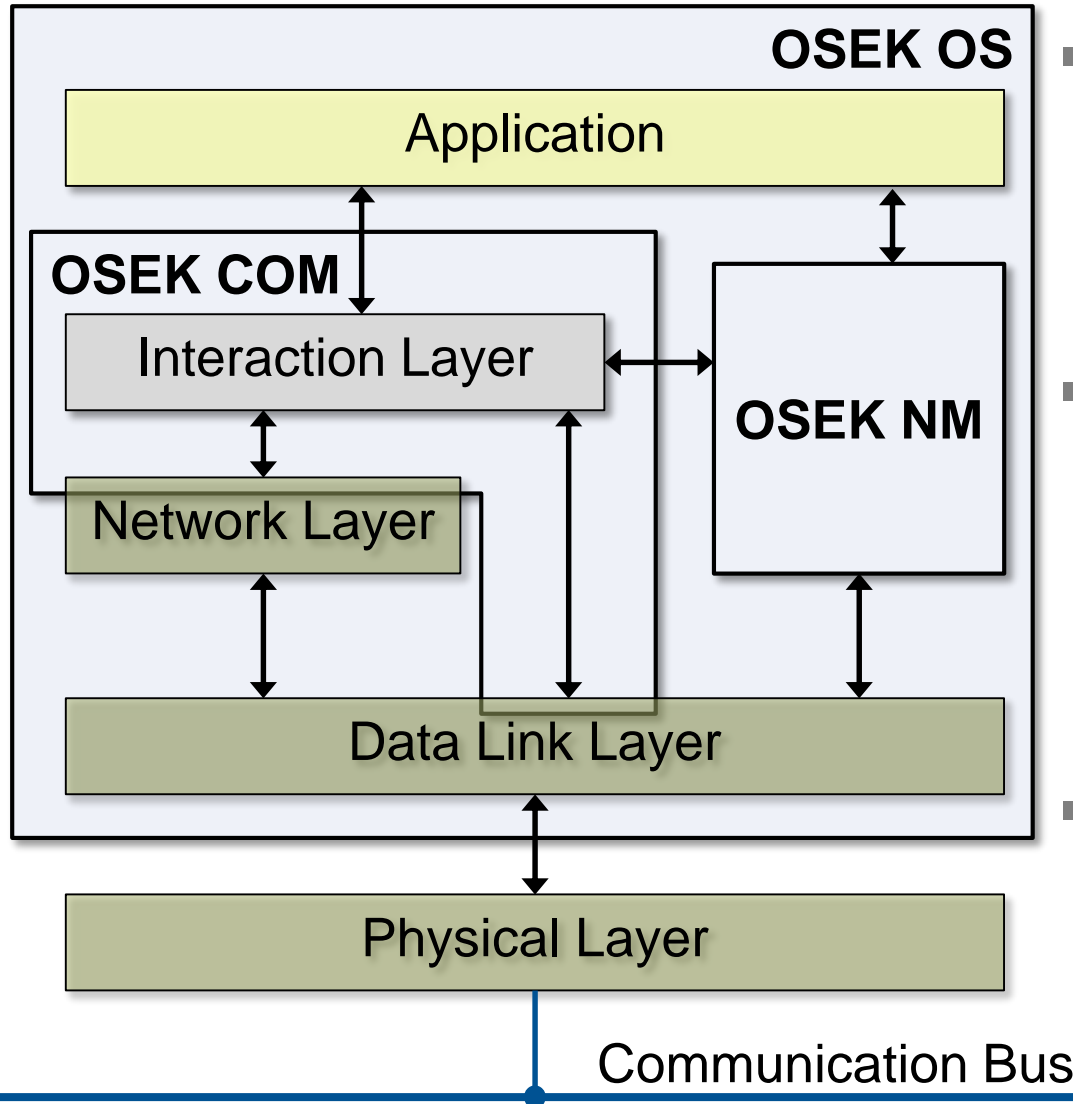
Exact Schedulability Test

- Worst-case response time (WCRT) analysis
 - For T_k , $w_k = \text{WCRT} \rightarrow$ if $w_k \leq d_k$, T_k is schedulable

$$t^{(j+1)} = e_k + \sum_{\substack{\forall T_i \in \\ \text{HP}(k)}} \left\lceil \frac{t^{(j)}}{p_i} \right\rceil \cdot e_i \quad - \text{HP}(k) = \text{set of tasks with higher priority than } T_k$$

- Pseudo-polynomial complexity
 - Depends on the number and parameters of tasks
 - Running time may vary with the task set

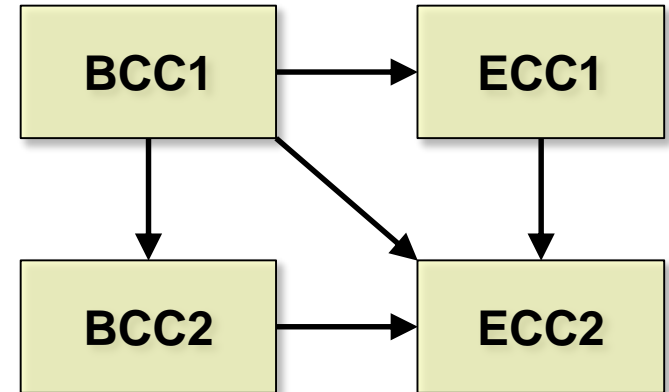
OSEK-VDX Specifications



- **Operating System**
 - Single-core processors
 - Standardized interfaces
- **Communication**
 - Transparent Communication
 - Requirements for Network and Data Link
- **Network Management**
 - Node monitoring
 - Network diagnostics

OSEK-VDX Operating System

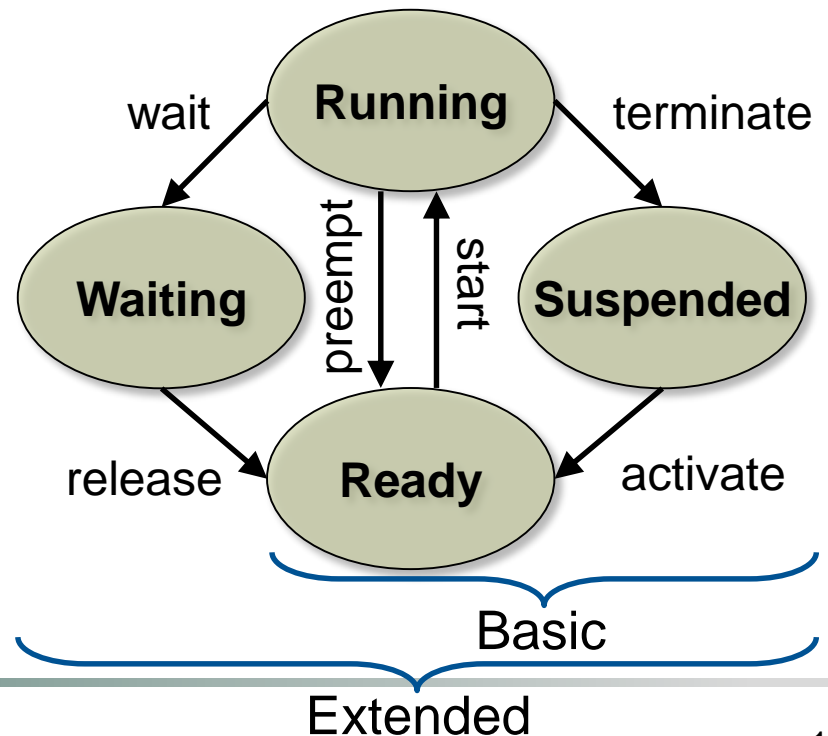
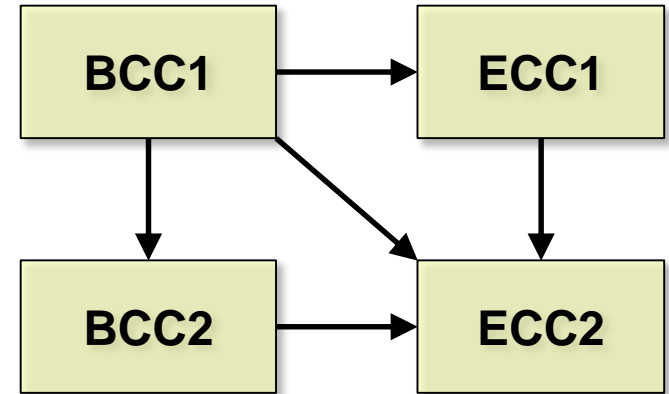
- Configurable and scalable
- Different conformance classes
- Predictable behavior
 - Real-time scheduling
 - Fixed priorities
 - Priority ceiling
- Special features
 - Single and cyclic alarms on counters



Property	BCC1	BCC2	ECC1	ECC2
Multiple activation	no	yes	BT:no ET:no	BT:yes ET:no
# tasks	8		16	
Tasks/ priority	=1	>1	=1	>1
Events/ task	-		8	
# priorities	8		16	

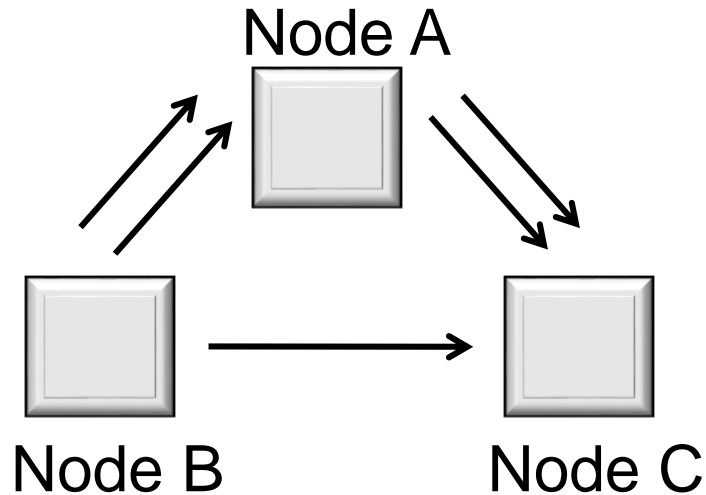
OSEK-VDX Operating System

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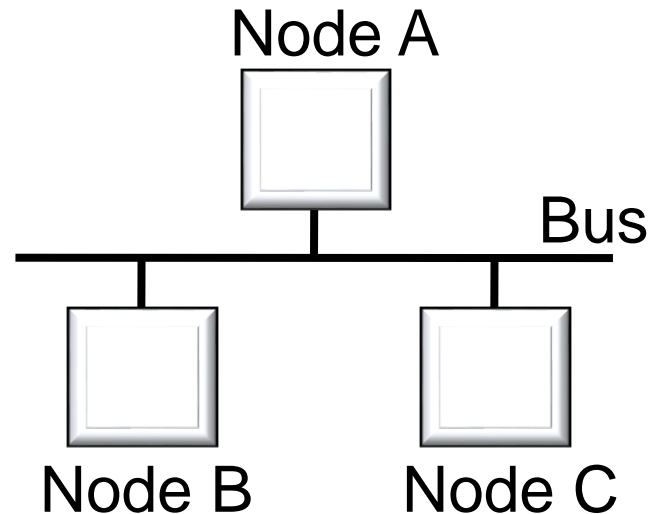


Communication in ECU Networks

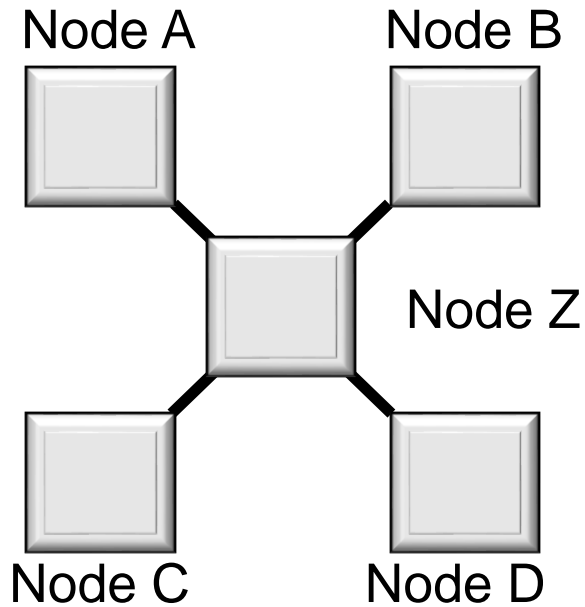
Logical system architecture



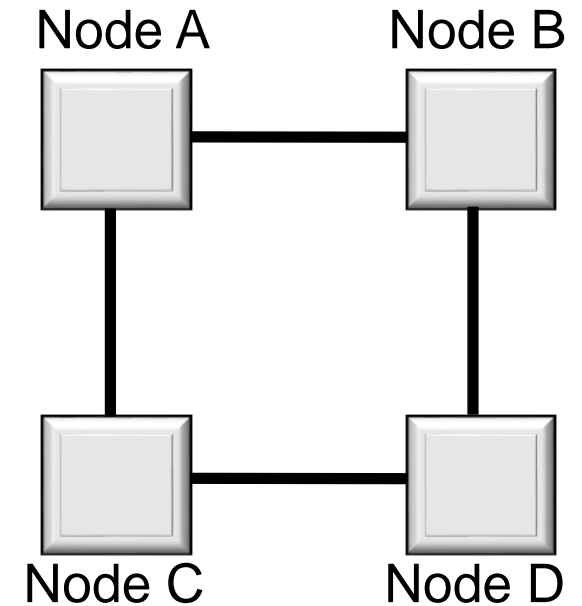
Technical system architecture



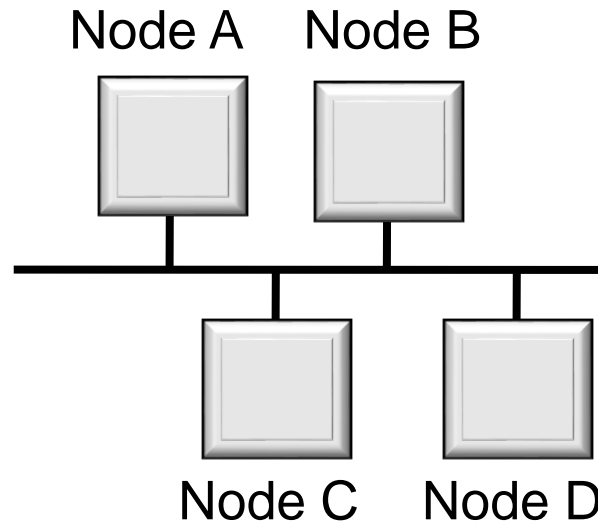
Common Topologies



Star



Ring

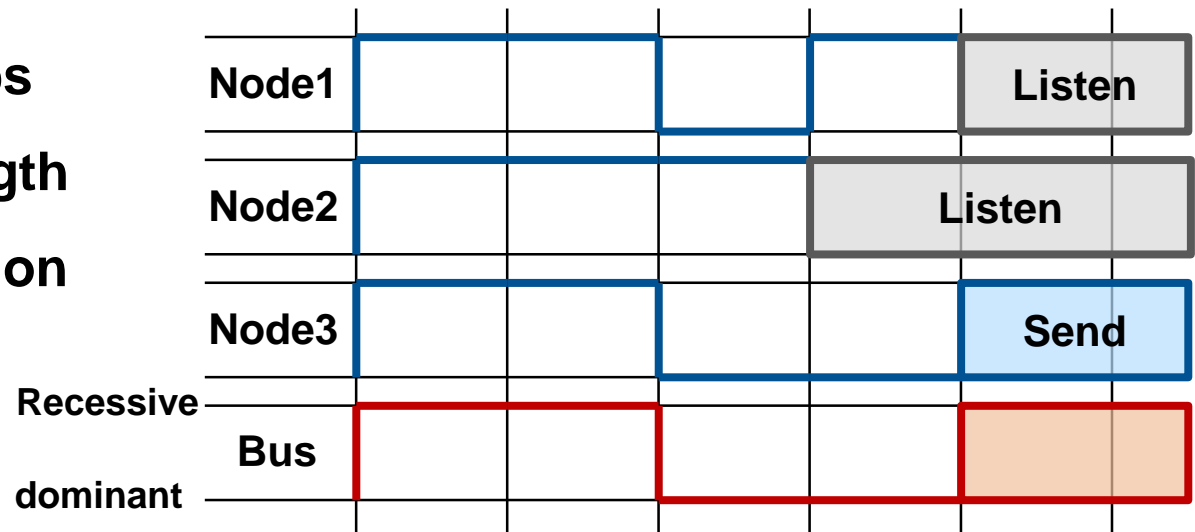
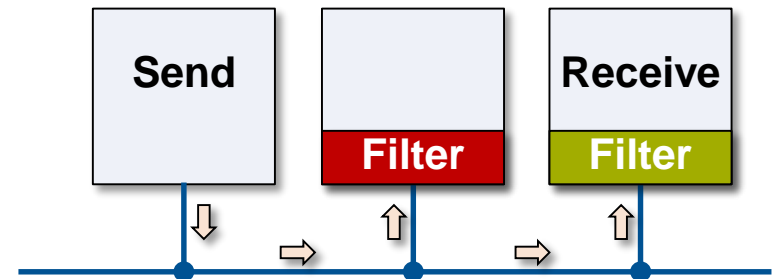


Line

Communication Technologies

■ Controller Area Network (CAN)

- Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)
- Bus topology
- Broadcast and filtering
- Messages are given priorities
 - Real-time transmission
- Maximum 1Mbps
 - For 40m length
- Bitwise arbitration



Communication Technologies

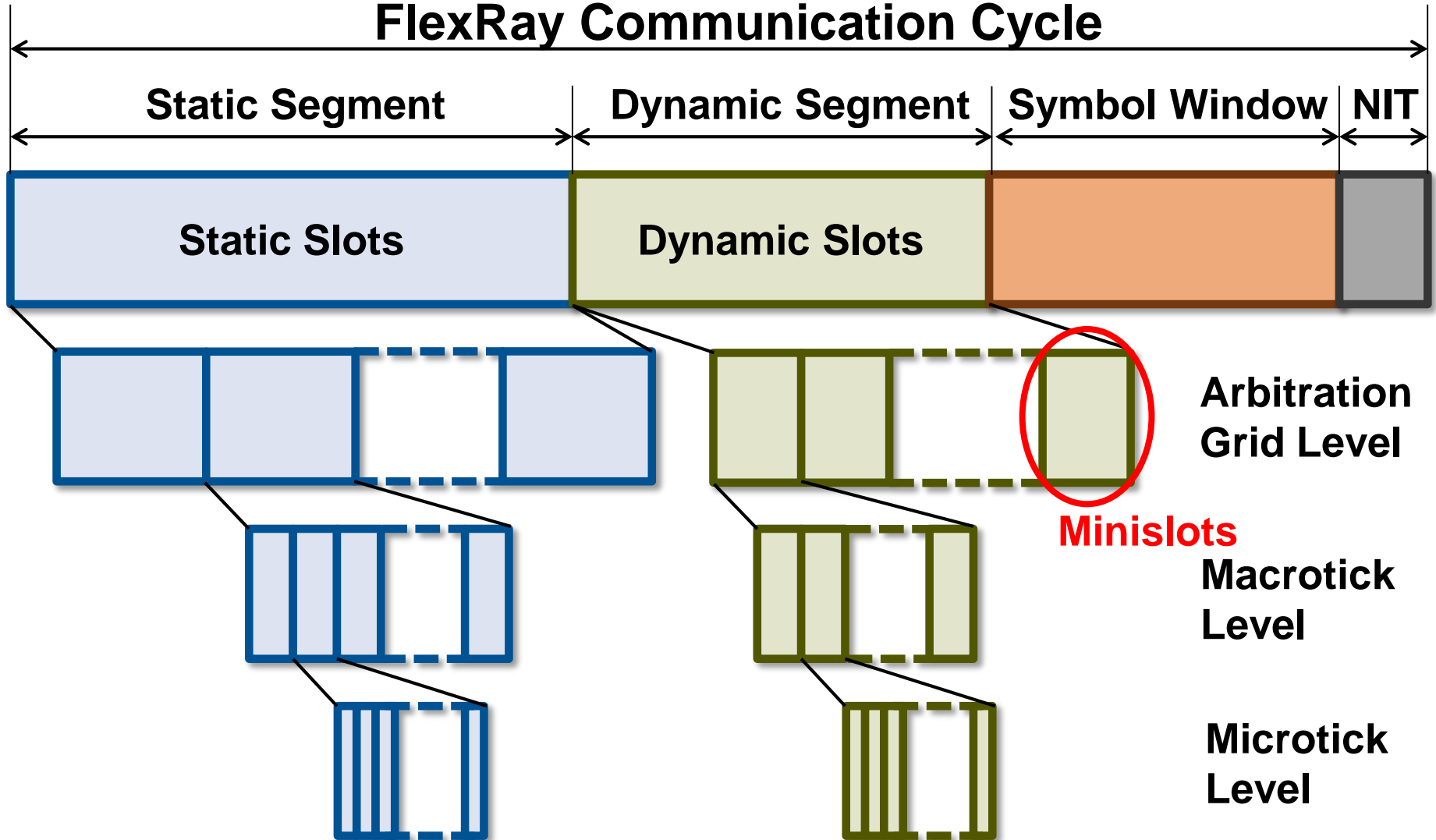
- **FlexRay**



- **Time Division Multiple Access (TDMA)**
 - **Synchronized (global) time base**
- **Bus, star and mixed topology**
- **Synchronous & asynchronous communication**
 - **Static segment = time-triggered slot**
 - **Dynamic segment = priority-based**
- **Two communication channels**
 - **Redundancy possible**
- **10 Mbps**

Communication Technologies

FlexRay Communication Cycle



Summary

- **Automotive software closely related to control**
 - An ECU is prepared to deal with input and output signal
 - Signal adaption is performed
 - Need to sample signals from the car environment
- **Real-time behavior is required**
 - In particular in vehicle centric domains
 - Need for a schedulability analysis and OS support
- **Communication between ECUs**
 - Common automotive technologies: CAN and FlexRay