Software Platforms for Automotive Systems

Lecture 2: Basic Concepts

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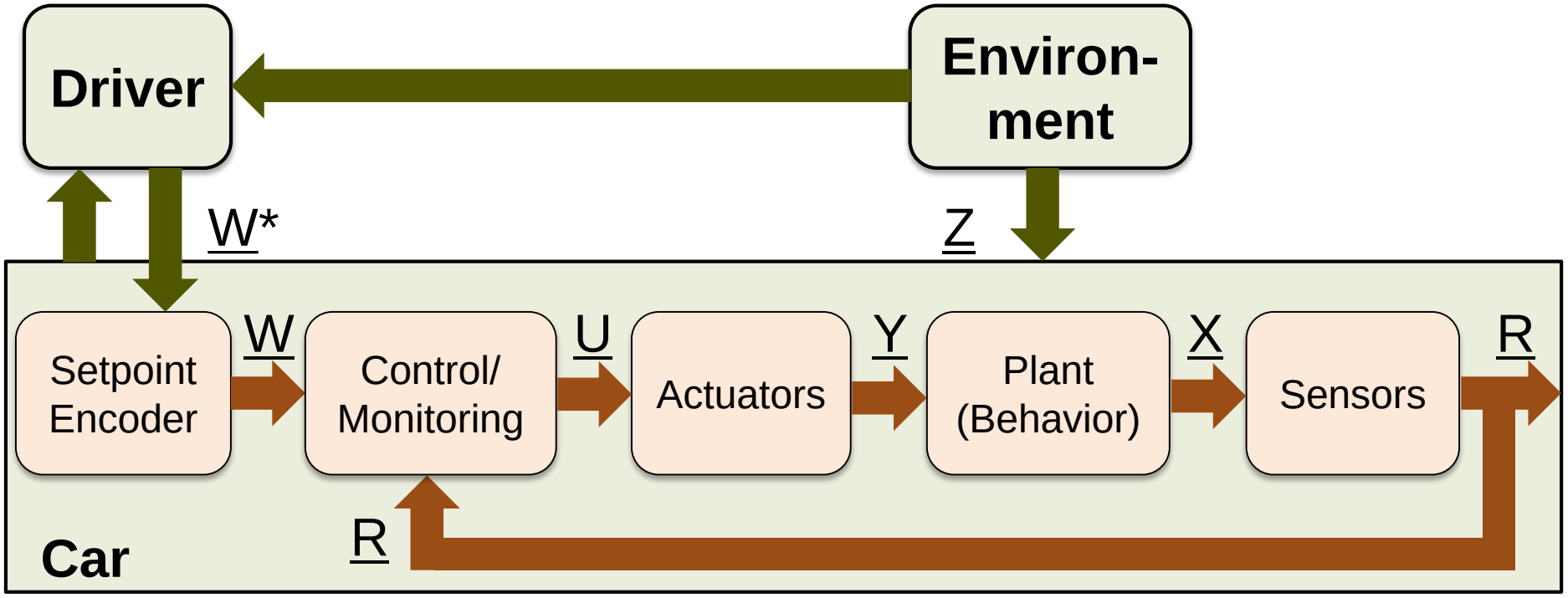
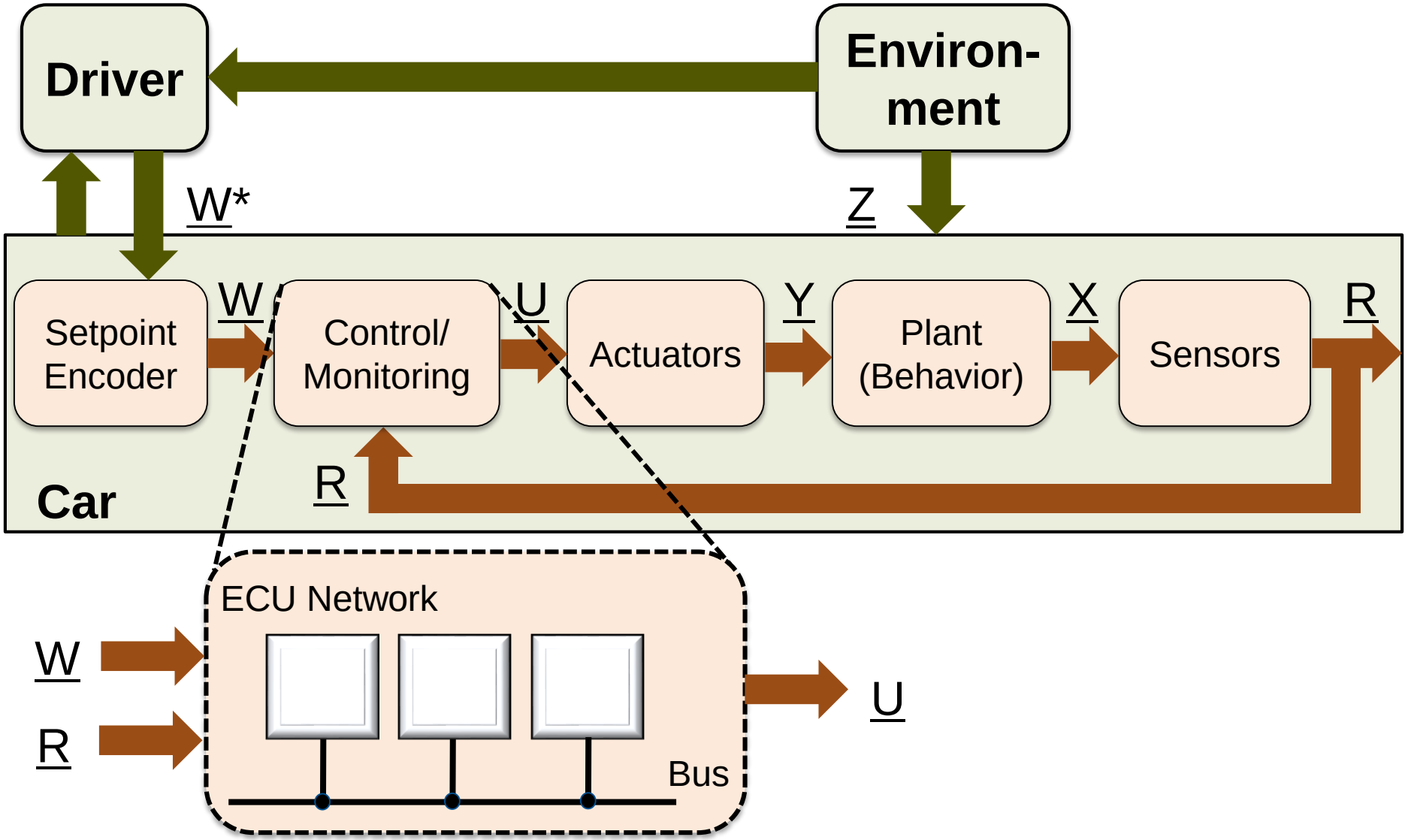
Automotive Control Systems



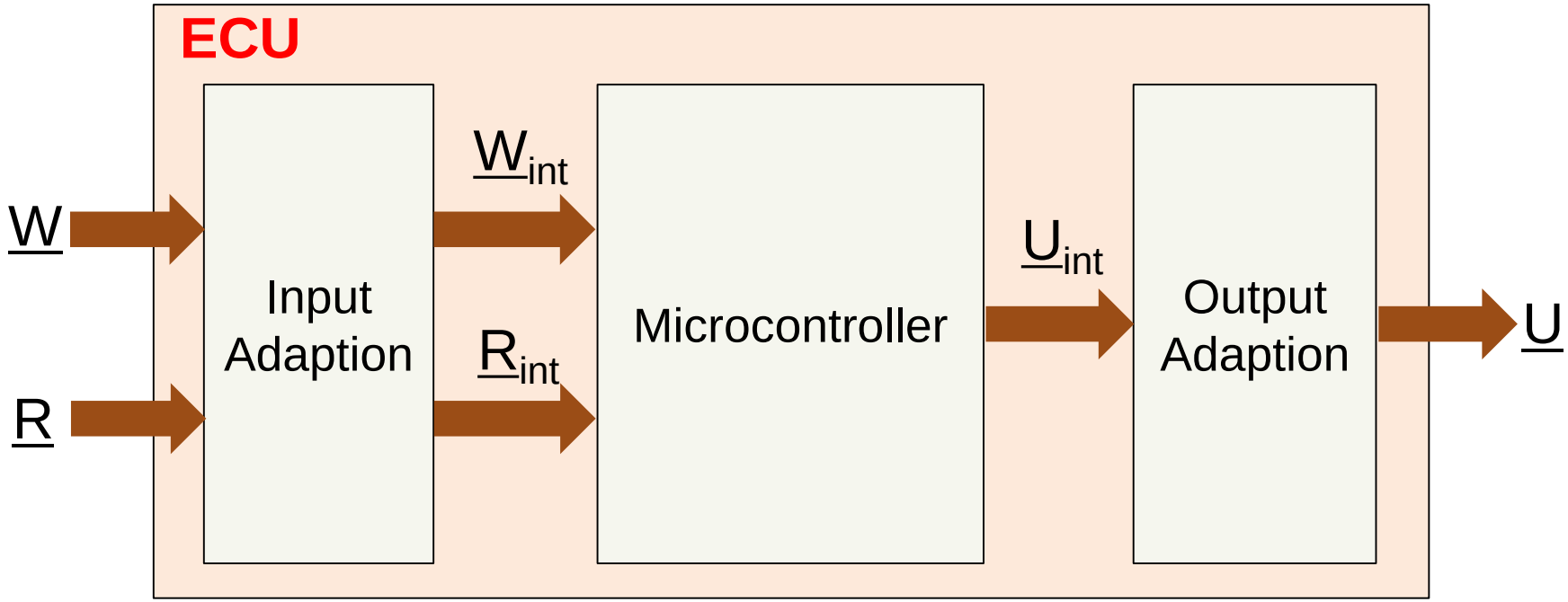
- **R: Feedback**
- **U: Controller output**
- **W: Reference**
- **W*: Input by the driver**

- **R: Sensed values**
- **X: Controlled signals**
- **Y: Actuation values**
- **Z: Disturbance**

ECU Network = Control Tasks

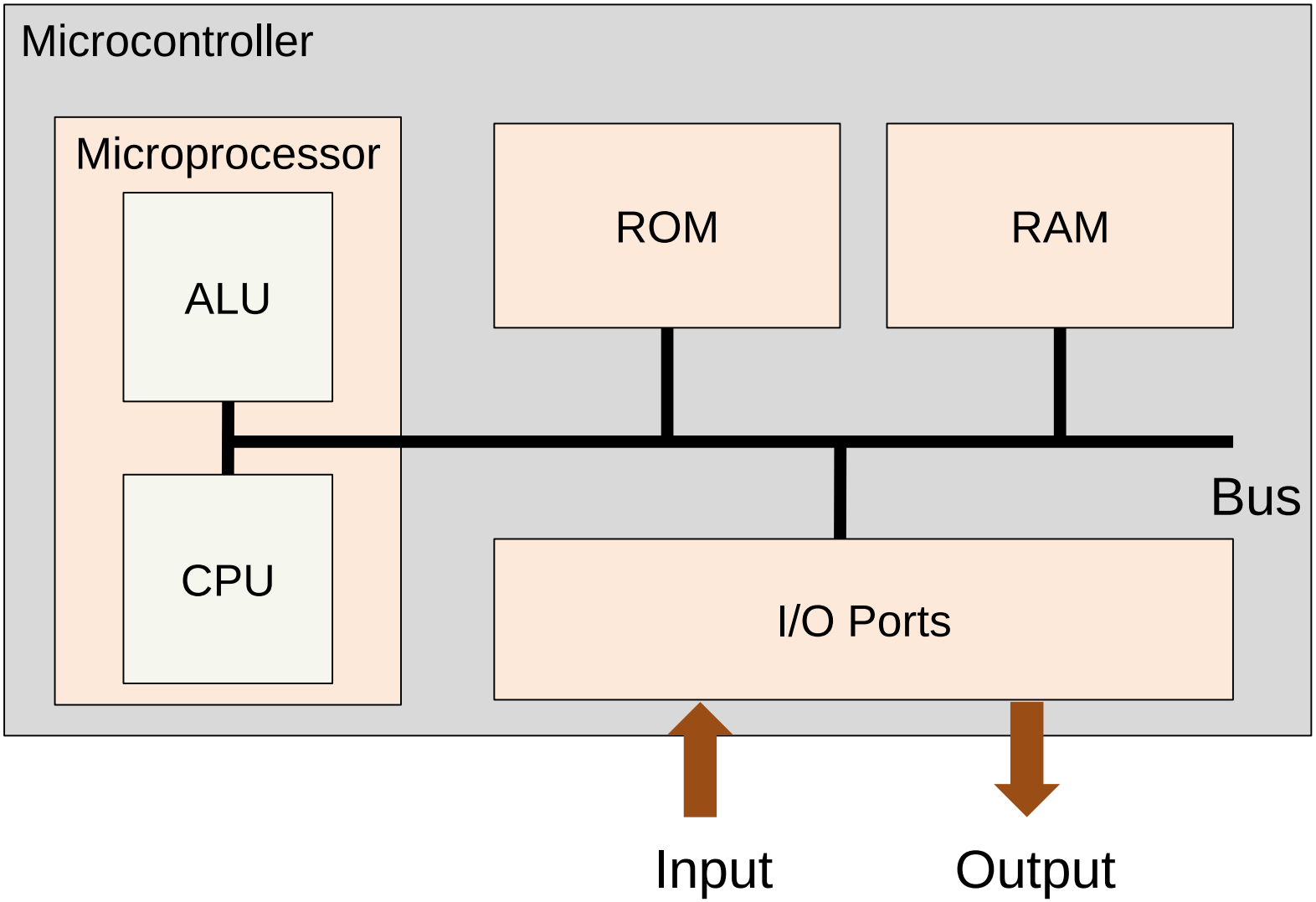


Block Diagram of an ECU



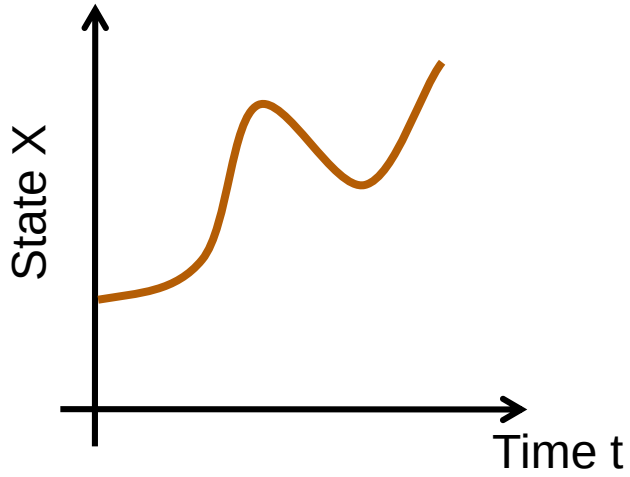
- **Input/output adaption**
  - **Translate voltage and current levels**

Block Diagram of a Microcontroller

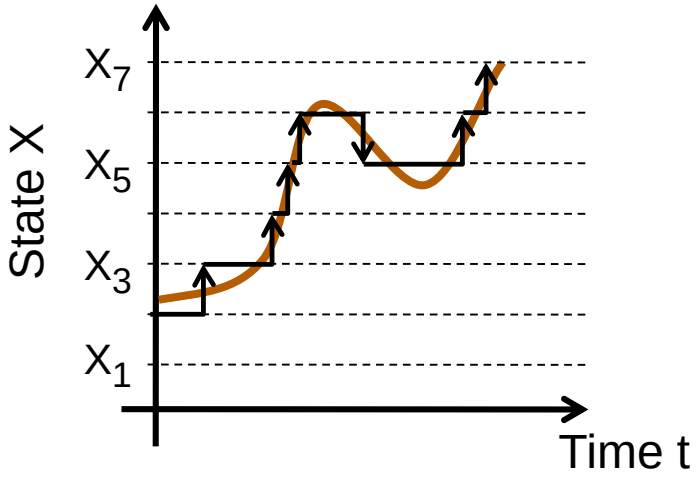


Sampling Signals

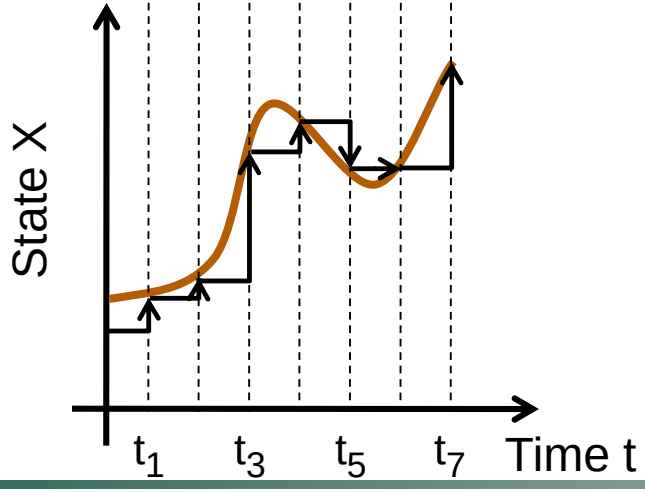
Continuous time and values



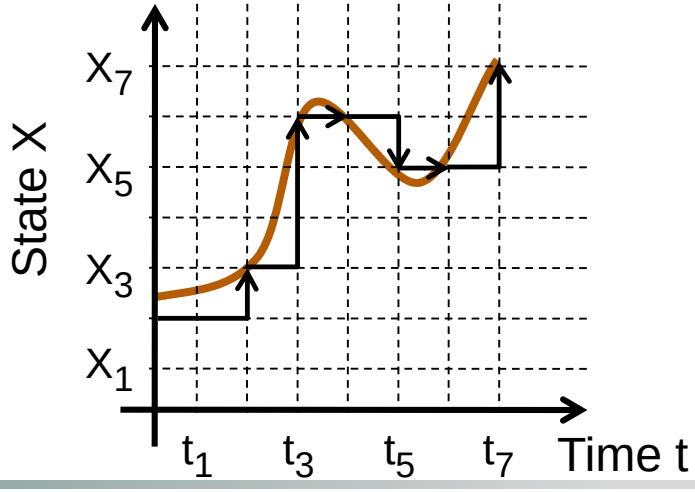
Continuous time and discrete values



Continuous values and discrete time



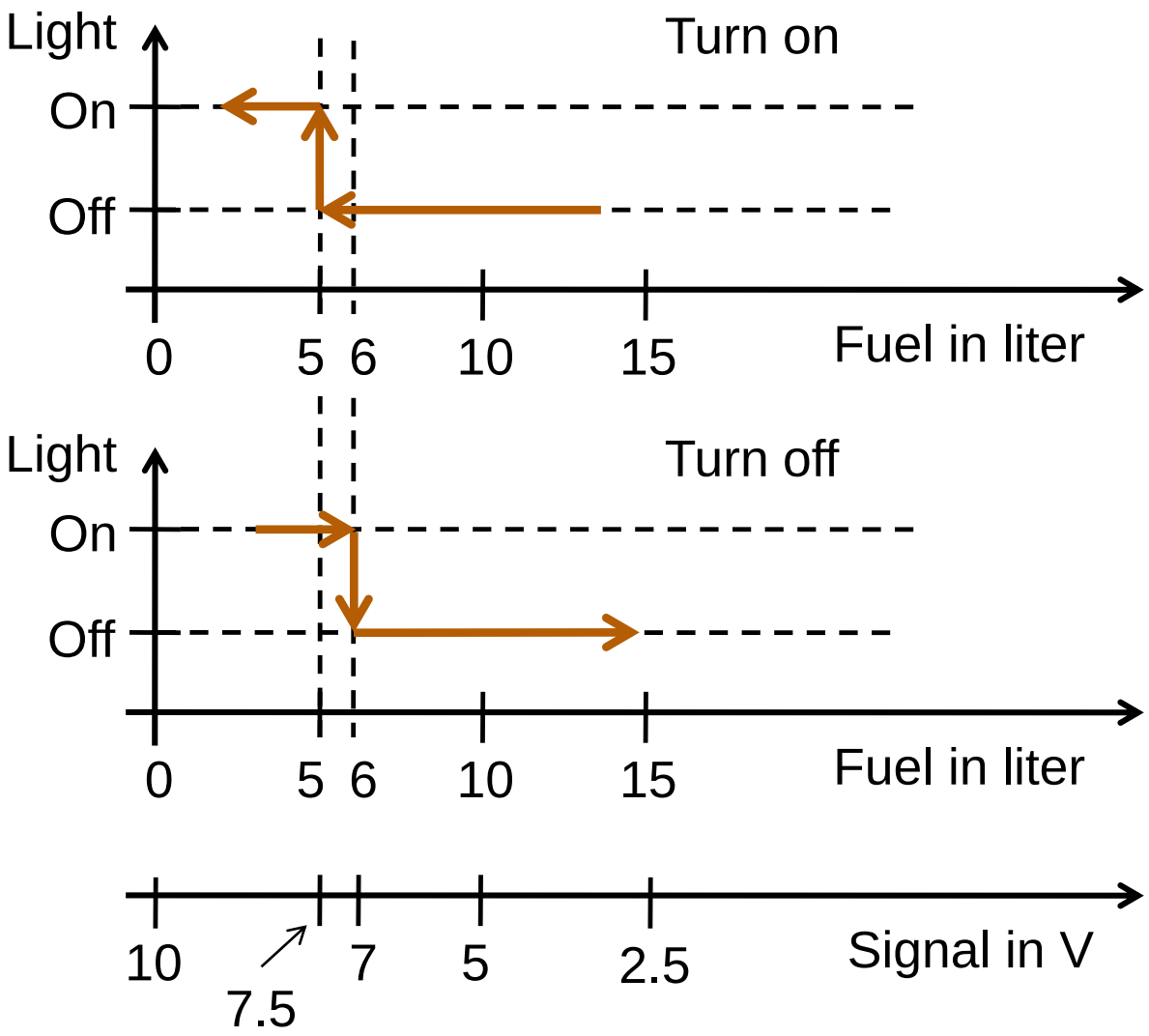
Discrete time and values

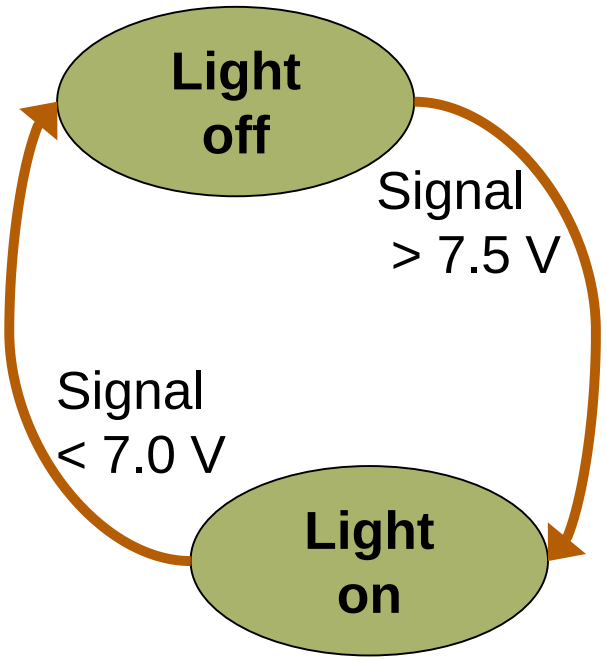


Light Indicator for Fuel Level

- **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

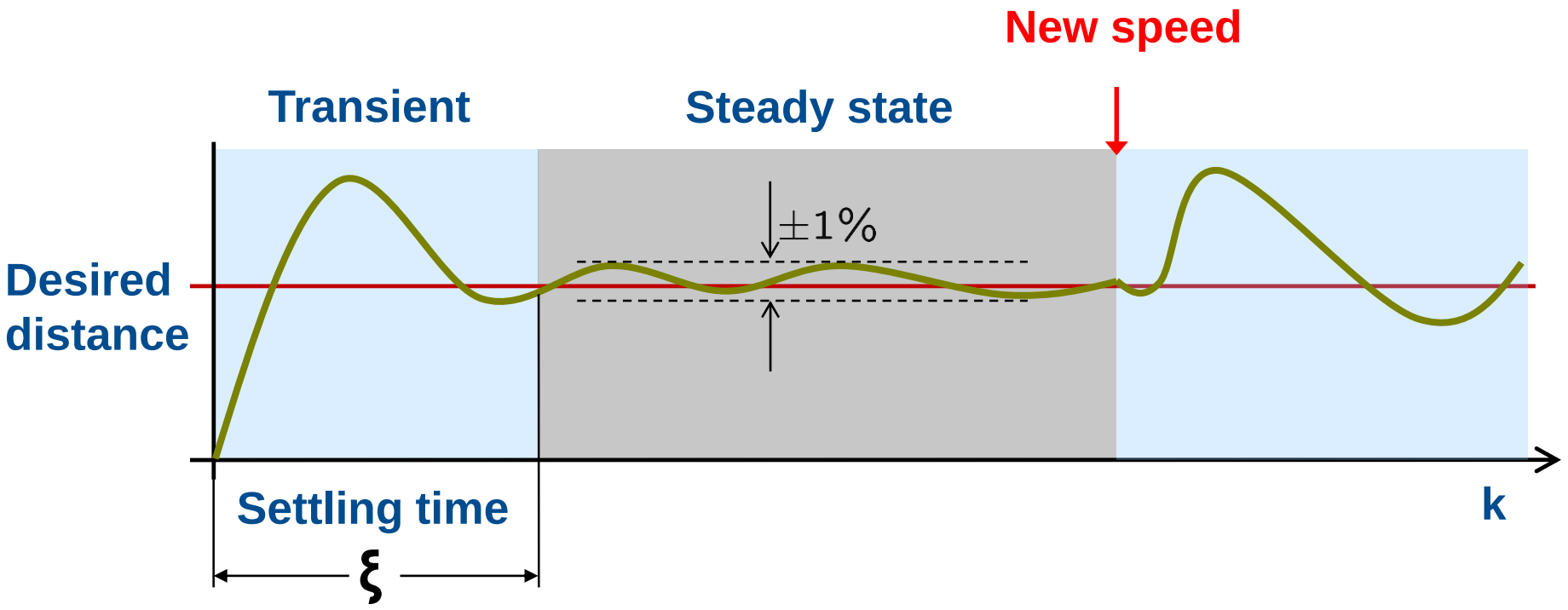




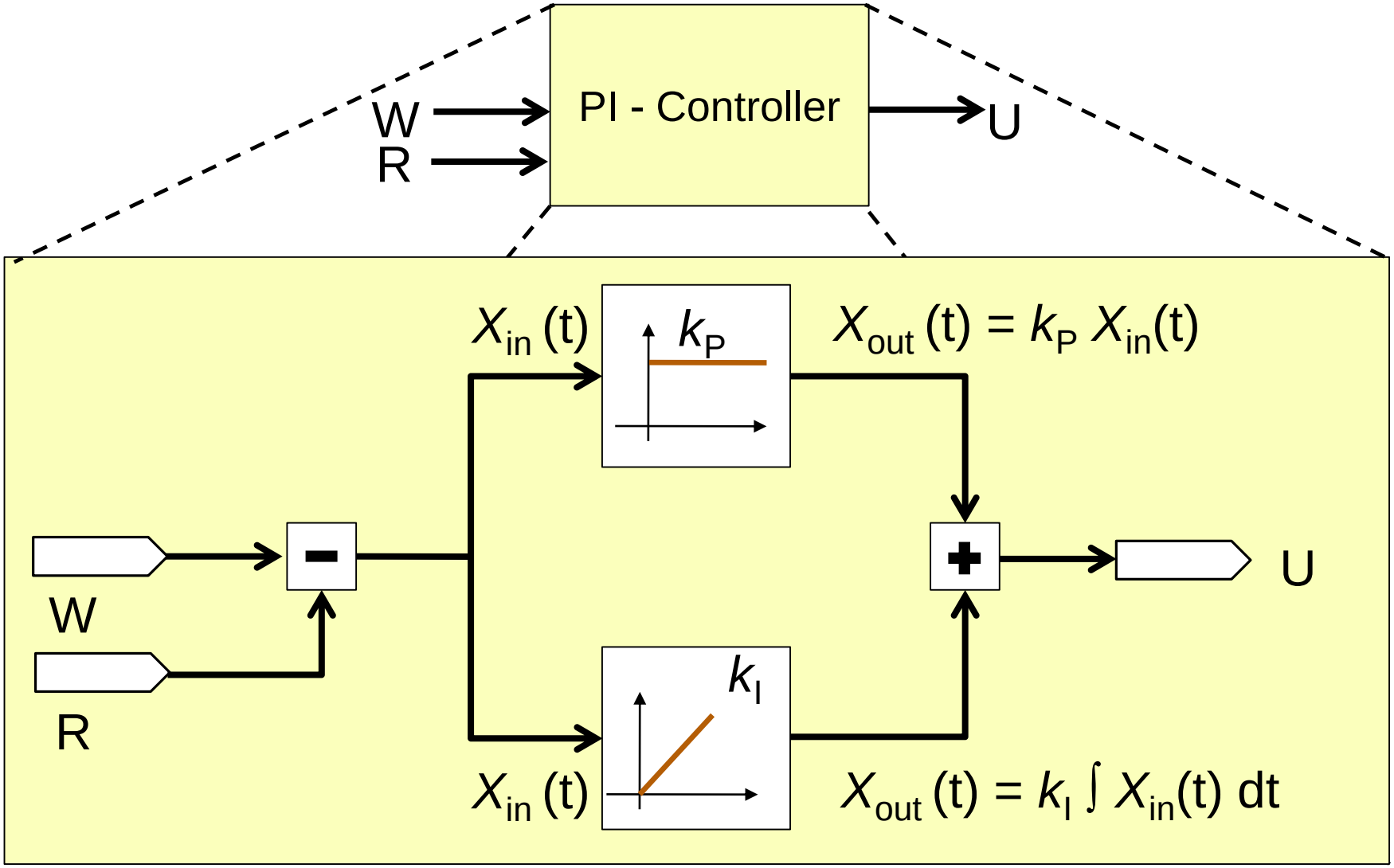
Distance Control

- 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

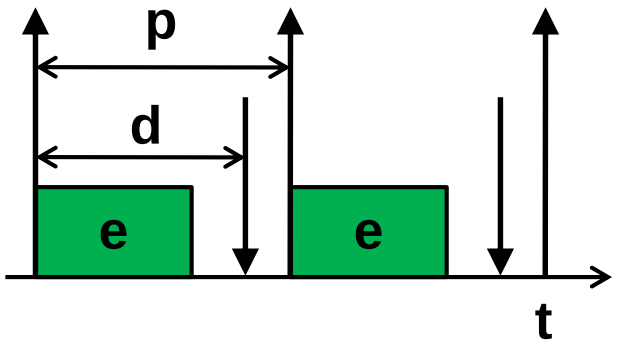


Real-Time Behavior

- Tasks need to 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 ≤ 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
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$$\sum_{i=1}^{n} \frac{e_i}{p_i} \le n \cdot \left(2^{1/n} - 1\right) \quad \Longrightarrow \quad \sum_{i=1}^{n} \frac{e_i}{d_i} \le n \cdot \left(2^{1/n} - 1\right)$$

DM

  - The hyperbolic bound:

$$\prod_{i=1}^{n} \left(1 + \frac{e_i}{p_i}\right) \le 2 \quad \Longrightarrow \quad \prod_{i=1}^{n} \left(1 + \frac{e_i}{d_i}\right) \le 2$$

DM

- These are sufficient but not necessary conditions

Exact Schedulability Test

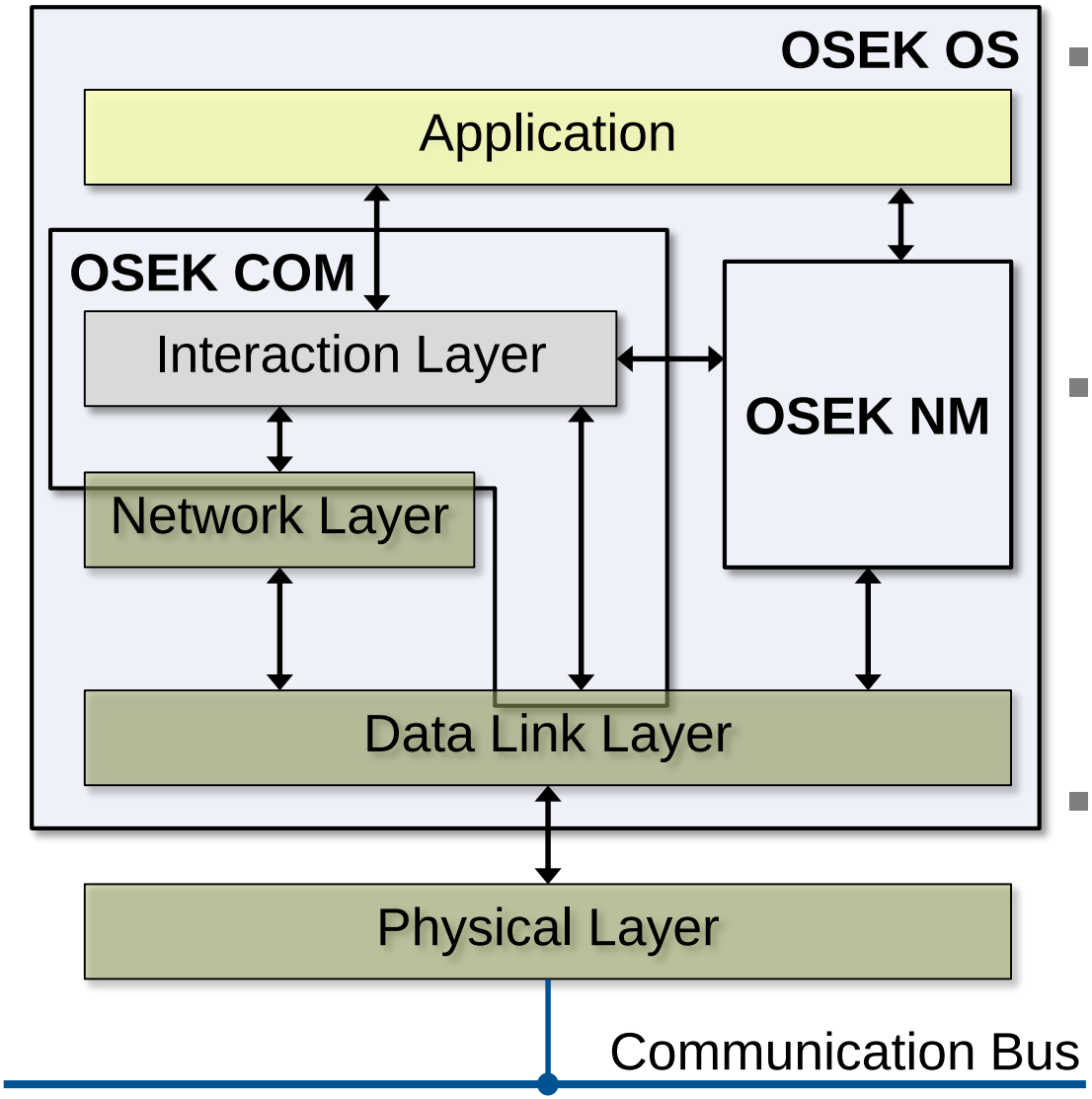
- **Worst-case response time (WCRT) analysis**
  - **For T_k, w_k = WCRT $\rightarrow$ if $w_k \leq d_k$, T_k is schedulable**

$$t^{(j+1)} = e_k + \sum_{\forall T_i \in HP(k)} \left\lceil \frac{t^{(j)}}{p_i} \right\rceil \cdot e_i$$

- HP(k)= 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**

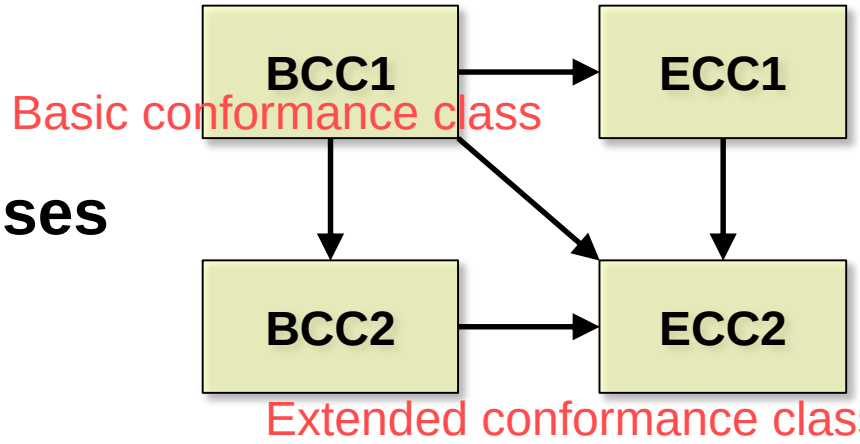
OSEK-VDX Specifications



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

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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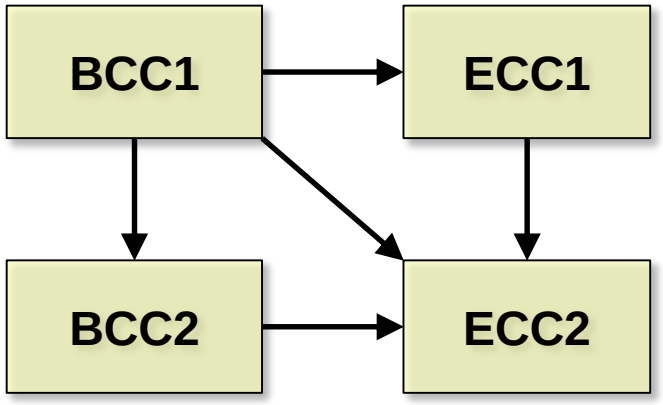
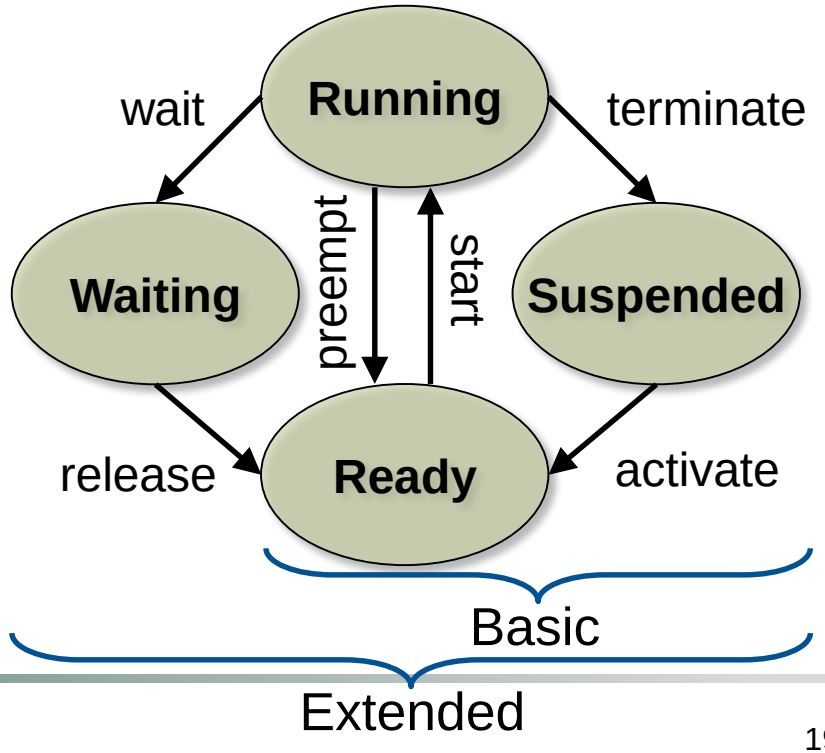
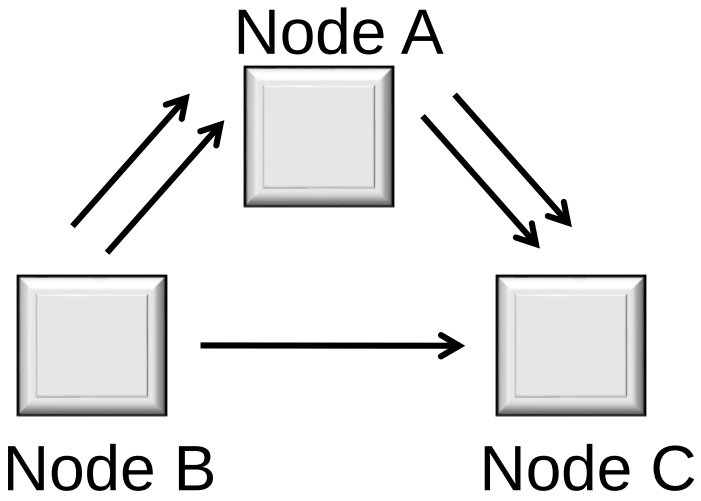


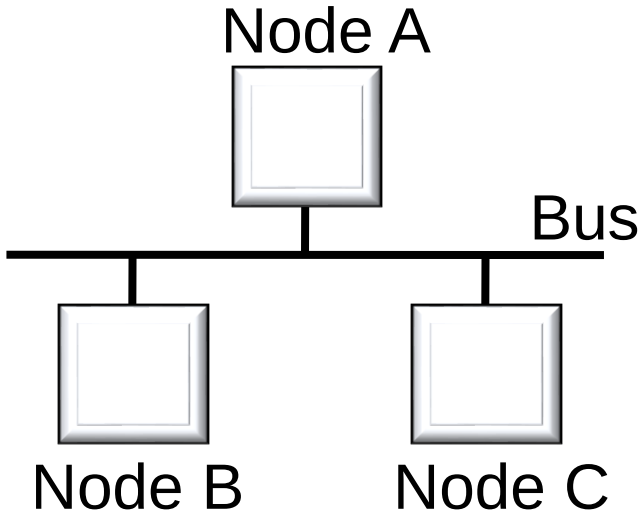


Communication in ECU Networks

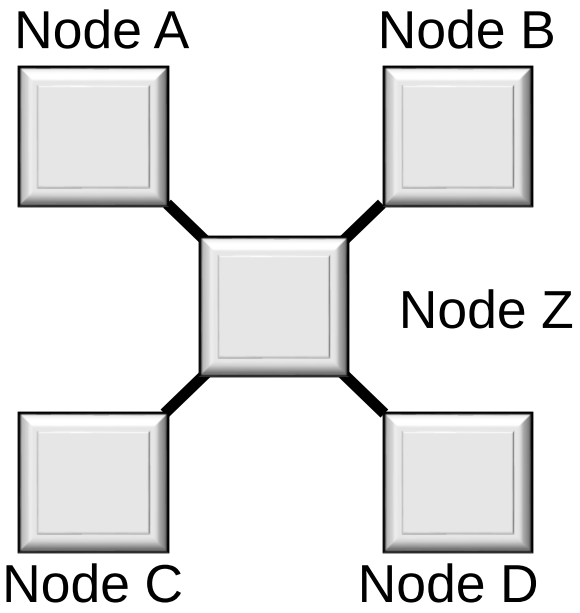
Logical system architecture



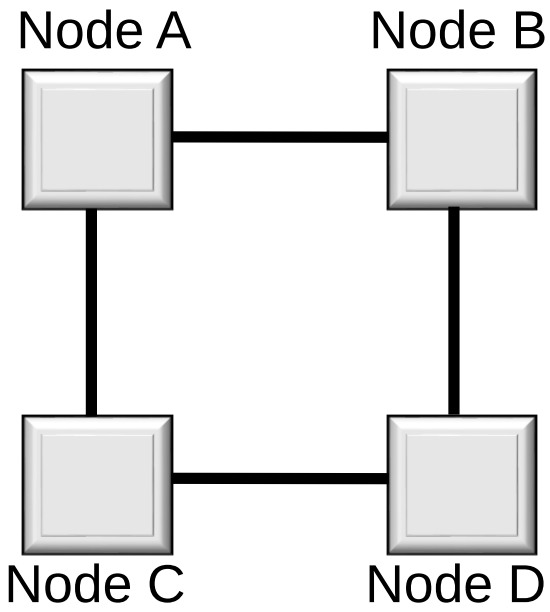
Technical system architecture



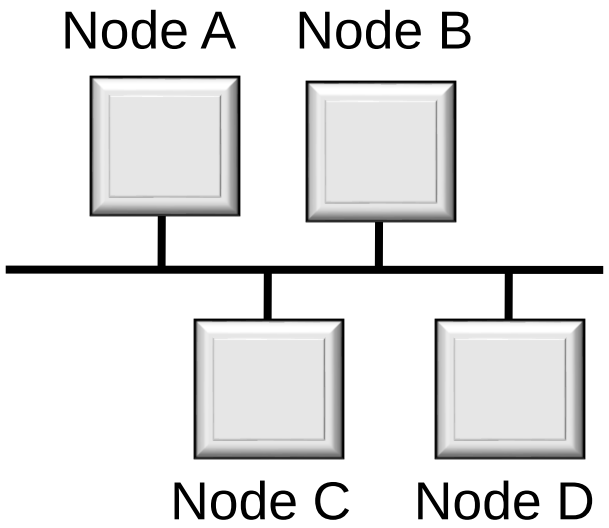
Common Topologies



Star



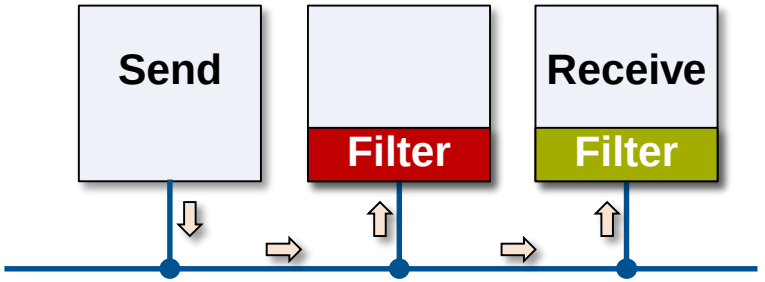
Ring

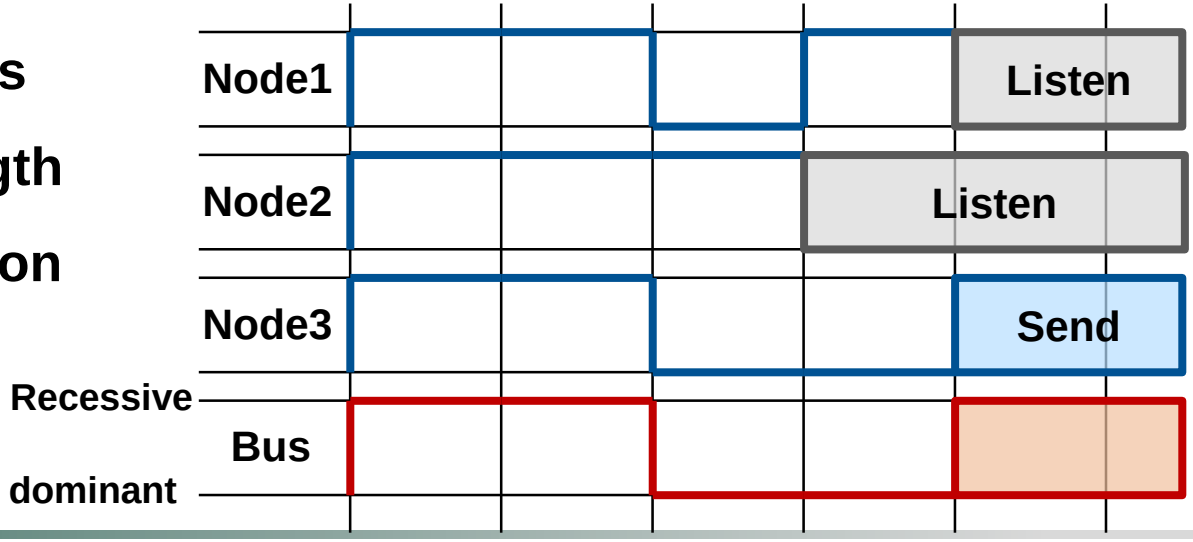


Line

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

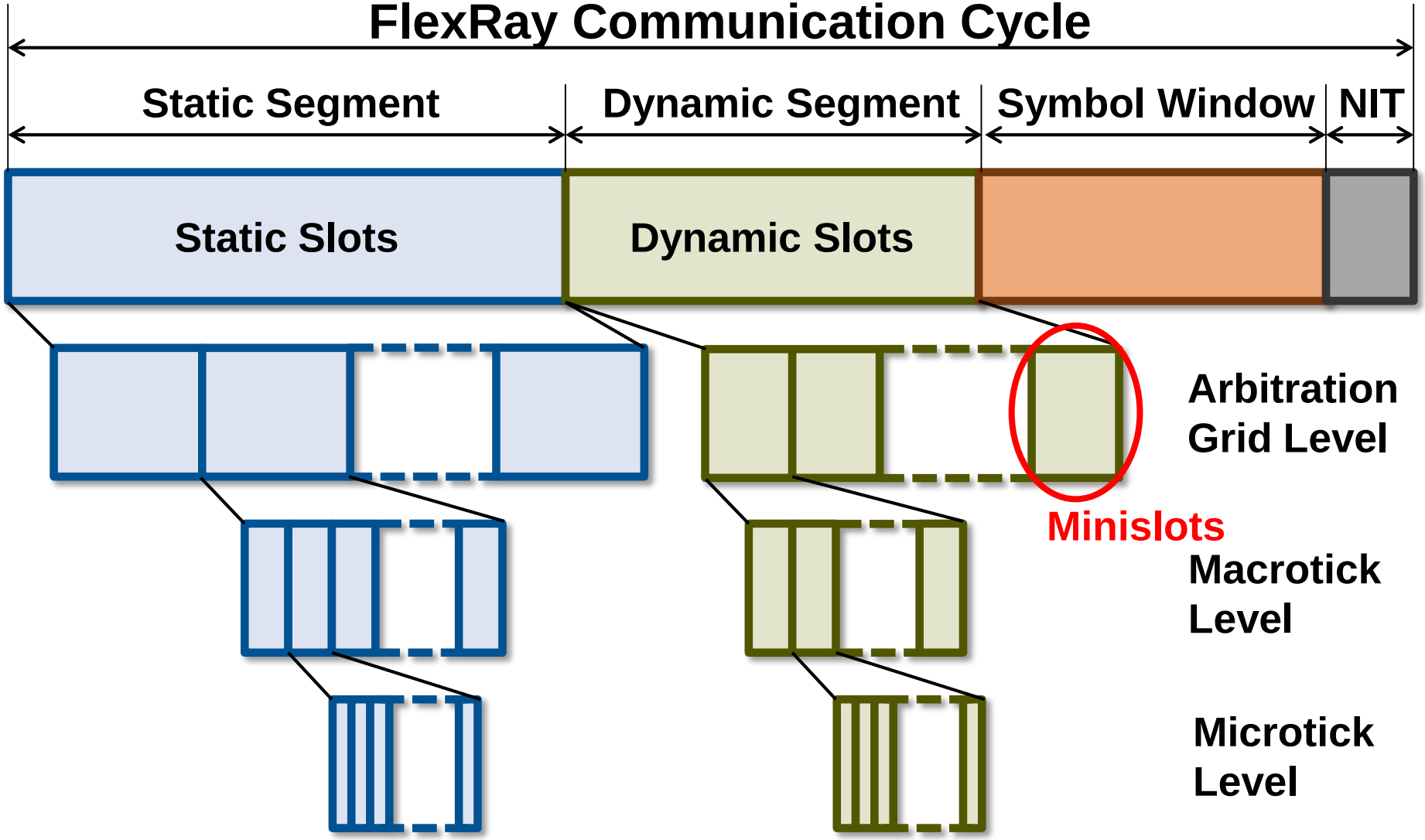




Communication Technologies

- **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



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**