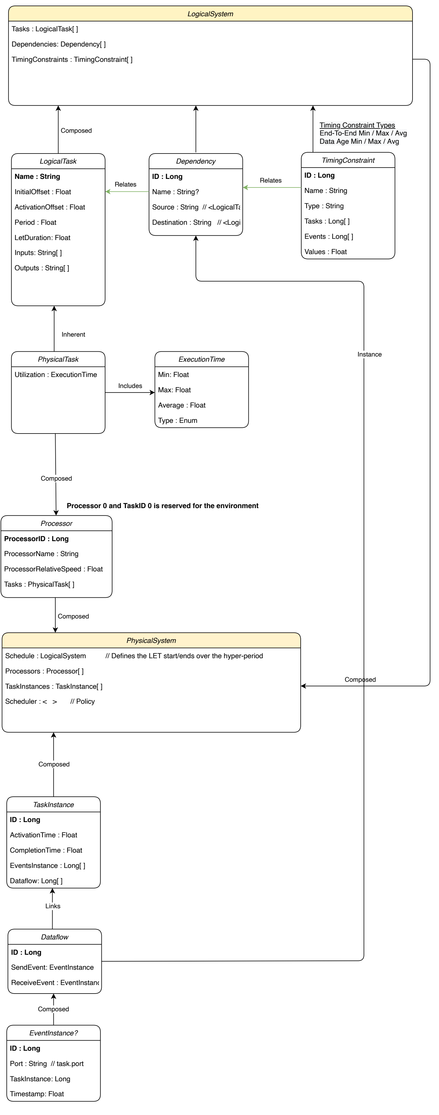

Timing Constraints

- Event triggering constraint
  - Periodic
    - Period
    - Jitter: Maximum deviation from the start of the period. Could be larger than period. Does not cause the period to drift
    - Min inter-arrival time: Minimum time between two consecutive events.

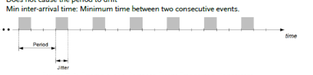

Figure 7.4: Example of a Periodic Event Triggering Constraint
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 118.

  - Sporadic (Generalisation of periodic; events can be absent)
    - Period (optional)
    - Jitter (optional)
    - Min/Max inter-arrival time: Minimum and maximum time between two consecutive events

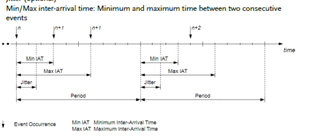

Figure 7.10: Parameters characterizing the Sporadic Event Triggering
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 122.

  - Concrete pattern (Precisely known event occurrences)
    - Pattern period (optional)
    - Pattern jitter (optional)
    - Pattern length: Duration of the event pattern
    - Offset: Set of event occurrences, defined as timing offsets into the pattern length

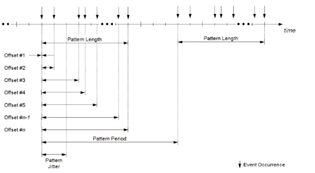

Figure 7.13: Parameters characterizing the Concrete Pattern Event Triggering when periodically being repeated
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 124.

  - Burst pattern (Typically used to model worst case activation scenarios)
    - Pattern period (optional)
    - Pattern jitter (optional)
    - Min number of occurrences (optional): Min number of times the event has to occur during the pattern itself
    - Max number of occurrences: Max number of times the event can occur during the pattern itself
    - Min inter-arrival time
    - Pattern length

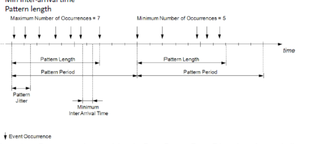

Figure 7.16: Parameters characterizing the Burst Pattern Event Triggering when periodically being repeated
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 128.

  - Arbitrary (Abstracts the event occurrences captured by data logging tools)
    - Min/Max distance: Minimum and maximum during which *n* number of events must occur. A min and max are defined for *n* = 2, 3, 4, ... event occurrences
    - Confidence interval: Probability that the min/max distances are observed

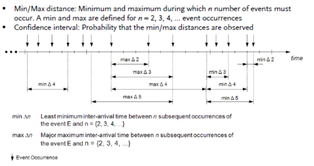

Figure 7.18: Parameters characterizing the Arbitrary Event Triggering
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 131.

- Latency constraint (on event chains)
  - Scope: Event chain
  - Latency constraint type: Age or Reaction
  - Min/Max/Nominal: Min/max/nominal duration between a stimulus and corresponding response
  - In multi-rate networks, data can get lost (under sampling) and or duplicated (oversampling)
  - Two end-to-end semantics of interest: Age of a response (freshest input is best), and reaction time to a stimulus (first reaction to a stimulus is of importance)

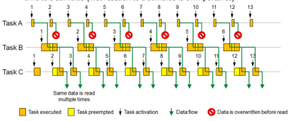

Figure 7.19: Loss and duplication of data due to under- and oversampling.
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 132.

- Age constraint (on data received at a port)
  - Scope: Timed event
  - Min/Max: Minimum and maximum age of an event
  - During design, the sender of data may be unknown, but still an age constraint is needed on the receiver port
  - Once the system is more developed and the sender becomes known, a timing event chain can be specified to refine the age constraint

- Synchronisation timing constraint
  - Scope: Timed events and timed event chains
  - Event occurrence kind: Single or multiple occurrences of an event within a given time interval
  - Synchronisation constraint type: Stimulus or response of event chains will occur simultaneously, or events will occur simultaneously.
  - Tolerance: Maximum time interval that the synchronised events are to occur simultaneously
  - Establish a consistent time base in a distributed environment

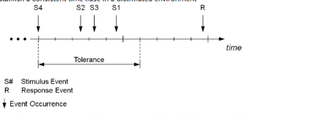

Figure 7.23: Parameters characterizing the Synchronization Timing Constraint imposed on the stimulus events of event chains.

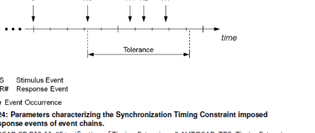

Figure 7.24: Parameters characterizing the Synchronization Timing Constraint imposed on the response events of event chains.
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 139.

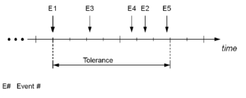

Figure 7.26: Parameter characterizing the Synchronization Constraint
AUTOSAR CP R19-11. "Specification of Timing Extensions," AUTOSAR_TPS_TimingExtensions, page 141.

- Synchronisation point constraint
  - Source: The executable entities that should finish executing before the synchronisation point
  - Target: The executable entities that should start executing after the synchronisation point
  - Specify that a group of executable entities can only execute once the execution of another group of executable entities have all finished, thus, the synchronisation point is logical
- Offset timing constraint
  - Source: Timing event that the target event will be synchronised with
  - Target: Timing event that will occur after the source event
  - Min/Max: Minimum and maximum offset that the target should occur relative to the source event
  - Bound the time offset between two timing events, even if there is no functional dependency between the source and target
- Execution order constraint
  - Execution order type: Ordinary (sequence of executable entities), Hierarchical (nesting of execution orders allowed), or repetitive (sets of execution order constraints that are repeated)
  - Ordered elements: List of executable entities to order
  - When an event occurs, the entities will be executed in their defined order
- Execution time constraint
  - Component and Executable: The executable and its parent component to which this execution time constraint applies
  - Execution time type: Gross (time without interruption, but with external calls) or net (time without interruption and without external calls) execution time
  - Min/Max: Minimum and maximum allowed execution time
  - Bound the allowed execution time of an executable entity

Use Cases

- **End-to-end timing** in control systems
  - Identify all the event-chains from sensor, controller, to actuator.
  - For closed-looped systems, identify and describe how the feedback loops are dealt.
  - Analyse the end-to-end delays for the event-chains.
  - Analyse the impact that various execution order and scheduling order have on timing properties.
  - Select the most reasonable variant.
- **Synchronisation** of concurrent event-chains that share a common functional context
  - **Sensor data fusion:** Compute sophisticated time-correlated sensor information from different sensors. For example, adaptive cruise control fuses radar and wheel data, or parking distance control fuses data from sensors of the same type to build an overall environment model.
  - **Actuator synchronisation:** Operate intelligent actuators simultaneously. For example, synchronous door opening, hazard warning lights, or anti-lock braking system.
  - **Bus synchronisation:** Reduce sending or reading delays between tasks by synchronising the gateway with its connected busses.
- **Early prediction** of timing behaviour during the design phase
  - **Analyse the impact of adding a component:** Component to be added must provide its own timing information. The component together with the existing system will impose timing constraints on each other, e.g., end-to-end response times or synchronisation.
  - **Hardware dimensioning:** Cost-effective hardware configurations that just satisfy the system's timing constraints can be chosen early on in the design phase.
  - **SW-C/ECU topology decisions:** Optimise the quality of the system, e.g., minimise latencies, minimise data ages, minimise bus loads, or balance out workloads.