# Annotation with Timing Constraints in the Context of EAST-ADL2 and AUTOSAR – the Timing Augmented Description Language

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*Abstract*— **The Timing Augmented Description Language extend the modeling of automotive systems as supported by EAST-ADL2 and AUTOSAR with events and event chains. The semantics of age and reaction time constraints utilizing event chains and input/output synchronization constraints on events are described.**

***Timing, Modeling, EAST-ADL2, AUTOSAR***

## I. Introduction

The European research project TIMMO (TIMing MOdel) [1] is in the area of automotive system timing management using a common, standardized approach for handling all timing-related information during the development process. One part of TIMMO is about developing a Timing Augmented Description Language (TADL); this is supplemented by methodology descriptions and validators.

The definition of the TADL is based on modeling concepts from EAST-ADL2 [2][3] and AUTOSAR [4], by which the structural definition of the considered system is modeled. The augmentation is done by adding information related to timing and events referring to structural elements. The challenges in the AUTOSAR context has been identified e.g. in [7]. Further inputs for the definition are the requirements and the methodology as defined within the TIMMO project, and the parameters used by the analysis tools from the TIMMO partners. MARTE (Modeling and Analysis of Real-Time Embedded systems) [5] from OMG also serves as an input to TADL as this gives a base for modeling the analysis steps and its results [8]. The MARTE UML2 profile may also serve as a basis for a UML2 implementation of TADL.

The semantics describes the meaning of the TADL concepts and a foundation is given for, e.g. event chains, end-to-end delay constraints, and paths.

## II. Structural Framework

The EAST-ADL2 and AUTOSAR provides the structural concepts which the Timing Augmented Description Language of TIMMO extends. EAST-ADL2 defines five abstraction levels called vehicle, analysis, design, implementation and operational level. On each abstraction level, a complete representation of the embedded system is defined. The content on each level is increasingly concrete and solution-oriented from vehicle level and down.

The model on the implementation level uses the AUTOSAR constructs to define a software architecture and a system topology. AUTOSAR defines different views of the model, the VFB view, Virtual Function Bus, where software components are connected but allocation is disregarded. This software view is supplemented by the ECU view of the target for allocation of the software, and the system view where the software architecture is allocated.

## III. EVENTS AND EVENT CHAINS

On the higher abstraction levels (vehicle, analysis, and design) structural modeling is performed as defined within EAST-ADL2. On the implementation level the AUTOSAR modeling is performed. The TADL constraints are defined separately from the structural modeling and refer to structural elements via Event Chains and Events, see Figure 1. The events are tailored to refer to specific elements in the structural model, i.e. different sets of events are available for the EAST-ADL2 model and the AUTOSAR model.

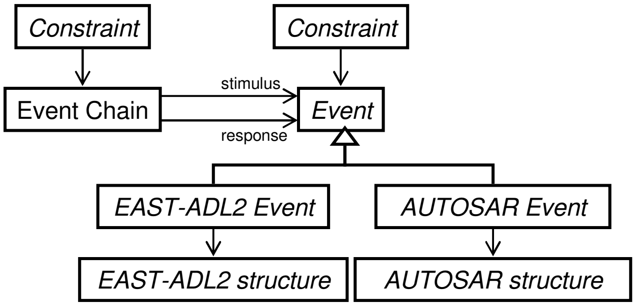


Figure 1. This is a simplified extract of the UML meta-model, which shows the relationships between the elements available for modeling of constraints, event chains, events, and structural elements.

Additionally all TADL constraints carry a timing bound and a mode. In Figure 2. this is seen in the ReactionConstraints .

The requirement support in EAST-ADL2 allows for tracing from solutions as modeled in the structural model to requirements, and from verification cases to requirements. The TADL constraints fit in the requirement support as refinements of the requirements.

Further support in EAST-ADL2 includes the tracing between abstraction levels by realization between e.g. a Vehicle Feature in the highest abstraction layer to functional descriptions in lower layers, and further down to software components and Runnables as found on the AUTOSAR level. Tracing between requirements is done by the SysML concepts DeriveReqt [6], and the refinement of a requirement by means of a constraint is done by the ADLRefine. Figure 2. shows an example with the concepts used for tracing requirements and the definition of an example ReactionConstraint with events. Note how the ADLFunction and FunctionalDevice in the analysis architecture realizes the VehicleFeature, and how these are detailed on the design level.

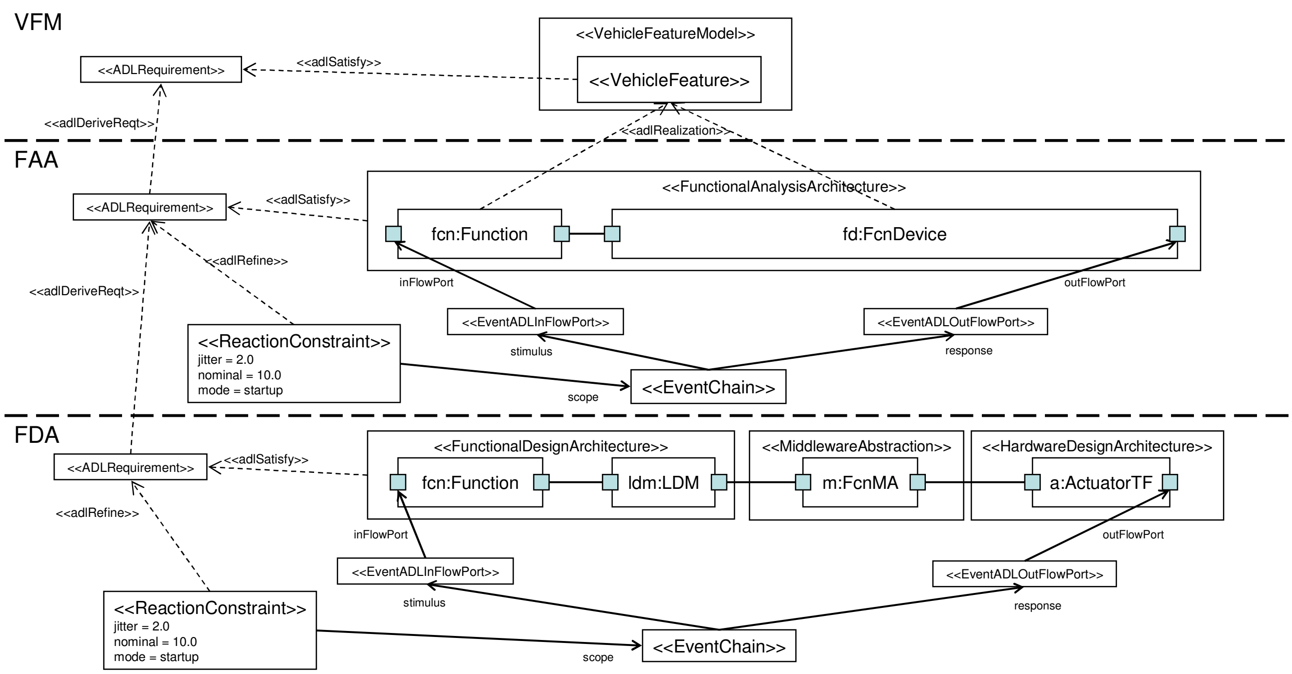


Figure 2. Relating requirements between abstraction levels

## IV. AGE AND REACTION TIMING CONSTRAINTS

Multirate systems, which are common in automotive applications, have over- and under-sampling effects, which an end-to-end delay semantics has to consider. Very often register based communication is used where message loss (under sampling) or duplication (oversampling) occurs. TIMMO has identified two end-to-end delay semantics, which are interesting for real world situations. These delays are the reaction delay and age delay.

The reaction delay is utilized when the first reaction to a stimulus is of importance. This is usually the case in body electronics, but may also be the case in other domains. One example is the time it takes from a button is pressed to the light is switched on. Another example, from the chassis domain, is the time from the brake pedal is pressed until the brakes are activated. In both these cases the constrained time of importance is the delay from a given stimulus to the first corresponding response.

The age of data is mainly important in control engineering, but may appear in all domains. Here the focus is from the response perspective rather than from the stimulus perspective. In other words, the assumption is that last is best, i.e. it is ok that a value is overwritten along the path from stimulus to response. When for example an actuator value is periodically updated, it is of importance that the corresponding input values are not to old. It is not a problem if some stimuli are lost as long as the ones reaching the response are not too old.

The delay from any of these semantics can be composed of segments of the same kind (reaction or age) throughout the complete system and might span multiple ECUs and buses. This is part of the time budgeting and decomposition as described in the TIMMO methodology.

Given these semantics and the corresponding TADL elements, it is possible to describe and verify end-to-end delay constraints throughout the complete supplier and car manufacturer chain. Furthermore there is the possibility to explicitly define the kind of delay, which will reduce misunderstandings even before implementation or design stage.

## V. INPUT AND OUTPUT SYNCHRONIZATION CONSTRAINTS

Constraining timing is not always about delays between stimuli and responses. An important class of constraints deals with the synchronization between either stimuli or responses, respectively. One example is a central lock function. The ReactionConstraint between button pressed (stimuli) and door locked (response) could typically have a span between fastest and slowest reaction of several hundreds of milliseconds. However, the tolerated difference between when the different doors are locked is perhaps just some tenths of milliseconds. This difference between a number of responses related to the same stimuli, is expressed in TADL by an additional attribute to a dedicated specialization to the class ReactionConstraint called OutputSynchronizationConstraint. Figure 3. depicts a central lock system where the locks of the four doors are controlled by the remote control in the key. The locking of one door is defined as an event each. The OutputSynchronizationConstraint constrains the maximum difference in time between any of these four events. Note that this range can be much less than the tolerated range in the ReactionConstraint between the stimulus event defined as pressing the key and any of these four response events defined as locking of a door.

In a similar way, there is also a constraint called InputSynchronizationConstraint in the TADL specializing the AgeConstraint. This is to constrain the maximum difference between a number of stimuli events, e.g. sampling of sensors.

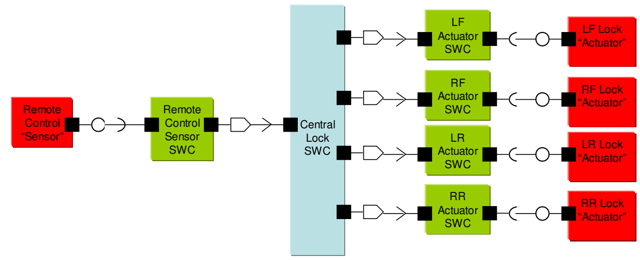


Figure 3. Central lock system.

## VI. EDITOR

The TADL is formally defined as a meta-model, which references the AUTOSAR meta-model and is embedded in the EAST-ADL2 metamodel. This is supplemented with structural concepts from EAST-ADL2, and all added concepts conform to the AUTOSAR meta-modeling rules. In this way, the exchange format of a timing model is defined and VSA, Vehicle System Architect - an AUTOSAR editor, is extended to allow for EAST-ADL2 and TADL modeling.

The conceptual example from Figure 2. has been modeled in the editor and a snapshot is seen in Figure 4. A Functional Analysis Architecture with two functions builds up the structural model. A Reaction Constraint with bound attributes has been defined; this refers to an Event Chain built up by an in event and an out event referring to structural ports.

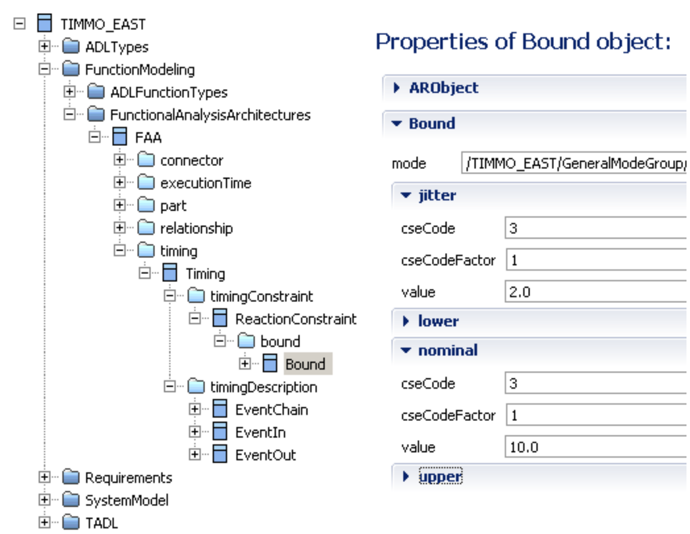


Figure 4. A snapshot of the editor.

## VII. TIMING ANALYSIS

The TADL concepts described so far has concentrated on specifying timing constraints. Analyzing the model to verify compliance with these constraints can be done in several ways.

One of the analytical approaches is to verify the timing constraints of the model based on model assumptions represented by other timing constraints. For example, it may be verified that the sum of all contained event chains meets the constraints of a containing event chain. This is possible because age and reaction time constraints are additive. Constraints on age are additive in the sense that we can derive that max age of an event chain can never be greater than the sum of the max ages of the segments of this event chain. The same is true for reaction times. But please note that age and reaction are not possible to add together, because they have different semantics.

Another analytical approach is to analyze the timing-related properties of the annotated model. For example, the response time of a part of the model is compared with corresponding reaction and age constraints. In EAST-ADL2, the execution time and trigger definition (period or minimum arrival time and jitter, is the basis for computing response time, see Figure 5. AUTOSAR has similar parameters, although more detailed since the task structure; OS overhead, resource contention, etc. shall be taken into account.

Further verification methods include simulation and testing of real hardware, in which case measured timing is compared with specified timing.

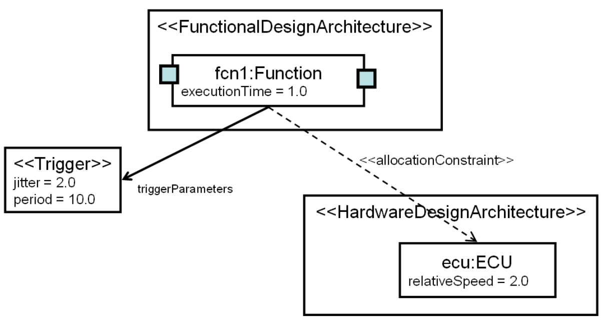


Figure 5. An allocated function with trigger parameters and an exectionTime.

## VIII. CONCLUSIONS

We have shown the concept of augmenting EAST-ADL2 and AUTOSAR models with timing information. An exchange format for the information and an editor can be generated from a defined metamodel. This facilitates modeling of the considered system and the timing information, and exchange of the models between tools.

The semantics of Age and Reaction timing constraints and Input and Output synchronization constraints have been described. These fit in the requirement management support of EAST-ADL2 which gives traceability and refinement of requirements.

## ACKNOWLEDGMENT


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