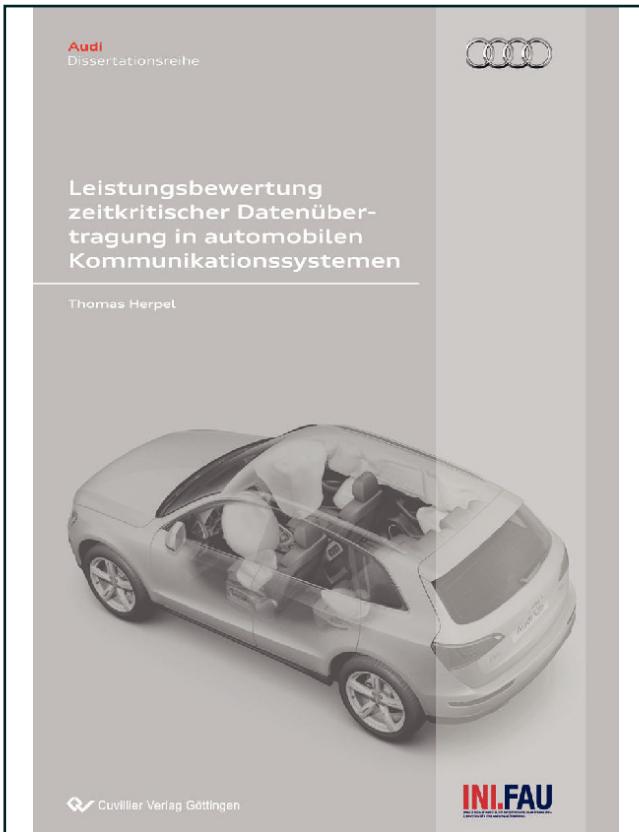




Thomas Herpel (Autor)

**Performance Evaluation of Time-Critical Data
Transmission in Automotive Communication Systems**
Leistungsbewertung zeitkritischer Datenübertragung in
automobilen Kommunikationssystemen



<https://cuvillier.de/de/shop/publications/760>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentzsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,
Germany

Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>

Contents

Acknowledgements	xi
Abstract	xiii
Zusammenfassung	xv
1 Introduction	1
1.1 Motivation	1
1.2 Airbag Control Systems	2
1.2.1 Airbag Control Unit	2
1.2.2 Crash Sensors	4
1.2.3 Airbags and Belt Tensioners	6
1.2.4 Functional Safety of the Airbag Control System	6
1.3 Future Vehicle Safety Approaches	7
1.3.1 The Intelligent Car	8
1.3.2 Precrash Systems	9
1.3.3 Time-Critical Precrash Data Transfer	13
2 Related Work	15
2.1 Measurements	15
2.2 Simulation	15
2.3 Analytical Modeling	16
3 In-Car Communication System	19
3.1 CAN - Controller Area Network	19
3.2 FlexRay	22
3.3 Automotive Gateway Architectures	23
3.4 Other Communication Technologies	25

4 Prototype Measurements of In-Car Data Transmission	27
4.1 Motivation	27
4.2 Measurement Hardware Setup	28
4.3 Software Tooling for Data Evaluation	29
4.3.1 Communication Access Programming Language and VECTORS CANoe	29
4.3.2 ExpertFit®	31
4.4 Measurement Studies of In-Car Communication	31
4.4.1 Frequency Drift of Controller Quartzes	31
4.4.2 Durations and Distributions of CAN ECU Startup Times	39
4.4.3 Cycle Time Jitter of CAN Messages	43
4.4.4 Routing Delay in Central Gateway	46
4.5 Discussion of Prototype Measurements and Data Evaluation Results	54
5 Discrete Event Simulation of In-Car Data Transmission	57
5.1 Motivation	57
5.2 Discrete Event Simulation	58
5.3 AnyLogic™	59
5.4 Modeling Elements for Simulation of In-Car Data Transmission	60
5.4.1 Message Objects	60
5.4.2 CAN	62
5.4.3 FlexRay	69
5.4.4 Gateway	75
5.4.5 Overall In-Car Communication Network	78
5.5 Discussion of Discrete Event Simulation Approach	79
6 Worst-Case Analysis of In-Car Data Transmission	81
6.1 Motivation	81
6.2 Network Calculus	82
6.2.1 Theoretical Foundations	84
6.3 Application of Network Calculus to CAN Communication	90
6.3.1 Input Data	90
6.3.2 Generation of Arrival Curves	91
6.3.3 Determination of the Service Curve	93
6.3.4 Calculation of Delay Bounds	94
6.3.5 Exemplary Message Schedule	99

6.4 Application of Network Calculus to Overall In-Car Communication Topology	101
6.4.1 Methodical Approach	101
6.5 Discussion of Worst-Case Analysis Approach	112
7 Application Examples	113
7.1 Local CAN Bus Communication	113
7.1.1 Simulation Experiments	113
7.1.2 Network Calculus	115
7.1.3 Performance Evaluation Results	115
7.1.4 Comparison and Discussion	117
7.2 Network-Wide Data Transmission	119
7.2.1 Simulation	120
7.2.2 Network Calculus	121
7.2.3 Performance Evaluation Results	122
7.2.4 Comparison and Discussion	131
8 Conclusions and Future Work	135
8.1 Conclusions	135
8.2 Future Work	136