

Table of Contents

Part I: Hard Real-Time Development Environments

1	Executive Overview on Hard Real-Time Development Environments	1
1.1	Motivation and Objectives	1
1.2	Essential Characteristics.....	2
1.3	Role in Future Embedded Systems	3
1.4	Overall Challenges and Work Directions.....	4
1.5	Document Structure	9
2	Hard Real-Time System Development.....	10
2.1	Brief Discussion of Current Practice: The V-Shaped Lifecycle.....	10
2.2	An Emerging Approach: Platform-Based Design	11
3	Current Design Practice and Needs in Selected Industrial Sectors.....	15
3.1	Automotive Systems	15
3.2	Aeronautics: A Case Study	24
3.3	Consumer Electronics: A Case Study	31
3.4	Automation Applications	35
4	Tools for Requirements Capture and Exploration	39
4.1	Definitions of Hard Real-Time Dependability Features.....	39
4.2	Scientific Engineering Tools and Physical Systems Modellers	45
4.3	State-Based Design: Dealing with Complex Discrete Control.....	50
5	Tools for Architecture Design and Capture.....	54
6	Tools for Programming, Code Generation, and Design	63
6.1	Structure	63
6.2	Code Generation from Synchronous Languages.....	63
6.3	Back-End Code Generation – Below C	68
7	Tools for Verification and Validation	72
7.1	Building Blocks for Verification and Validation	72
7.2	Model Checking	72
7.3	Static Program Analysis	76
7.4	Testing Embedded Systems	80
8	Middleware for Implementing Hard Real-Time Systems.....	85

9	Review of Some Advanced Methodologies	92
9.1	The Setta Project	92
9.2	The SafeAir Project.....	96

Part II: Component-Based Design and Integration Platforms

10	Executive Overview on Component-Based Design and Integration Platforms	103
10.1	Motivation and Objectives	104
10.2	Essential Characteristics.....	105
10.3	Role in Future Embedded Systems	108
10.4	Overall Challenges and Work Directions.....	109
10.5	Document Structure	112
11	Component-Based System Development	114
11.1	Lifecycle of Component-Based Systems.....	114
11.2	Lifecycle of Components	117
11.3	Issues Specific for Embedded Systems	117
11.4	Summary and Conclusions.....	118
12	Current Design Practice and Needs in Selected Industrial Sectors.....	120
12.1	Automotive.....	120
12.2	Industrial Automation	124
12.3	Consumer Electronics	129
12.4	Telecommunication Software Infrastructure.....	131
12.5	Avionics and Aerospace.....	134
12.6	Summary and Challenges.....	136
13	Components and Contracts.....	139
13.1	Introduction.....	139
13.2	Level 1 – Syntactic Interfaces	140
13.3	Level 2 – Functional Properties.....	143
13.4	Level 3 – Functional Properties.....	145
13.5	Level 4a – Timing Properties	147
13.6	Level 4b – Quality of Service	153
13.7	Specifying and Reasoning About Contracts: Summary and Analysis.....	158
14	Component Models and Integration Platforms: Landscape.....	160
14.1	Widely Used Component Models	160
14.2	Component Models for Embedded System Design.....	172

14.3	Integration Platforms for Heterogeneous System Design	181
14.4	Hardware/Software Modelling Languages.....	186
14.5	Component Models and Integration Platforms: Summary and Conclusions.....	187
14.6	Component Libraries: Approaches to Component Retrieval.....	189
15	Standardization Efforts.....	194
15.1	Specification Standards.....	194
15.2	Implementation Technology Standards.....	202
15.3	Conclusions and Challenges.....	203
16	References	204

Part III: Adaptive Real-Time Systems for Quality of Service Management

17	Executive Overview on Adaptive Real-Time Systems for Quality of Service Management	216
17.1	Motivation and Objectives	216
17.2	Essential Characteristics.....	217
17.3	Role in Future Embedded Systems	218
17.4	Overall Challenges and Work Directions.....	220
17.5	Document Structure	225
18	Adaptive Real-Time System Development	227
19	Current Design Practice and Needs in Selected Industrial Sectors.....	229
19.1	Industrial Sector 1: Consumer Electronics in Philips.....	229
19.2	Industrial Sector 2: Industrial Automation	232
19.3	Industrial Sector 3: Consumer Electronics: Ericsson Mobile Platforms	237
19.4	Industrial Sector 4: Telecommunications – The PT-Inovação Case Study.....	240
20	Real-Time Scheduling	242
20.1	Landscape.....	242
20.2	Assessment.....	248
20.3	Trends.....	248
20.4	Recommendations for Research.....	252
20.5	References	254
21	Real-Time Operating Systems.....	258
21.1	Landscape.....	259
21.2	Assessment.....	275

21.3	Trends.....	279
21.4	Recommendations for Research.....	282
21.5	References.....	283
22	QoS Management.....	287
22.1	Landscape.....	287
22.2	Assessment.....	294
22.3	Trends.....	295
22.4	Recommendations for Research.....	299
22.5	References.....	300
23	Real-Time Middleware.....	305
23.1	Landscape.....	306
23.2	Assessment.....	310
23.3	Trends.....	311
23.4	Recommendations for Research.....	313
23.5	References.....	314
24	Networks	316
24.1	Landscape.....	316
24.2	Assessment.....	325
24.3	Trends.....	326
24.4	Recommendations for Research.....	333
24.5	References.....	335
25	Programming Languages for Real-Time Systems	338
25.1	Landscape.....	338
25.2	Assessment.....	344
25.3	Trends.....	346
25.4	Recommendations for Research.....	347
25.5	References.....	349
26	Other Issues	352
26.1	Power Awareness	352
26.2	Media-Processing Applications.....	358
26.3	Integrating Real-Time and Control Theory	358
26.4	Probabilistic Time Analysis	365
26.5	Hardware Trends.....	369

Part IV: Execution Platforms

27	Executive Overview on Execution Platforms.....	373
27.1	Motivation and Objectives	373
27.2	Essential Characteristics.....	374
27.3	Role in Future Embedded Systems	374
27.4	Overall Challenges and Work Directions.....	374
27.5	Document Structure	375
28	Current Design Practice and Needs in Selected Sectors.....	377
28.1	Automotive Industry	377
28.2	Mechatronics Industry.....	383
29	Computing Platforms	388
29.1	Multiprocessor Systems – Modelling and Simulation.....	388
29.2	Distributed Embedded Real-Time Systems – Analysis and Exploration.....	406
29.3	Reconfigurable Hardware Platforms	423
29.4	Software Integration – Automotive Applications.....	440
30	Low Power Engineering	450
30.1	Power-Aware and Energy Efficient Middleware	450
30.2	Memory Hierarchy and Low Power Embedded Processors	464
	Index	479