



contents

Preface	xiii
Acknowledgments	xv

CHAPTER 1

Benefits and Applications of the In-Vehicle Network for Data Acquisition	1
1.1 Overview: Data Goldmine	1
1.2 Focus and Assumptions of This Book	2
1.3 Access to the Data	2
1.4 Normal and Requested Messages	3
1.4.1 Normal Messages	3
1.4.2 Requested Messages	3
1.5 Comparing Light- and Heavy-Duty Vehicle Designs	3
1.6 Applications	5
1.7 How to Use This Book	5
References	6

CHAPTER 2

Comparison with Traditional Data Acquisition	7
2.1 Acquiring Data with Added Sensors	7
2.2 In-Vehicle Network Data	8
2.3 Acquiring Parameters from the Network	9
2.4 Complications of Network versus Direct Sensors	9

CHAPTER 3

Binary, Hex, Bits, and Bytes	11
3.1 Introduction to Bits, Binary, and Hexadecimal Conventions	11
3.2 Hexadecimal Designations	12
3.3 Introduction to Bits and Bytes	12
3.4 11 and 29-Bit CAN IDs	12

3.5 Data Conventions	13
3.5.1 Conversion Format	13
3.5.2 Byte Format	13
3.5.3 Byte Order	14

CHAPTER 4

Controller Area Network (CAN) Protocol	17
4.1 What Is CAN?	17
4.2 What Does CAN Define?	19
4.2.1 Layer 1: Physical Layer	19
4.2.2 Level 2: Data Link Layer	20
4.3 Applications of CAN	22
4.4 CAN on Light-Duty Vehicles Using ISO 15765	23
References	23

CHAPTER 5

On-Board Diagnostics (OBD) Background and Standards	25
5.1 OBD Background	25
5.2 Relevant OBD-II Standards	27
5.2.1 OBD and Protocol Relationship	29
5.2.2 OBD-II Information Defined in J1979	29
5.2.3 Legacy OBD Protocols	29
5.2.4 ISO 15765: OBD-II on CAN	30
5.3 Additional OBD-II-Related Standards	30
5.3.1 J1930: Terms and Definitions	31
5.3.2 J1962: Diagnostic Connector	31
5.3.3 J1978: Diagnostic Tool Requirements	32
5.3.4 J2012: Diagnostic Trouble Code (DTC) Definitions	32
5.3.5 J2186: Data Link Security	33
5.3.6 J2534: Recommended Practice for Pass-Thru Vehicle Programming	33
5.3.7 J1699: Vehicle OBD-II Compliance Test Cases Recommended Practice	34

5.3.8	J1699-3: Vehicle OBD-II Compliance Test Cases	34
5.3.9	J1699-4: OBD-II Communications Anomaly List	35
5.3.10	J2284-3: High-Speed CAN (HSC) for Vehicle Applications at 500 kbps	35
5.3.11	J3005-1 Permanently or Semi-Permanently Installed Diagnostic Communication Devices	35
5.3.12	J3005-2 Permanently or Semi-Permanently Installed Diagnostic Communication Devices—Security Guideline	36

References

36

CHAPTER 6

OBD-II Diagnostic Messages and Test Modes 39

6.1 J1979 and J1979-DA: Electrical/Electronic Systems Diagnostic Test Modes 39

6.1.1 Priority 40

6.1.2 Controller IDs 40

6.2 Test Mode 41

6.2.1 Mode \$01: Request Current Powertrain Diagnostic Data 42

6.2.2 Mode \$02: Request Powertrain Freeze Frame Data 42

6.2.3 Mode \$03/\$04: Request/Clear Emission-Related Diagnostic Trouble Code (Confirmed DTCs) 42

6.2.4 Mode \$05: Request Oxygen Sensor Monitoring Test Results 42

6.2.5 Mode \$06: Request On-Board Monitoring Test Results for Specific Monitored Systems 43

6.2.6 Mode \$07: Request Emission-Related Diagnostic Trouble Codes Detected During Current or Last Completed Driving Cycle (Pending DTCs) 43

6.2.7 Mode \$08: Request Control of On-Board System, Test, or Component 43

6.2.8 Mode \$09: Request Vehicle Information 44

6.2.9 Mode \$0A: Request Emission-Related Diagnostic Trouble Codes with Permanent Status 47

6.3 Parameter ID (PIDs) 47

6.3.1 PID \$00: Finding Available Parameters 48

6.4 Broadcast vs. Targeted Requests 48

6.5 11- and 29-Bit CAN Message Examples 49

References

51

CHAPTER 7

J1979 OBD-II Data with Mode \$01	53
7.1 Overview	53
7.2 Mode \$01 – Request Current Powertrain Diagnostic Data	53
7.3 Required OBD-II Mode \$01 Parameters	54
7.3.1 Required OBD-II, Mode \$01 Parameters – Gasoline Engines	54
7.3.2 Required OBD-II, Mode \$01 Parameters – Diesel Engines	58
7.4 Sample Rate, Scaling, and Amplitude Resolution for Mode \$01 Parameters	62
7.5 Sample Message Data and Conversion for Test Mode \$01	62
7.5.1 Example 1 Vehicle Speed (\$0D)	63
7.5.2 Example 2 Intake Air Temperature (\$0F)	63
7.5.3 Example 3 RPM (\$0C)	63
7.6 Example OBD Database Editor	63
References	65

CHAPTER 8

Mode \$06: Request On-Board Monitoring Test Results for Specific Monitored Systems	67
8.1 Purpose	67
8.2 Diagnostic Monitor ID (MIDs): Component Identifier	68
8.3 Test IDs (TIDs)	68
8.4 Data Format	70
8.5 Data Display of Mode \$06 Data	71
8.6 Oxygen Sensor	71
8.7 Supported MIDs	73
8.8 PID \$41: Monitor Status This Driving Cycle	73
8.9 Mode \$06 Serial Monitor	74
8.10 Mode \$06 Parallel Monitor	74
8.11 Logging Mode \$06	75
8.12 The Missing Mode	76
References	77

CHAPTER 9

Enhanced Diagnostics	79
9.1 Comparing OBD-II to EOBD	79
9.2 Enhanced OBD Test Modes	80
9.3 Sources of LD Network Data	81
9.4 J2190 Enhanced E/E Diagnostic Test Modes	82
9.5 ISO 14229: Unified Diagnostic Services (UDS)	82
9.6 ISO14230: Road Vehicles—Diagnostic Communication over K-Line (DoK-Line)	83
9.7 ISO 15765 Road Vehicles: Diagnostic Communication over Controller Area Network (DoCAN)	86
9.7.1 General Information and Use Case Definition	86
9.7.2 Transport Protocol and Network Layer Services	87
9.7.3 Implementation of Unified Diagnostic Services (UDS on CAN)	88
9.7.4 Requirements for Emissions-Related Systems	88
References	90

CHAPTER 10

Additional Protocols	91
10.1 LIN Protocol	91
10.2 MOST Protocol	91
10.3 FlexRay Protocol	92
10.4 Automotive Ethernet	92
10.4.1 Time-Triggered Ethernet	93
10.5 CAN FD	94
10.6 Protocol Speed Summary	95
10.7 OBD-III	96
References	96

CHAPTER 11

Diagnostic Trouble Codes (DTCs)	97
11.1 Overview	97
11.2 J1979 OBD-II Fault Codes (Modes \$03, \$07, \$0A)	97

11.3 UDS ISO 14229 EOBD Fault Codes	99
11.4 Comparing HD and LD Standards	100
11.4.1 Comparing HD and LD Approaches	101
11.4.2 Comparing LD Test Modes with HD Messages	102
11.5 J1939 Fault Codes	102
11.6 WWH-OBD Fault Codes	103
11.6.1 Severity (Byte 4 of Request and Byte 5 of Response)	105
11.6.2 Class of the DTC Severity (Byte 7)	105
11.6.3 Status (Byte 11)	105
11.7 Clearing Codes	107
11.7.1 Clearing OBD Codes	107
11.7.2 Clearing EOBD Codes	107
11.7.3 Clearing J1939 Trouble Codes	108
References	108

CHAPTER 12

Steps to Acquire LD In-Vehicle Network Data	109
12.1 Overview	109
12.2 Logging OBD Data with a Test Tool	110
12.3 Example OBD Database Editor	110
12.3.1 Selecting Parameters to Acquire	111
12.3.2 Sorting by Name, Unit, or PID	111
12.3.3 Defining the Acquisition Rate and Source Address	112
12.3.4 Importing Proprietary Messages	112
12.4 Data Logger/Streamer Specifications	113
Reference	114

CHAPTER 13

Applications and Example Data	115
13.1 Overview of OBD Applications	115
13.2 Web-Based Dashboards	115
13.3 Types of Analyses and Displays	116
13.3.1 Point-by-Point Trip Data	117

13.3.2	Statistical Data	118
13.3.3	Vehicle Comparison Data	119
13.3.4	Correlating Controller Data	119
13.4	Fleet Data	121
13.4.1	Diagnostics and Alerts	122
13.4.2	Driver Behavior/Performance/Training	123
13.4.3	Electronic Logging Device (ELD)	123
13.5	Diagnosing and Servicing Intermittent Problems	124
13.5.1	Air Conditioning Intermittent Problem	124
13.5.2	Transmission Intermittent Problem	125
13.6	Additional Data Sources	126
13.6.1	GPS	126
13.6.2	Geofencing	127
13.6.3	Telematics and Remote Diagnostics	127
13.6.4	Adding Sensors to the Vehicle	128
13.7	Calculated Parameters from In-Vehicle Network Parameters	129
13.7.1	Vehicle Weight	129
13.7.2	Triaxial Accelerometer and Road Grade	130
13.7.3	Fuel Economy	133
References		133

CHAPTER 14

Calculating Fuel Economy	135	
14.1 Fuel Economy and Emissions	135	
14.2 Calculating Fuel Economy	135	
14.2.1	Injector Volume	135
14.2.2	Manifold Air Flow and Air Fuel Ratio	136
14.2.3	Using Manifold Air Pressure (MAP) and Ideal Gas Law	138
14.3 Fuel Economy Studies	138	
14.3.1	Conclusions from HEV Testing	138
14.3.2	Conclusions from Fleet Testing	139
14.3.3	Conclusions from the Fleet Study	140
14.4 PEMS from PAMS	141	
References	141	

CHAPTER 15**Reverse Engineering Messages 143****15.1 Reverse Engineering EOBD Mode \$21 or \$22 143****15.2 Reverse Engineering Normal Messages 144****15.3 Software 145****15.4 Example OBD-II, EOBD, and Normal Data 146**

15.4.1 Example OBD-II Data 146

15.4.2 Example EOBD Data using Mode \$22 148

15.4.3 Example Normal Data 149

CHAPTER 16**Data Storage and Transfer 153****16.1 File Size 153**

16.1.1 Estimating File Size 154

16.1.2 File Format and Compression 154

16.2 Data Transfer Options and Data Rates 155

16.2.1 WiFi 155

16.2.2 Cellular 156

16.2.3 Bluetooth 156

16.2.4 USB 156

16.3 Real-Time vs. Logged Data 157

16.3.1 Real-Time Data 157

16.3.2 Logging 157

16.3.3 Acquisition, Storage, Display, and Analysis Trade-Offs 158

Acronyms and Abbreviations 159**About the Authors 161****Index 163**