

Bosch Professional  
Automotive Information



**BOSCH**  
Invented for life



Robert Bosch GmbH *Ed.*

# Bosch Automotive Electrics and Automotive Electronics

Systems and Components,  
Networking and Hybrid Drive

*5th Edition*



**Springer** Vieweg



---

Robert Bosch GmbH (Ed.)

# Bosch Automotive Electrics and Automotive Electronics

Systems and Components,  
Networking and Hybrid Drive

5th Edition

*Editor:*

Robert Bosch GmbH  
Automotive Aftermarket (AA/COM3)  
Robert Bosch GmbH  
Plochingen, Germany

*Published by:*

© Robert Bosch GmbH, 2007  
Postfach 11 29  
D-73201 Plochingen  
Automotive Aftermarket Division, Business Unit Diagnostics Marketing – Test Equipment  
(AA-DG/MKT)  
3rd Edition updated and extended, pub. 1999  
4th Edition, completely revised and extended, January 2004  
5th Edition, completely revised and extended, July 2007  
Straight reprint of the 5th edition, published by John Wiley & Sons. Inc. and Bentley Publishers until 2007.

ISBN 978-3-658-01783-5

ISBN 978-3-658-01784-2 (eBook)

DOI 10.1007/978-3-658-01784-2

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Library of Congress Control Number: 2013938481

Springer Vieweg

© Springer Fachmedien Wiesbaden 1999, 2004, 2007, 2013, 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer Vieweg is a brand of Springer DE.

Springer DE is part of Springer Science+Business Media.

[www.springer-vieweg.de](http://www.springer-vieweg.de)

In recent decades, the development of the motor vehicle has been marked by the introduction of electronics. At first, electronic systems were used to control the engine (electronic fuel-injection systems), then electronic components entered the domain of driving safety (e.g. antilock brake system, ABS). More recently, completely new fields of application have emerged in the areas of driving assistance, infotainment and communication as a result of continuous advancements in semiconductor technology. Consequently, the proportion of electrics and electronics in the motor vehicle has continuously increased.

A typical feature of many of these new systems is that they no longer perform their function as stand-alone systems but operate in interaction with other systems. If the flow of information between these systems is to be maintained, the electronic control units must be networked with each other. Various bus systems have been developed for this purpose. Networking in the motor vehicle is a topic that receives comprehensive coverage in this book.

Powerful electronic systems not only require information about operating states, but also data from the vehicle's surroundings. Sensors therefore play an important role in the area of automotive electronics. The number of sensors used in the motor vehicle will continue to rise.

The complexity of the vehicle system is set to increase still further in the near future. To guarantee operational reliability in view of this complexity, new methods of electronics development are called for. The objective is to create a standardized architecture for the electrical system/electronics that also offers short development times in addition to high reliability for the electronic systems.

Besides the innovations in the areas of comfort/convenience, safety and infotainment, there is a topic that stands out in view of high fuel prices and demands for cutting CO<sub>2</sub> emissions: fuel consumption. In the hybrid drive, there is great potential for lowering fuel consumption and reducing exhaust-gas emissions. The combination of internal-combustion engine and electric motor enables the use of smaller engines that can be operated in a more economically efficient range. Further consumption-cutting measures are start/stop operation and the recuperation of brake energy (recuperative braking). This book addresses the fundamental hybrid concepts.

The traditional subject areas of automotive electrical systems are the vehicle electrical system, including starter battery, alternator and starter. These topics have been revised for the new edition. New to this edition is the subject of electrical energy management (EEM), which coordinates the interaction of the alternator, battery and electrical consumers during vehicle operation and controls the entire electrical energy balance.

The new edition of the “Automotive Electric/Automotive Electronics” technical manual equips the reader with a powerful tool of reference for information about the level of today's technology in the field of vehicle electrical systems and electronics. Many topics are addressed in detail, while others – particularly the electronic systems – are only presented in overview form. These topics receive in-depth coverage in other books in our series.



<b>10 Electrical and electronic systems in the vehicle</b>	<b>168 Electronic components in the vehicle</b>
10 Overview	168 Basic principles of semiconductor technology
13 Motronic-engine management system	172 Passive components
24 Electronic diesel control (EDC)	176 Semiconductor components
32 Lighting technology	186 Manufacture of semiconductor components and circuits
46 Electronic stability program (ESP)	
54 Adaptive cruise control (ACC)	<b>196 Control units</b>
62 Occupant-protection systems	196 Operating conditions
	196 Design
<b>70 Basic principles of networking</b>	196 Data processing
70 Network topology	200 Digital modules in the control unit
74 Network organization	204 Control unit software
76 OSI reference model	
78 Control mechanisms	
	<b>208 Automotive sensors</b>
<b>82 Automotive networking</b>	208 Basics and overview
82 Cross-system functions	211 Automotive applications
83 Requirements for bus systems	214 Details of the sensor market
85 Classification of bus systems	215 Features of vehicle sensors
85 Applications in the vehicle	216 Sensor classification
87 Coupling of networks	218 Error types and tolerance requirements
87 Examples of networked vehicles	219 Reliability
	222 Main requirements, trends
<b>92 Bus systems</b>	229 Overview of the physical effects for sensors
92 CAN bus	231 Overview and selection of sensor technologies
106 LIN bus	
112 MOST bus	<b>232 Sensor measuring principles</b>
122 Bluetooth	232 Position sensors
132 FlexRay	259 Speed and rpm sensors
144 Diagnosis interfaces	271 Acceleration sensors
	276 Pressure sensors
<b>152 Architecture of electronic systems</b>	279 Force and torque sensors
152 Overview	288 Flowmeters
155 Vehicle system architecture	294 Gas sensors and concentration sensors
	298 Temperature sensors
<b>162 Mechatronics</b>	308 Imaging sensors (video)
162 Mechatronic systems and components	
164 Development methods	
166 Outlook	

**310 Sensor types**

- 310 Engine-speed sensors
- 312 Hall phase sensors
- 313 Speed sensors for transmission control
- 316 Wheel-speed sensors
- 320 Micromechanical yaw-rate sensors
- 323 Piezoelectric “tuning-fork” yaw-rate sensor
- 324 Micromechanical pressure sensors
- 326 High-pressure sensors
- 327 Temperature sensors
- 328 Accelerator-pedal sensors
- 330 Steering-angle sensors
- 332 Position sensors for transmission control
- 335 Axle sensors
- 336 Hot-film air-mass meters
- 339 Piezoelectric knock sensors
- 340 SMM acceleration sensors
- 342 Micromechanical bulk silicon acceleration sensors
- 343 Piezoelectric acceleration sensors
- 344 iBolt™ force sensor
- 346 Torque sensor
- 347 Rain/light sensor
- 348 Two-step Lambda oxygen sensors
- 352 LSU4 planar wide-band lambda oxygen sensor

**354 Actuators**

- 354 Electromechanical actuators
- 359 Fluid-mechanical actuators
- 360 Electrical machines

**366 Hybrid drives**

- 366 Drive concepts
- 370 Operating strategies for electric hybrid vehicles
- 376 Recuperative brake system
- 380 Electrical energy accumulators

**384 Vehicle electrical systems**

- 384 Electrical energy supply in the passenger car
- 388 Electrical energy management
- 390 Two-battery vehicle electrical system
- 391 Vehicle electrical systems for commercial vehicles
- 394 Wiring harnesses
- 396 Plug-in connections

**400 Starter batteries**

- 400 Function and requirements
- 402 Design
- 407 Operating principle
- 411 Battery designs
- 418 Battery characteristics
- 422 Type designations
- 423 Practical and laboratory battery testing
- 427 Battery maintenance

**434 Alternators**

- 434 Electrical power generation in the vehicle
- 435 Operating principle of the alternator
- 443 Voltage regulation
- 448 Overvoltage protection
- 451 Characteristic curves
- 453 Power losses
- 453 Alternator circuits
- 455 Alternator designs

**462 Starting systems**

- 462 Overview
- 462 Starter
- 472 Other types of starter motor
- 476 Starting systems
- 481 Design
- 484 Overview of the types of starters

**486 Electromagnetic compatibility (EMC) and interference suppression**

- 486 EMC ranges
- 487 EMC between different systems in the vehicle
- 494 EMC between the vehicle and its surroundings
- 498 Guarantee of immunity and interference suppression

**500 Symbols and circuit diagrams**

- 500 Circuit symbols
- 508 Circuit diagrams
- 519 Designations for electrical devices
- 521 Terminal designations

**524 Index of technical terms**

- Technical terms
- Abbreviations

**Background Information**

- 52 ABS versions
- 53 History of radar
- 69 Micromechanics
- 81 Comparison of bus systems
- 175 Miniaturization
- 199 Performance of electronic control units
- 297 Piezoelectric effect
- 383 Greenhouse effect
- 399 History of the alternator
- 426 History of the battery

#### **Electrical and electronic systems in the vehicle**

Dipl.-Ing. Bernhard Mencher;  
Dipl.-Ing. (BA) Ferdinand Reiter;  
Dipl.-Ing. Andreas Glaser;  
Dipl.-Ing. Walter Gollin;  
Dipl.-Ing. (FH) Klaus Lerchenmüller;  
Dipl.-Ing. Felix Landhäußer;  
Dipl.-Ing. Doris Boebel,  
Automotive Lighting Reutlingen GmbH;  
Dr.-Ing. Michael Hamm,  
Automotive Lighting Reutlingen GmbH;  
Dipl.-Ing. Tilman Spingler,  
Automotive Lighting Reutlingen GmbH;  
Dr.-Ing. Frank Niewels;  
Dipl.-Ing. Thomas Ehret;  
Dr.-Ing. Gero Nenninger;  
Prof. Dr.-Ing. Peter Knoll;  
Dr. rer. nat. Alfred Kuttenberger.

#### **Networking**

Dipl.-Inform. Jörn Stuphorn,  
Universität Bielefeld;  
Dr. Rainer Constapel,  
DaimlerChrysler AG Sindelfingen;  
Dipl.-Ing. (FH) Stefan Powolny;  
Dipl.-Ing. Peter Häußermann,  
DaimlerChrysler AG, Sindelfingen;  
Dr. rer. nat. Alexander Leonhardi,  
DaimlerChrysler AG, Sindelfingen;  
Dipl.-Inform. Heiko Holtkamp,  
Universität Bielefeld;  
Dipl.-Ing. (FH) Norbert Löchel.

#### **Architecture of electronic systems**

Dr. phil. nat. Dieter Kraft;  
Dipl.-Ing. Stefan Mischo.

#### **Mechatronics**

Dipl.-Ing. Hans-Martin Heinkel;  
Dr.-Ing. Klaus-Georg Bürger.

#### **Electronic components**

Dr. rer. nat. Ulrich Schaefer.

#### **Control units**

Dipl.-Ing. Martin Kaiser;  
Dr. rer. nat. Ulrich Schaefer;  
Dipl.-Ing. (FH) Gerhard Haaf.

#### **Sensors**

Dr.-Ing. Erich Zabler;  
Dr. rer. nat. Stefan Finkbeiner;  
Dr. rer. nat. Wolfgang Welsch;  
Dr. rer. nat. Hartmut Kittel;  
Dr. rer. nat. Christian Bauer;  
Dipl.-Ing. Günter Noetzel;  
Dr.-Ing. Harald Emmerich;  
Dipl.-Ing. (FH) Gerald Hopf;  
Dr.-Ing. Uwe Konzelmann;  
Dr. rer. nat. Thomas Wahl;  
Dr.-Ing. Reinhard Neul;  
Dr.-Ing. Wolfgang-Michael Müller;  
Dr.-Ing. Claus Bischoff;  
Dr. Christian Pfahler;  
Dipl.-Ing. Peter Weiberle;  
Dipl.-Ing. (FH) Ulrich Papert;  
Dipl.-Ing. Christian Gerhardt;  
Dipl.-Ing. Klaus Miekley;  
Dipl.-Ing. Roger Frehöff;  
Dipl.-Ing. Martin Mast;  
Dipl.-Ing. (FH) Bernhard Bauer;  
Dr. Michael Harder;  
Dr.-Ing. Klaus Kasten;  
Dipl.-Ing. Peter Brenner,  
ZF Lenksysteme GmbH, Schwäbisch Gmünd;  
Dipl.-Ing. Frank Wolf;  
Dr.-Ing. Johann Riegel.



**Actuators**

Dr.-Ing. Rudolf Heinz;  
Dr.-Ing. Robert Schenk.

**Hybrid drives**

Dipl.-Ing. Michael Bildstein;  
Dipl.-Ing. Boyke Richter;  
Dr. rer. nat Richard Aumayer;  
Dr.-Ing. Karsten Mann;  
Dipl.-Ing. Tim Fronzek,  
Toyota Deutschland GmbH;  
Dipl.-Ing. Hans-Peter Wandt,  
Toyota Deutschland GmbH.

**Vehicle electrical systems**

Dipl.-Ing. Clemens Schmucker;  
Dipl.-Ing. (FH) Hartmut Wanner;  
Dipl.-Ing. (FH) Wolfgang Kircher;  
Dipl.-Ing. (FH) Werner Hofmeister;  
Dipl.-Ing. Andreas Simmel.

**Starter batteries**

Dipl.-Ing. Ingo Koch,  
VB Autobatterie GmbH & Co. KGaA, Hannover;  
Dipl.-Ing. Peter Etzold;  
Dipl.-Kaufm. techn. Torben Fingerle.

**Alternators**

Dipl.-Ing Reinhard Meyer.

**Starting systems**

Dipl.-Ing. Roman Pirsch;  
Dipl.-Ing. Hartmut Wanner.

**Electromagnetic compatibility**

Dr.-Ing. Wolfgang Pfaff

and the editorial team in cooperation with the  
responsible technical departments at Bosch.

Unless otherwise specified, the above are  
all employees of Robert Bosch GmbH.

# Electrical and electronic systems in the vehicle

The amount of electronics in the vehicle has risen dramatically in recent years and is set to increase yet further in the future. Technical developments in semiconductor technology support ever more complex functions with the increasing integration density. The functionality of electronic systems in motor vehicles has now surpassed even the capabilities of the Apollo 11 space module that orbited the Moon in 1969.

## Overview

### Development of electronic systems

Not least in contributing to the success of the vehicle has been the continuous string of innovations which have found their way into vehicles. Even as far back as the 1970s, the aim was to make use of new technologies to help in the development of safe, clean and economical cars. The pursuit of economic efficiency and cleanliness was closely linked to other customer benefits

such as driving pleasure. This was characterized by the European diesel boom, upon which Bosch had such a considerable influence. At the same time, the development of the gasoline engine with gasoline direct injection, which would reduce fuel consumption by comparison with intake-manifold injection, experienced further advancements.

An improvement in driving safety was achieved with electronic brake-control systems. In 1978, the antilock brake system (ABS) was introduced and underwent continual development to such an extent that it is now fitted as standard on every vehicle in Europe. It was along this same line of development that the electronic stability program (ESP), in which ABS is integrated, would debut in 1995.

The latest developments also take comfort into account. These include the hill hold control (HHC) function, for example, which makes it easier to pull away on uphill gradients. This function is integrated in ESP.



