Modern Automotive Technology
Fundamentals, service, diagnostics

2nd English edition

The German edition was written by technical instructors, engineers and technicians

Editorial office (German edition): R. Gscheidle, Studiendirektor, Winnenden – Stuttgart

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All information given in this book corresponds to the state of the art. All testing, measuring and repair work on a specific vehicle must be carried out in accordance with the manufacturer’s specifications. The work described is performed at the user’s own risk. Warranty claims against the authors or the publisher are excluded.

2nd edition 2014
Impression 5 4
All impressions of the same edition can be used in parallel, as they do not differ from each other except with regard to the correction of printing errors.

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Foreword

“Modern Automotive Technology” is a standard work covering the subject of automotive technology. This second English edition is based on the 30th German edition titled “Fachkunde Kraftfahrzeugtechnik”. It has for many years proven to be a highly popular textbook used for training and further education. It provides apprentices, trainees, teachers and all those interested in this subject with the theoretical knowledge necessary to gain a firm grasp of the practical and technical skills involved. Fundamental, technical connections between individual systems are presented in a clear and comprehensible way.

The book is intended to be used as a reference work by employees in the automotive industry and in motor vehicle service outlets, by teachers, apprentices, trainees and automotive technology students to help them look up information and supplement their technical knowledge. The work is intended to be used by all those interested in automotive technology as a means of extending their technical knowledge through private study.

The 22 chapters are logically arranged by subject and cover the changes that have occurred in the field of automotive technology. The book is particularly suitable for practical training in all matters pertaining to motor vehicles.

This work covers the latest developments in automotive technology, including service and maintenance of vehicle systems, management, communication, supercharging technology, common-rail systems, dual clutch gearboxes, electronic transmission control, electronic brake systems, compressed-air monitoring systems, adaptive cornering lights, new headlamp systems, high-frequency technology, electrical circuit diagrams, multifunction regulators, new data bus systems (LIN, MOST, FlexRay), alternative drive concepts, electric drive systems, differential locks, axle alignment checks, driving dynamics, steering systems, electromagnetic compatibility and comfort and convenience systems such as adaptive cruise control, parking assistance and navigation. A large chapter is devoted to the subject of electrical engineering. Here, the detailed coverage of the fundamentals of electrical engineering forms the basis for all the crucial issues and topics pertaining to automotive electrics, up to and including data transmission in motor vehicles. A separate chapter is devoted to the increasing importance in engineering of comfort and convenience technology.

Reference is made to German and European standards in the chapters on environmental protection and occupational safety, emissions-control engineering, braking technology and motorcycle engineering. However, compliance with the standards applicable in the respective individual countries is required.

The work features numerous coloured pictures, drawings and system diagrams as well as particularly clearly and comprehensibly laid-out tables. These will help the reader to digest and comprehend the complex subject matter.

This edition includes a CD of all the illustrations found in the book.

The work has been written and compiled – in close co-operation with the automotive trade and industry – by a team of educationally experienced vocational school teachers, engineers and master tradesmen. The authors and the publishers will be grateful for any suggestions and constructive comments.

We would like to thank all the companies and organisations who have kindly contributed pictures and technical documents.

The Authors of the Automotive Technology Team

Spring 2014
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAS</td>
<td>Adaptive air suspension</td>
</tr>
<tr>
<td>A/C</td>
<td>Air conditioning</td>
</tr>
<tr>
<td>A/F</td>
<td>Air/fuel (mixture)</td>
</tr>
<tr>
<td>ABA</td>
<td>Active brake assist</td>
</tr>
<tr>
<td>ABC</td>
<td>Active body control</td>
</tr>
<tr>
<td>ABS</td>
<td>Antilock braking system</td>
</tr>
<tr>
<td>ABV</td>
<td>Automatic braking-force distribution (German: Automatische Bremskraftverteilung)</td>
</tr>
<tr>
<td>AC</td>
<td>Alternating current</td>
</tr>
<tr>
<td>ACC</td>
<td>Adaptive cruise control, automatic cruise control</td>
</tr>
<tr>
<td>ACEA</td>
<td>Association des Constructeurs Européens d'Automobiles</td>
</tr>
<tr>
<td>ACS</td>
<td>Automatic clutch system</td>
</tr>
<tr>
<td>AD</td>
<td>Analogue-digital (converter)</td>
</tr>
<tr>
<td>ADC</td>
<td>Analog digital converter</td>
</tr>
<tr>
<td>ADSL</td>
<td>Asymmetrical digital subscriber line</td>
</tr>
<tr>
<td>AFS</td>
<td>Airflow sensor</td>
</tr>
<tr>
<td>AFRP</td>
<td>Aramid fibre reinforced plastic</td>
</tr>
<tr>
<td>AGM</td>
<td>Absorbed glass mat battery</td>
</tr>
<tr>
<td>AHL</td>
<td>Automatic headlight leveling</td>
</tr>
<tr>
<td>ALDBFR</td>
<td>Automatic load-dependent brake force regulator</td>
</tr>
<tr>
<td>ALSD</td>
<td>Automatic limited-slip differential</td>
</tr>
<tr>
<td>AM</td>
<td>Amplitude modulation</td>
</tr>
<tr>
<td>API</td>
<td>American Petroleum Institute</td>
</tr>
<tr>
<td>APB</td>
<td>Automatic parking brake</td>
</tr>
<tr>
<td>ARS</td>
<td>Angle of rotation sensor</td>
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<tr>
<td>ASC</td>
<td>Anti-stability control, acceleration skid control</td>
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<tr>
<td>ASHEV</td>
<td>Axle split hybrid electric vehicle</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>ATC</td>
<td>Adaptive transmission control</td>
</tr>
<tr>
<td>ATF</td>
<td>Automatic transmission fluid</td>
</tr>
<tr>
<td>AWD</td>
<td>All-wheel drive</td>
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<td>AYC</td>
<td>Active yaw control</td>
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<td>BAS</td>
<td>Brake assist system</td>
</tr>
<tr>
<td>BDC</td>
<td>Bottom dead centre</td>
</tr>
<tr>
<td>BDW</td>
<td>Brake disc wiping</td>
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<tr>
<td>BEV</td>
<td>Battery powered electric vehicle</td>
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<td>CA</td>
<td>Crankshaft angle</td>
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<td>CS</td>
<td>Camshaft</td>
</tr>
<tr>
<td>CAN</td>
<td>Controller area network</td>
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<td>CAT</td>
<td>Catalytic converter, catalyst</td>
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<td>CB</td>
<td>Centre bore, Common ball</td>
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<td>CBS</td>
<td>Combined brake system</td>
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<tr>
<td>CC</td>
<td>Cruise control</td>
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<td>CDI</td>
<td>Capacitive discharge ignition</td>
</tr>
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<td>CFPP</td>
<td>Cold filter plugging point</td>
</tr>
<tr>
<td>CFFR</td>
<td>Carbon fibre reinforced plastic</td>
</tr>
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<td>CH</td>
<td>Combination hump</td>
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<tr>
<td>CIH</td>
<td>Camshaft in head</td>
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<td>CIP</td>
<td>Continuous improvement process</td>
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<tr>
<td>CN</td>
<td>Cetane number</td>
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<td>CNG</td>
<td>Compressed natural gas</td>
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<tr>
<td>COPD</td>
<td>Child Seat Presence and Orientation Detection</td>
</tr>
<tr>
<td>CPU</td>
<td>Central processing unit</td>
</tr>
<tr>
<td>CR</td>
<td>Common rail</td>
</tr>
<tr>
<td>CRDI</td>
<td>Common rail direct injection</td>
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<td>CB</td>
<td>Centre bore</td>
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<td>CS</td>
<td>Crankshaft</td>
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<td>CV</td>
<td>Commercial vehicle</td>
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<td>Check valve</td>
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<td>CVf</td>
<td>Check valve left</td>
</tr>
<tr>
<td>CVrt</td>
<td>Check valve right</td>
</tr>
<tr>
<td>CVT</td>
<td>Continuously variable transmission</td>
</tr>
<tr>
<td>DA</td>
<td>Drive axle</td>
</tr>
<tr>
<td>DC</td>
<td>Direct current</td>
</tr>
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<td>DCT</td>
<td>Dual clutch transmission</td>
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<td>DI</td>
<td>Direct injection</td>
</tr>
<tr>
<td>DIN</td>
<td>Deutsches Institut für Normung</td>
</tr>
<tr>
<td>DIP</td>
<td>Distributor injection pump</td>
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<tr>
<td>DME</td>
<td>Digital motor electronics</td>
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<tr>
<td>DOHC</td>
<td>Double overhead camshaft</td>
</tr>
<tr>
<td>DOT</td>
<td>Department of Transportation</td>
</tr>
<tr>
<td>DPNR</td>
<td>Diesel particulate NOx reduction system</td>
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<tr>
<td>DSC</td>
<td>Dynamic stability control</td>
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<tr>
<td>DSG</td>
<td>Direct-shift gearbox</td>
</tr>
<tr>
<td>DSP</td>
<td>Dynamic shift program selection</td>
</tr>
<tr>
<td>DVD</td>
<td>Digital versatile disc</td>
</tr>
<tr>
<td>EBA</td>
<td>Electronic brake assist, emergency brake system</td>
</tr>
<tr>
<td>EBS</td>
<td>Electronic braking system</td>
</tr>
<tr>
<td>Ec</td>
<td>Exhaust valve closes</td>
</tr>
<tr>
<td>ECE</td>
<td>Economic Commission for Europe</td>
</tr>
<tr>
<td>ECM</td>
<td>Electronic clutch management</td>
</tr>
<tr>
<td>ECS</td>
<td>Electronic clutch system</td>
</tr>
<tr>
<td>ECU</td>
<td>Electronic control unit, engine control unit</td>
</tr>
<tr>
<td>EDC</td>
<td>Electronic diesel control, electronic damper control</td>
</tr>
<tr>
<td>EDP</td>
<td>Electronic data processing</td>
</tr>
<tr>
<td>EDTC</td>
<td>Engine drag torque control</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electrically erasable programmable read-only memory</td>
</tr>
<tr>
<td>EGR</td>
<td>Exhaust gas recirculation</td>
</tr>
<tr>
<td>EGS</td>
<td>Electronic gearbox control unit (German: Elektronisches Getriebesteuergerät)</td>
</tr>
<tr>
<td>EH</td>
<td>Extended hump</td>
</tr>
<tr>
<td>EHB</td>
<td>Electro-hydraulic braking system</td>
</tr>
<tr>
<td>EI</td>
<td>Emissions inspection, electronic ignition</td>
</tr>
<tr>
<td>ELSD</td>
<td>Electronic limited-slip differential</td>
</tr>
<tr>
<td>EMC</td>
<td>Electromagnetic compatibility</td>
</tr>
<tr>
<td>EMS</td>
<td>Electronic service information</td>
</tr>
<tr>
<td>ESP</td>
<td>Electronic stability program</td>
</tr>
<tr>
<td>ETC</td>
<td>Electronic throttle control</td>
</tr>
<tr>
<td>ETN</td>
<td>European type number</td>
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<tr>
<td>EV</td>
<td>Exhaust valve</td>
</tr>
<tr>
<td>FA</td>
<td>Front axle</td>
</tr>
<tr>
<td>FB</td>
<td>Function button</td>
</tr>
<tr>
<td>FC</td>
<td>Fuel cell</td>
</tr>
<tr>
<td>FF</td>
<td>Free-form (reflector)</td>
</tr>
<tr>
<td>FH</td>
<td>Flat hump</td>
</tr>
<tr>
<td>FL</td>
<td>Front left</td>
</tr>
<tr>
<td>FOC</td>
<td>Fibre optic cable</td>
</tr>
<tr>
<td>FOT</td>
<td>Fibre optic transceiver</td>
</tr>
<tr>
<td>FR</td>
<td>Front right</td>
</tr>
<tr>
<td>GD/GND</td>
<td>Ground</td>
</tr>
<tr>
<td>GDI</td>
<td>Gasoline direct injection</td>
</tr>
<tr>
<td>GFRP</td>
<td>Glass fibre reinforced</td>
</tr>
<tr>
<td>GI</td>
<td>General inspection</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
</tr>
<tr>
<td>HDC</td>
<td>Hill descent control</td>
</tr>
<tr>
<td>HEV</td>
<td>Hybrid electric vehicle</td>
</tr>
<tr>
<td>HF</td>
<td>High frequency</td>
</tr>
<tr>
<td>HGV</td>
<td>Heavy goods vehicle</td>
</tr>
<tr>
<td>HHC</td>
<td>Hill hold control</td>
</tr>
<tr>
<td>HNS</td>
<td>Homogeneous numerically calculated surface</td>
</tr>
<tr>
<td>HS</td>
<td>High-solid (paints)</td>
</tr>
<tr>
<td>HTHS</td>
<td>High temperature, high shear</td>
</tr>
<tr>
<td>HUD</td>
<td>Head up display</td>
</tr>
</tbody>
</table>
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tr>
<td>HV</td>
<td>Hybrid vehicle, high voltage</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated circuit</td>
</tr>
<tr>
<td>Ic</td>
<td>Inlet valve closes</td>
</tr>
<tr>
<td>IC</td>
<td>Individual control</td>
</tr>
<tr>
<td>IHPF</td>
<td>Internal high-pressure forming</td>
</tr>
<tr>
<td>Io</td>
<td>Inlet valve opens</td>
</tr>
<tr>
<td>IP</td>
<td>Input passage</td>
</tr>
<tr>
<td>IPO</td>
<td>Input/Processing/Output (principle)</td>
</tr>
<tr>
<td>IS</td>
<td>Input shaft</td>
</tr>
<tr>
<td>ISA</td>
<td>Integrated starter alternator</td>
</tr>
<tr>
<td>ISAD</td>
<td>Integrated starter alternator damper</td>
</tr>
<tr>
<td>ISC</td>
<td>Idle speed control</td>
</tr>
<tr>
<td>ISG</td>
<td>Integrated starter generator</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>IV</td>
<td>Inlet valve</td>
</tr>
<tr>
<td>IVlft</td>
<td>Inlet valve left</td>
</tr>
<tr>
<td>IVrt</td>
<td>Inlet valve right</td>
</tr>
<tr>
<td>LA</td>
<td>Lifting axle</td>
</tr>
<tr>
<td>LAN</td>
<td>Local area network</td>
</tr>
<tr>
<td>LDC</td>
<td>Liquid crystal display</td>
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<tr>
<td>LDR</td>
<td>Light-dependent resistor</td>
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<td>LED</td>
<td>Light-emitting diode</td>
</tr>
<tr>
<td>LEV</td>
<td>Low-emission vehicle</td>
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<tr>
<td>LF</td>
<td>Low frequency</td>
</tr>
<tr>
<td>Li</td>
<td>Load index</td>
</tr>
<tr>
<td>LIN</td>
<td>Local interconnect network</td>
</tr>
<tr>
<td>Li-ion</td>
<td>Lithium ion</td>
</tr>
<tr>
<td>LNG</td>
<td>Liquefied natural gas</td>
</tr>
<tr>
<td>LS</td>
<td>Limited slip</td>
</tr>
<tr>
<td>LSG</td>
<td>Laminated safety glass</td>
</tr>
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<td>LU</td>
<td>Logical unit</td>
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<td>LV</td>
<td>Low voltage</td>
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<tr>
<td>LW</td>
<td>Long wave</td>
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<td>MAF</td>
<td>Mass air flow</td>
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<td>MAG</td>
<td>Metal active-gas (welding)</td>
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<tr>
<td>MC</td>
<td>Microcomputer</td>
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<tr>
<td>MC</td>
<td>Main cylinder</td>
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<tr>
<td>ME</td>
<td>Motor electronics</td>
</tr>
<tr>
<td>MED</td>
<td>Motor electronics direct injection</td>
</tr>
<tr>
<td>MG</td>
<td>Motor generator</td>
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<td>MIG</td>
<td>Metal inert-gas (welding)</td>
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<td>MIL</td>
<td>Malfunction indicator lamp</td>
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<td>MODIC</td>
<td>Mobile diagnostic computer</td>
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<tr>
<td>MON</td>
<td>Motor octane number</td>
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<td>MOST</td>
<td>Media oriented systems</td>
</tr>
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<td>MPI</td>
<td>Multipoint injection</td>
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<td>MS</td>
<td>Medium-solid (paints)</td>
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<td>MW</td>
<td>Medium wave</td>
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<td>NEDC</td>
<td>New European driving cycle</td>
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<td>NF</td>
<td>Non-ferrous</td>
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<td>NIT</td>
<td>Network idle time</td>
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<td>NLGi</td>
<td>National Lubricating Grease Institute</td>
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<tr>
<td>NTC</td>
<td>Negative temperature coefficient</td>
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<td>OBD</td>
<td>On-board diagnostics</td>
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<td>OD</td>
<td>Outside diameter</td>
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<td>OHC</td>
<td>Overhead camshaft</td>
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<td>OHV</td>
<td>Overhead valves</td>
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<td>ON</td>
<td>Octane number</td>
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<td>OV</td>
<td>Outlet valve</td>
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<td>OVlft</td>
<td>Outlet valve left</td>
</tr>
<tr>
<td>OVrt</td>
<td>Outlet valve right</td>
</tr>
<tr>
<td>PBC</td>
<td>Parking brake circuit</td>
</tr>
<tr>
<td>PC</td>
<td>Polycarbonate, personal computer</td>
</tr>
<tr>
<td>PCD</td>
<td>Pitch circle diameter</td>
</tr>
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<td>PEM</td>
<td>Proton exchange membrane</td>
</tr>
<tr>
<td>PES</td>
<td>Poly ellipsoid system (reflector)</td>
</tr>
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<td>PHEV</td>
<td>Plug-in hybrid electric vehicle</td>
</tr>
<tr>
<td>PIN</td>
<td>Personal identification number</td>
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<tr>
<td>PM</td>
<td>Particulate matter</td>
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<tr>
<td>POF</td>
<td>Plastic optical fibre</td>
</tr>
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<td>POT</td>
<td>Plastic optical transceiver</td>
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<td>PS</td>
<td>Pressure sensor</td>
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<td>PTC</td>
<td>Positive temperature coefficient</td>
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<td>PWM</td>
<td>Pulse width modulation</td>
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<td>QA</td>
<td>Quality assurance</td>
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<td>QM</td>
<td>Quality management</td>
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<td>RA</td>
<td>Rear axle</td>
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<tr>
<td>RAM</td>
<td>Random access memory</td>
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<td>RDS</td>
<td>Radio data system</td>
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<td>RL</td>
<td>Rear left</td>
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<td>RLFS</td>
<td>Return-less fuel system</td>
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<td>RON</td>
<td>Research octane number</td>
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<td>ROM</td>
<td>Read-only memory</td>
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<td>ROP</td>
<td>Rollover protection</td>
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<td>ROV</td>
<td>Rotating high voltage distribution (German: Rotierende Hochspannungs-Verteilung)</td>
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<td>RR</td>
<td>Rear right</td>
</tr>
<tr>
<td>RRC</td>
<td>Radio remote control</td>
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<tr>
<td>RUV</td>
<td>Static high voltage distribution (German: Ruhende Hochspannungs-Verteilung)</td>
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<td>SAC</td>
<td>Self-adjusting clutch</td>
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<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<td>SAM</td>
<td>Signal acquisition and actuation module</td>
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<td>SBC</td>
<td>Sensotronic brake control</td>
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<tr>
<td>SC</td>
<td>Signal conditioning</td>
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<td>SCR</td>
<td>Selective catalytic reduction</td>
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<td>SCV</td>
<td>Solenoid control valve</td>
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<tr>
<td>SDC</td>
<td>Semi-drop centre</td>
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<td>Strain gauge</td>
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<td>Safety inspection</td>
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<td>SL</td>
<td>Special ledge</td>
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<td>SLC</td>
<td>Select-low control</td>
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<td>SoC</td>
<td>State of charge</td>
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<td>SPI</td>
<td>Single-point injection</td>
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<td>SRR</td>
<td>Short range radar</td>
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<td>SRS</td>
<td>Safety restraint systems, supplemental restraint system</td>
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<tr>
<td>SSRt</td>
<td>Speed sensor right</td>
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<tr>
<td>SSIf</td>
<td>Speed sensor left</td>
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<td>SRT</td>
<td>Shielded twisted pair</td>
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<tr>
<td>STP</td>
<td>Shielded twisted pair</td>
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<td>STVZO</td>
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<td>SUV</td>
<td>Sport Utility Vehicle</td>
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<td>SV</td>
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<td>SW</td>
<td>Side valve</td>
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<td>TMC</td>
<td>Traffic message channel</td>
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<td>TP</td>
<td>Transfer passage</td>
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<td>Tyre pressure check, tyre pressure control</td>
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<td>Temperaturabsetzung</td>
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<td>TUV</td>
<td>German technical inspection association</td>
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<td>TWI</td>
<td>Tread wear indicator</td>
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<td>UIS</td>
<td>Unit injector system</td>
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<td>UPS</td>
<td>Unit pump system</td>
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<tr>
<td>VDC</td>
<td>Vehicle dynamics controller</td>
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<td>VDR</td>
<td>Voltage-dependent resistor</td>
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<td>VF</td>
<td>Variable focus (reflector)</td>
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<td>VHF</td>
<td>Very high frequency</td>
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<td>VI</td>
<td>Viscosity index</td>
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<td>VT</td>
<td>Viscosity temperature</td>
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<tr>
<td>VTEC</td>
<td>Variable valve timing and lift electronic control</td>
</tr>
<tr>
<td>VTG</td>
<td>Variable turbine geometry</td>
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1 Motor vehicle

1.1 Evolution of the motor vehicle

1860 The Frenchman Lenoir constructs the first internal-combustion engine; this powerplant relies on city gas as its fuel source. Thermal efficiency is in the 3% range.

1867 Otto and Langen display an improved internal-combustion engine at the Paris International Exhibition. Its thermal efficiency is approximately 9%.

1876 Otto builds the first gas-powered engine to utilise the four-stroke compression cycle. At virtually the same time Clerk constructs the first gas-powered two-stroke engine in England.

1883 Daimler and Maybach develop the first high-speed four-cycle petrol engine using a hot-tube ignition system.

1885 The first automobile from Benz (patented in 1886). First self-propelled motorcycle from Daimler (Fig. 1).

1886 First four-wheeled motor carriage with petrol engine from Daimler (Fig. 2).

1887 Bosch invents the magneto ignition.

1889 Dunlop in England produces the first pneumatic tyres.

1893 Maybach invents the spray-nozzle carburettor. Diesel patents his design for a heavy oil-burning powerplant employing the self-ignition concept.

1897 MAN presents the first workable diesel engine.

1897 First Electromobile from Lohner-Porsche (Fig. 2).

1913 Ford introduces the production line to automotive manufacturing. Production of the Tin Lizzy (Model T, Fig. 3). By 1925, 9,109 were leaving the production line each day.

1916 The Bavarian Motor Works are founded.

1923 First motor lorry powered by a diesel engine produced by Benz-MAN (Fig. 4).

1938 The VW Works are founded in Wolfsburg.

1949 First low-profile tyre and first steel-belted radial tyre produced by Michelin.

1954 NSU-Wankel constructs the rotary engine (Fig. 4).

Fig. 1: Daimler motorcycle and Benz motor carriage

Fig. 2: Daimler motor carriage and the first Electromobile

Fig. 3: Ford Model T and VW Beetle

Fig. 4: Diesel-engined lorry and Passenger car with Wankel rotary engine

1966 Electronic fuel injection (D-Jetronic) for standard production vehicles produced by Bosch.

1970 Seatbelts for driver and front passengers.

1978 Mercedes-Benz installs the first Antilock Braking System (ABS) in vehicles.

1984 Debut of the airbag and seatbelt tensioning system.

1985 Advent of a catalytic converter designed for operation in conjunction with closed-loop mixture control, intended for use with unleaded fuel.

1997 Electronic suspension control systems (ESP). Toyota builds first passenger car with a hybrid drive. Alfa Romeo introduces the common-rail direct injection (CRDI) system for diesel engines.

As of Advanced driver assistance systems, such as parking assistance, distance warning systems, lane change assistance.
### 1.2 Motor vehicle classifications

There are basically two vehicle classes: motor vehicles and trailers. Motor vehicles always possess an integral mechanical propulsion system.

**Dual-track vehicles**
Motor vehicles with more than two wheels can be found in dual-track and multiple-track versions. These include:

- **Passenger cars.** These are primarily intended for use in transporting people, as well as their luggage and other small cargo. They can also be used to pull trailers. The number of seats, including that of the driver, is restricted to nine.

- **Commercial vehicles.** These are designed to transport people and cargo and for pulling trailers. Passenger cars are not classified as commercial vehicles.

**Single-track vehicles**
- **Motorcycles.** These are single-track vehicles with 2 wheels. A sidecar may be attached to the motorcycle, which remains classified as such provided that the unladen weight of the combination does not exceed 400 kg. A motorcycle can also be employed to pull a trailer. Single-track vehicles include:
  - **Motorcycles.** These are equipped with permanent, fixed-location components (fuel tank, engine) located adjacent to the knees as well as footrests.
  - **Motor scooters.** Since the operator’s feet rest on a floor board, there are no fixed components at knee level on these vehicles.
  - **Bicycles with auxiliary motors.** These vehicles share the same salient features as bicycles, e.g. pedals (mopeds, motorised bicycles, etc.).

### 1.3 Design of the motor vehicle

The motor vehicle consists of component assemblies and their individual components.

The layout of the individual assemblies and their relative positions is not governed by invariable standards. Thus, for example, the engine may be designed as an independent assembly, or it may be integrated as a subassembly within a larger powertrain unit.

One of the options described in this book is to divide the vehicle into 5 main assembly groups: engine, drivetrain, chassis, vehicle body and electrical system. The relationships between the assemblies and their constituent components are illustrated in Fig. 2.
1.4 The motor vehicle as technical system

1.4.1 Technical systems

Every machine forms a complete technical system.

Characteristics of technical systems:
- Defined system borders delineate their limits relative to the surrounding environment.
- They possess input and output channels.
- The salient factor defining system operation is the total function, and not the individual function, which is discharged internally, within the system.

The smaller rectangle symbolises the system limit (hypothetical boundary) separating each individual technical system from the other systems and/or the surrounding environment.

The distinctive, defining features of individual systems include:
- Input (input variables or parameters) entering from beyond the system limits
- Processing within the system limits
- Output (output variables or parameters) issued and relayed to destinations lying outside the limits of the system (IPO concept)

1.4.2 Motor vehicle system

The motor vehicle is a complex technical system in which various subsystems operate in harmony to fulfill a defined function.

The function of the passenger car is to transport people, while the function of the motor lorry, or truck, is to carry cargo.

Operational units within the motor vehicle

Systems designed to support operational processes are combined in operational units (Fig. 1). Familiarity with the processes performed in operational units such as the engine, drivetrain, etc. can enhance our
understanding of the complete system represented by the motor vehicle in its implications for maintenance, diagnosis and repair.

The concept is suitable for application with any technical system. Among the operational units that comprise the motor vehicle are the:

- Power unit
- Power-transfer assembly
- Support and load-bearing structure
- Electro-hydraulic systems (open and closed-loop control systems, etc.)
- Electrical and electronic systems (such as safety devices)

Each operational unit acts as a subsystem by assuming a specific function.

**Operational unit:** Power unit – engine

**Subfunction:** Provides energy for propulsion purposes

**Operational unit:** Power-transfer assembly, such as drivetrain

**Subfunction:** Relays mechanical energy from the power unit to the drive wheels

**Operational unit:** Vehicle structure as support structure, exemplified by body

**Subfunction:** Support function, support for all subsystems

**Operational unit:** Electro-hydraulic systems (open and closed-loop control systems, such as ABS, ESP, etc.)

**Subfunction:** Active occupant protection, improvements in dynamic response

**Operational unit:** Electr., electron. systems (safety and security devices, such as airbags, seatbelt tensioners)

**Subfunction:** Passive protection for vehicle occupants
Various subsystems must operate together for the motor vehicle to perform its primary functions (Fig. 1). Reducing the scale of the system’s limits shifts the focus to progressively smaller subsystems, ultimately leading to the level of the individual component.

The motor vehicle as a complete system
Defining the limits of the system to coincide with those of the overall vehicle produces boundaries in which the system’s limits border on environmental entities such as air and the road surface. On the input side, air and fuel are the only factors entering from beyond the system’s limits, while exhaust gas joins kinetic and thermal energy outside this boundary on the output side (Fig. 2, Fig. 3).

1.4.3 Subsystems in the motor vehicle
Each subsystem is subject to the IPO concept (Fig. 3).

Fig. 1: The motor vehicle as composite system

Fig. 2: System: Motor vehicle

Fig. 3: Subsystem: Gearbox

Input. The factors operating on the input side of the gearbox are engine speed, engine torque and engine power.

Processing. The crankshaft’s rotational speed and the transferred torque are converted in the gearbox.

Output. The elements exiting the subsystem on the output side include output-shaft speed, output torque and output power as well as heat.

Efficiency level. The efficiency of the drivetrain is reduced by energy losses sustained within the gearbox.

The "gearbox" subsystem is connected to the drive wheels via other subsystems, such as the propeller shaft, final-drive unit, and half shafts.
1.4.4 Classifications of technical systems and subsystems by processing mode

Technical systems (Fig. 1) are classified according to the type of processing within overall systems:

- **Material-processing systems** such as the fuel-supply system
- **Energy-processing systems** such as the internal-combustion engine
- **Information-processing systems** such as the onboard computer, the steering system, etc.

**Material-processing systems** modify materials in their geometrical configuration (reshape) or transport them from one position to another (reposition).

Transport media and basic machinery are employed to convey substances and materials. Machine tools assume responsibility for shaping materials. To cite an example: in the material-transport process, a pump induces motion in a static fluid (gasoline in the fuel tank) in order to transport it to the fuel-injection system. For this purpose, electrical energy must be supplied to the operational machinery, such as a fuel pump, that is responsible for the process.

Overview of material-processing systems:

**Machines for reshaping** include machine tools such as drills, mills and lathes as well as the equipment found in foundries and stamping plants such as metal presses.

**Machines for repositioning** include all conveyors, transporters and machines used to transport solid materials (conveyor belts, fork lift trucks, trucks, passenger cars), liquids (pumps) and gases (fans, turbines).

Examples of material-processing systems within the motor vehicle:
- Lubrication system, in which the oil pump provides the motive power for material propulsion.
- Cooling system, in which the water pump transports a medium to support thermal transfer.

**Energy-processing systems** transform energy from an external source into another form.

This class embraces all manner of power-generation machines, including internal-combustion engines and electric motors, steam engines and gas power plants, as well as energy units such as heat pumps, photovoltaic systems and fuel cells. In the realm of energy conversion the operative distinction is between:

- **Heat engines**, such as spark-ignition and diesel engines, and gas turbines
- **Hydraulically powered machines**, such as water turbines
- **Wind-energy devices**, such as wind-powered generators
- **Solar-energy converters**, such as photovoltaic systems
- **Fuel cells**

Within the internal-combustion engine, the fuel’s chemical energy is initially converted into thermal energy before undergoing a second transformation to emerge as kinetic energy (Fig. 2).

**Fig. 1: Systems classified according to processing mode**

**Fig. 2: Energy processing in the spark-ignition engine**

This process can generate additional substances and information. Since these are of secondary importance in the operation of the energy-processing machine, they are not usually primary objects of attention.

The flow of substances and materials (entry of fuel and emission of exhaust gases) and the flow of information (fuel/air mixture, engine-speed control, steering, etc.) all assume the role of secondary functions.

**Energy-processing system**. The primary focus is on converting chemical energy contained in fuel into kinetic energy to propel the vehicle, with the **internal-combustion engine** serving as the energy-processing system.
Information-processing systems

These systems monitor, process and relay information and data and support communications.

Information-processing and relay systems, such as electronic control units (ECU), CAN bus controllers and diagnostic equipment (testers) assume vital significance in the maintenance of modern vehicles.

Information. Knowledge concerning conditions and processes. Examples within the vehicle include information on engine temperature, driving speed, load factor, etc. required to support vehicle operation. This information can be relayed from one electronic control unit to another. The data are registered in the form of signals.

Signals. Signals are data portrayed in physical form. Within the motor vehicle, sensors generate signals to represent parameters such as rotational speed, temperature and throttle-valve position.

Examples of information-processing systems in motor vehicles:

● Engine control unit. The engine-management ECU registers and processes an entire array of relevant data in order to adapt engine performance to provide ideal operation under any given conditions.

● On-board computer. Among its functions are to furnish the driver with information on average and current fuel consumption, estimated cruising range, average speed and outside temperature.

1.4.5 Using technical systems

Extensive familiarity with technical systems is essential for the operation and maintenance of motor vehicles. The manufacturer provides operating instructions (owner’s manual) to help ensure that its vehicles operate in an environmentally responsible manner with optimal safety, security and reliability.

Operating instructions contain, among other information:

● System descriptions
● Explanations of functions and operation
● System illustrations
● Operating diagrams
● Instructions on correct operation and use of the controls
● Maintenance and service inspection schedules
● Instructions for responding to malfunctions
● Information on approved fluids, lubricants and service products, such as engine oils

● Technical data
● Emergency service addresses

Operation. Motor vehicles and machines should be operated by qualified and duly-authorised persons only.

Applicable stipulations include the following:

● The driver of a passenger car operating on public roads must be in possession of the regular driving licence required in the country of operation.

● Lift platforms and hydraulic hoists in automotive service facilities are to be operated exclusively by individuals over 18 years of age who have also received corresponding instruction in and authorisation for its use.

● The driver of a truck equipped with a crane must be in possession of a crane operator’s licence.

This stipulation is intended to ensure that drivers of crane-equipped trucks have received the required training for operating lifts and hoisting equipment, and will provide the vehicle with the correct supplementary support (Fig. 1) while simultaneously observing all applicable accident-prevention regulations and operating the crane in a professional manner.

Fig. 1: Correct load distribution on a crane hoist

REVIEW QUESTIONS

1 What are the parameters that define a technical system?
2 What is the IPO concept?
3 What are the different operational units in the motor vehicle?
4 Name three subsystems in the motor vehicle, and describe the corresponding input and output variables.
5 What is the primary function of an energy-processing system?
6 What information is available in the operating instructions (vehicle owner’s manual)?
1.5 Service and maintenance

Professional-quality service and maintenance, performed in accordance with the manufacturer’s instructions (by the factory service organisation, etc.) are vital elements in ensuring continued vehicle safety and in maintaining the validity of the manufacturer’s warranty.

Manufacturers issue service and maintenance schedules, spare part catalogues and repair instructions to guide and support these activities. This documentation is available in many forms, including menu-guided computer programs designed to run on personal computers (PCs).

Service and maintenance. Service procedures include:

- Inspections, such as test procedures
- General maintenance, comprising oil changes, lubrication and cleaning
- Remedial action, such as repairs and component replacement

Aftersales service. Vehicle manufacturers and automotive repair operations offer professional services to their customers. The services offered by these facilities include performing the prescribed preparations on new vehicles prior to delivery to the customer. Professional technicians also carry out service and maintenance work that the vehicle operator may not be able to perform. In the official service and maintenance guidelines the manufacturer defines an action catalogue intended to ensure unrestricted functionality and maintain the vehicle’s value. The individual procedures are contained in the service and maintenance schedules for the specific vehicles.

Service intervals can be defined according to the following criteria:

- Fixed service intervals (maintenance schedule)
- Flexible service intervals
- Demand-based service concepts

Flexible service intervals

Modern engine-management systems have allowed the advent of a new service concept characterised by adaptive scheduling. This concept reflects each individual vehicle’s requirements based on its actual operating conditions. In addition to mileage, the system records and evaluates a variety of other factors (influencing variables) for inclusion in its calculations. A display then provides the driver with prompt notice as the inspection date approaches (Fig. 1). The process culminates with execution of the prescribed operations at the service facility in accordance with the service inspection schedule (Fig. 1, Page 19).

Oil change intervals. Two methods are available for defining oil change intervals:

- A virtual database, derived from such factors as mileage, overall fuel consumption and oil temperature curves, provides an index indicating how much the oil ages over a given period.
- The actual condition of the oil, meaning the quality and level of the oil as determined via the oil level sensor, in combination with the mileage and the registered engine load factors.

Brake pad wear. Brake pad wear is monitored electrically. When the brake pad reaches its wear limit a contact wire within the pad is perforated. The system then considers such factors as braking frequency, the duration of brake actuations and mileage in calculating the theoretically available mileage reserves, which are then reflected in the replacement intervals displayed to the driver.

Interior compartment filter wear status. Data gleaned from the outside air temperature sensor, information on heater use, use of the recirculated-air mode, vehicle speed, fan blower speed, mileage and dates all flow into calculations to determine the period remaining until the dust and pollen filter will be due for replacement.

Service, maintenance and inspection operations must be performed in accordance with defined schedules. Once operations have been carried out, they should be confirmed in a service record and signed by the responsible service technician.

Maintenance schedule

This provides information on the specified service and inspection intervals by specifying (for example) a major inspection every 20,000 km or 12 months.

Service inspection schedule. This schedule defines the contents and lists the procedures included in the service inspection (Fig. 1, Page 19).

Spark plug replacement intervals are still based on a specific mileage, such as replacement after 100,000 km.

Replacement dates for fluids and lubricants, such as the coolant and brake fluid, are defined according to time, for instance, at intervals of 2 or 4 years.
Demand-based service concepts
The service date is calculated on the basis of data collected on the actual condition of wearing parts, fluids and lubricants, as well as information on the vehicle’s operating conditions. When defined by this demand-based service concept, service and maintenance are carried out only when needed, for instance, when a component reaches its wear limit, or a fluid or lubricant has reached the end of its service life.

On-board computers now feature the ability to transmit coded data on the customer and the extent of the required service to the service facility. This gives the service representative time to order any required replacement parts such as brake pads and to consult with the customer in advance about a convenient service date. Early recognition of potential problems should help avoid repairs stemming from vehicle breakdowns. Additional advantages include:
- Precisely defined dates
- Minimal waiting times
- No data loss
- Flexible service

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**Service inspection schedule**

<table>
<thead>
<tr>
<th>Job no.: 900109</th>
<th>Vehicle model: Passat</th>
<th>Vehicle owner: Smith Passat</th>
</tr>
</thead>
<tbody>
<tr>
<td>km reading/ mileage: 53,400</td>
<td>Vehicle age: 3</td>
<td>Additional work, e.g. emissions inspection: ...............</td>
</tr>
</tbody>
</table>

Servicing to be carried out

**Electrical system**
- Front lights: Check function: Parking lights, dipped beam, main beam, fog lamps, direction indicators and hazard-warning signals
- Rear lights: Check function: Brake lights, tail lights, reversing lights, fog lamps, number plate lights, luggage compartment light, parking lights, turn indicators and hazard warning signals
- Interior and glove-compartment lights, cigarette lighter, signal horn and indicator lamps: Check function
- Self-diagnosis: Interrogate fault memories of all systems (insert printout at back of logbook wallet)

**Vehicle from the outside**
- Door arresters and retaining bolts: Lubricate
- Windscreen wash/wipe system and headlight washer system: Check function and spray-nozzle setting
- Windscreen wiper blades: Check for damage, check home position; in event of rubbing wiper blades: Check contact angle

**Tyres**
- Tyres: Check condition, tyre tread pattern and inflation pressure, enter tread depth
  - FL _____ mm FR _____ mm
  - RL _____ mm RR _____ mm

**Vehicle from below**
- Engine oil: Drain or draw off, replace oil filters
- Engine and components in engine compartment: Visually check for leaks and damage
- V-belts, ribbed V-belts: Check condition and tension
- Gearbox, final-drive unit and joint boots: Visually check for leaks and damage
- Manual gearbox / axle drive: Check oil level
- Brake system: Visually check for leaks and damage
- Front and rear brake pads: Check thickness
- Undercoating: Visually check for damage
- Exhaust system: Visually check for leaks and damage
- Track-rod ends: Check play, mounting and sealing gaiters; axle joints: Visually check sealing gaiters for leaks and damage

**Engine compartment**
- Engine oil: Check oil level (during inspection service with filter change, change oil)
- Engine and components in engine compartment (from above): Visually check for leaks and damage
- Windscreen wash/wipe system: Top up fluid
- Cooling system: Check coolant level and antifreeze; setpoint value: –25°C
- Actual value (measured value): _____°C
- Dust and pollen filter: Replace filter element (every 12 months or every 15,000 km)
- Toothed belt for camshaft drive: Check condition and tension
- Air filter: Clean housing and replace filter element
- Fuel filter: Replace
- Power steering: Check fluid level
- Brake-fluid level (dependent on brake-pad wear): Check
- Battery: Check
- Idle speed: Check
- Headlight adjustment / documentation / final inspection
- Headlight adjustment: Check
- Service sticker: Enter date/mileage for next service (also brake-fluid renewal) on sticker and attach sticker to door pillar (B-pillar)
- Take vehicle for test drive
- Date / Signature (mechanic)
- Date / Signature (final inspection)

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**Fig. 1: Service inspection schedule**
Filters installed in the motor vehicle protect the engine, other vehicle components, and the air of the vehicle’s occupants against contaminants and impurities.

Motor vehicle filters (Fig. 1) can be classified according to two criteria: the filtration concept and the medium being filtered.

**Filtration concepts.** Solid contaminants are filtered from flowing media such as air, oil, fuel and water by:
- screen filtration, using sieve-type filter screens and fibre filters, etc.
- adhesive filtration, including wet filters
- magnetic filtration, as with magnetic separators
- centrifugal filtration, with centrifugal filters, etc.

**Strainers (filter screens).** Filter mesh dimensions smaller than the contaminants facilitate filtration (Fig. 2).

**Adhesive filters.** These are usually wet air filters. Contaminants such as dust adhere to the filter surface on contact.

**Magnetic filter.** The filter (for instance, on the oil drain plug) attracts and retains ferromagnetic contaminants suspended in the flowing medium.

**Centrifugal filter.** The object medium (such as air) is placed in a state of rotation. Centrifugal force propels the contaminants onto the filter’s walls, where they settle as deposits.

**Filter types include:**
- Air and exhaust-gas filters
- Fuel filters
- Filters for lubricating oils
- Interior filters, such as pollen, smog and ozone filters
- Hydraulic filters, for ATF, etc.

**1.6.1 Air filters**

The purpose of the air filter is to purify induction air while simultaneously subduing induction roar.

Airborne dust particles are minute in size (0.005 mm to 0.05 mm). The air can also contain quartz. Dust concentrations vary considerably according to vehicle operating conditions (motorway, construction site). Should it enter the oil, this dust would form an abrasive film, leading to extreme wear, especially on the cylinder walls, the pistons and the valve guides.