

Contents

<i>Preface</i>	xii	2.5 Electrical diagnostic techniques	18
<i>Acknowledgements</i>		2.5.1 Check the obvious first	18
1 Introduction	1	2.5.2 Test lights and analogue meters – warning	18
1.1 Diagnosis	1	2.5.3 Generic electrical testing procedure	19
1.1.1 Introduction	1	2.5.4 Volt drop testing	19
1.2 Safe working practices	2	2.5.5 Testing for short circuits to earth	19
1.2.1 Risk assessment and reduction	2	2.5.6 On and off load tests	19
1.3 Terminology	2	2.5.7 Black box technique	19
1.3.1 Introduction	2	2.5.8 Sensor to ECU method	21
1.3.2 Diagnostic terminology	3	2.5.9 Flight recorder tests	22
1.3.3 General terminology	3	2.5.10 Faultfinding by luck – or is it logic?	22
1.4 Report writing	3	2.5.11 Colour codes and terminal numbers	23
1.4.1 Introduction	3	2.5.12 Back probing connectors	24
1.4.2 Main headings of a report	4	2.6 Fault codes	24
1.4.3 Example report	4	2.6.1 Fast and slow	24
1.5 Autonomous driving	6	2.6.2 Fault code examples	25
1.5.1 First steps	6	2.6.3 Clearing	25
1.5.2 Levels of driving automation	7	2.7 Systems	26
2 Diagnostic techniques	9	2.7.1 What is a system?	26
2.1 Introduction	9	2.7.2 Vehicle systems	26
2.1.1 Logic	9	2.7.3 Open-loop systems	27
2.1.2 Information	9	2.7.4 Closed-loop systems	27
2.1.3 Where to stop?	9	2.7.5 Block diagrams	27
2.2 Diagnostic process	9	2.8 Data sources	28
2.2.1 Six-stage process	9	2.8.1 Introduction	28
2.2.2 The art of diagnostics	10	2.8.2 Autodata	29
2.2.3 Concern, cause, correction	11	2.8.3 Bosch ES!tronic	29
2.2.4 Root cause analysis	12	2.9 Summary	29
2.2.5 Summary	14		
2.3 Diagnostics on paper	14	3 Tools and equipment	35
2.3.1 Introduction	14	3.1 Basic equipment	35
2.3.2 Examples	14	3.1.1 Introduction	35
2.3.3 How long is a piece of string?	14	3.1.2 Basic hand tools	35
2.4 Mechanical diagnostic techniques	15	3.1.3 Accuracy of test equipment	35
2.4.1 Check the obvious first	15	3.1.4 Multimeters	36
2.4.2 Noise, vibration and harshness	15	3.1.5 Logic probe	37
2.4.3 Noise conditions	16	3.2 PicoScope oscilloscope kits	38
2.4.4 Vibration conditions	16	3.2.1 Introduction	38
2.4.5 Road test	16	3.2.2 Scan tool or scope?	38
2.4.6 Engine noises	17		
2.4.7 Sources of engine noise	18		

Contents

3.2.3	New features	39	4.5	Communication networks	100
3.2.4	Waveform library	44	4.5.1	CAN	100
3.2.5	PicoDiagnostics	44	4.5.2	LIN	101
3.2.6	Pressure sensor	44	4.5.3	FlexRay	101
3.2.7	Noise and vibration	44	4.6	Summary	104
3.3	Scanners/Fault code readers and analysers	47	5	On-board diagnostics	105
3.3.1	On-board diagnostics introduction	47	5.1	History	105
3.3.2	Serial port communications	47	5.1.1	Introduction	105
3.3.3	OBD2 signal protocols	48	5.1.2	Vehicle emissions and environmental health	105
3.3.4	Entry-level scanners	49	5.1.3	History of the emissions control legislation	106
3.3.5	Bosch KTS diagnostic equipment	53	5.1.4	Introduction of vehicle emissions control strategies	107
3.3.6	Engine analysers	54	5.2	What is on-board diagnostics?	108
3.4	Emission testing	57	5.2.1	OBD scenario example	108
3.4.1	Introduction	57	5.2.2	Origins of OBD in the United States	109
3.4.2	Exhaust gas measurement	57	5.2.3	P-code composition	109
3.4.3	Exhaust analyser	58	5.2.4	European on-board diagnostics and global adoption	110
3.4.4	Emission limits	58	5.2.5	Summary	111
3.5	Pressure testing	59	5.3	Petrol/Gasoline on-board diagnostic monitors	111
3.5.1	Introduction	59	5.3.1	Introduction	111
3.5.2	Automotive pressure oscilloscope transducer	60	5.3.2	Legislative drivers	111
4	Sensors, actuators and oscilloscope diagnostics	63	5.3.3	Component monitoring	111
4.1	Introduction	63	5.3.4	Rationality testing	111
4.2	Sensors	63	5.3.5	Circuit testing	111
4.2.1	Introduction and sensor diagnostics	63	5.3.6	Catalyst monitor	112
4.2.2	Inductive sensors	63	5.3.7	Evaporative system monitor	112
4.2.3	Variable resistance	69	5.3.8	Fuel system monitoring	114
4.2.4	Hot wire airflow sensor	72	5.3.9	Exhaust gas recirculation monitor	115
4.2.5	Thermistors	73	5.3.10	Secondary air monitor	115
4.2.6	Hall effect sensors	74	5.3.11	Monitors and readiness flags	116
4.2.7	Piezo accelerometer	76	5.4	Misfire detection	117
4.2.8	Oxygen sensors	78	5.4.1	Misfire monitor	117
4.2.9	Pressure sensors	79	5.4.2	Crank speed fluctuation	119
4.2.10	Variable capacitance	81	5.4.3	Ionising current monitoring	120
4.2.11	Optical sensors	83	5.4.4	Cylinder pressure sensing	121
4.2.12	Dynamic position sensors	83	5.4.5	Exhaust pressure analysis	122
4.2.13	Rain sensor	84	5.5	OBD summary	122
4.3	Actuators	84	5.5.1	OBD2	123
4.3.1	Introduction	84	5.5.2	EOBD	123
4.3.2	Testing actuators	84	5.5.3	Features and technology of current systems	125
4.3.3	Motorised and solenoid actuators	84	5.6	Driving cycles	125
4.3.4	Solenoid actuators	87	5.6.1	Introduction	125
4.3.5	Thermal actuators	93	5.6.2	Europe	125
4.4	Engine waveforms	95	5.6.3	United States	126
4.4.1	Ignition primary	95	5.7	Future developments in diagnostic systems	126
4.4.2	Ignition secondary	96			
4.4.3	Diesel glow plugs	98			
4.4.4	Alternator waveform	98			
4.4.5	Relative compression petrol	99			

5.7.1 OBD3	126	6.9.3 Catalytic converters	156
5.7.2 Diesel engines	128	6.10 Diagnostics – emissions	158
5.7.3 Rate-based monitoring	128	6.10.1 Testing procedure	158
5.7.4 Model-based development	128	6.10.2 Emissions fault diagnosis table	158
5.7.5 OBD security	128	6.11 Fuel injection	160
5.8 Summary	129	6.11.1 Introduction	160
6 Engine systems	131	6.11.2 Injection systems	160
6.1 Introduction	131	6.11.3 Fuel injection components	162
6.2 Engine operation	131	6.11.4 Fuel mixture calculation	163
6.2.1 Four-stroke cycle	131	6.12 Diagnostics – fuel injection systems	163
6.2.2 Cylinder layouts	131	6.12.1 Testing procedure	163
6.2.3 Camshaft drives	132	6.12.2 Fuel injection fault diagnosis	
6.2.4 Valve mechanisms	133	table	164
6.2.5 Valve and ignition timing	133	6.13 Diesel injection	164
6.3 Diagnostics – engines	135	6.13.1 Introduction	164
6.3.1 Systematic testing example	135	6.13.2 Electronic control of	
6.3.2 Test equipment	135	diesel injection	164
6.3.3 Test results	135	6.13.3 Common rail diesel systems	166
6.3.4 Engine fault diagnosis table 1	136	6.13.4 Diesel exhaust emissions	168
6.3.5 Engine fault diagnosis table 2	136	6.13.5 Catalytic converter diesel	168
6.4 Fuel system	137	6.13.6 Filters	168
6.4.1 Introduction	137	6.14 Diagnostics – diesel injection systems	168
6.4.2 Carburation	137	6.14.1 Test equipment	168
6.5 Diagnostics – fuel system	141	6.14.2 Diesel injection fault	
6.5.1 Systematic testing example	141	diagnosis table	169
6.5.2 Test equipment	141	6.14.3 Diesel engine smoke	169
6.5.3 Test results	141	6.14.4 Glow plug circuit	170
6.5.4 Fuel fault diagnosis table 1	142	6.14.5 Diesel systems	170
6.5.5 Fuel fault diagnosis table 2	143	6.15 Engine management	170
6.6 Introduction to engine management	143	6.15.1 Introduction	170
6.7 Ignition	143	6.15.2 Closed-loop lambda control	171
6.7.1 Basics	143	6.15.3 Engine management operation	172
6.7.2 Advance angle (timing)	143	6.15.4 Gasoline direct injection	176
6.7.3 Electronic ignition	144	6.15.5 ECU calibration	177
6.7.4 Hall effect distributor	145	6.16 Diagnostics – combined ignition and	
6.7.5 Inductive distributor	145	fuel systems	178
6.7.6 Current-limiting and		6.16.1 Testing procedure	178
closed-loop dwell	146	6.16.2 Combined ignition and fuel	
6.7.7 Programmed ignition/electronic	146	control fault diagnosis table	180
spark advance	146	6.16.3 Fuel pump testing	181
6.7.8 Distributorless ignition	148	6.16.4 Injector testing	181
6.7.9 Direct ignition	150	6.16.5 ECU fuel trim diagnostics	181
6.7.10 Spark plugs	151	6.17 Engine management and faultfinding	
6.8 Diagnostics – ignition system	152	information	185
6.8.1 Testing procedure	152	6.17.1 Diagnosis charts	185
6.8.2 Ignition fault diagnosis table	152	6.17.2 Circuit diagrams	185
6.8.3 Ignition components and		6.17.3 Component testing data	185
testing	154	6.18 Air supply and exhaust systems	185
6.8.4 DIS diagnostics	154	6.18.1 Exhaust system	185
6.8.5 Spark plugs	154	6.18.2 Catalytic converters	185
6.9 Emissions	156	6.18.3 Air supply system	189
6.9.1 Introduction	156	6.19 Diagnostics – exhaust and air supply	190
6.9.2 Exhaust gas recirculation	156	6.19.1 Systematic testing	190
		6.19.2 Test results	190

Contents

6.19.3 Exhaust and air supply fault diagnosis table 1	190	6.29 Diagnostics – charging	214
6.19.4 Exhaust fault diagnosis table 2	190	6.29.1 Testing procedure	214
6.20 Cooling	190	6.29.2 Charging fault diagnosis table	215
6.20.1 Air-cooled system	190	7 Chassis systems	217
6.20.2 Water-cooled system	191	7.1 Brakes	217
6.20.3 Sealed and semi-sealed systems	191	7.1.1 Introduction	217
6.21 Diagnostics – cooling	192	7.1.2 Principle of hydraulic braking	217
6.21.1 Systematic testing	192	7.1.3 Disc and drum brake systems	218
6.21.2 Test equipment	193	7.1.4 Brake adjustments	219
6.21.3 Test results	193	7.1.5 Servo-assisted braking	219
6.21.4 Cooling fault diagnosis table 1	193	7.2 Diagnostics – brakes	220
6.21.5 Cooling fault diagnosis table 2	193	7.2.1 Systematic testing	220
6.22 Lubrication	194	7.2.2 Test equipment	220
6.22.1 Lubrication system	194	7.2.3 Dial gauge	220
6.22.2 Oil filters	194	7.2.4 Test results	221
6.22.3 Oil pumps	194	7.2.5 Brakes fault diagnosis table 1	221
6.22.4 Crankcase ventilation engine breather systems	195	7.2.6 Brakes fault diagnosis table 2	222
6.23 Diagnostics – lubrication	196	7.2.7 Brake hydraulic faults	222
6.23.1 Systematic testing	196	7.3 Antilock brakes	222
6.23.2 Test equipment	196	7.3.1 Introduction	222
6.23.3 Test results	196	7.3.2 General system description	223
6.23.4 Lubrication fault diagnosis table 1	197	7.3.3 ABS components	223
6.23.5 Lubrication fault diagnosis table 2	197	7.4 Diagnostics – antilock brakes	225
6.24 Batteries	197	7.4.1 Systematic testing procedure	225
6.24.1 Safety	197	7.4.2 Antilock brakes fault diagnosis table	225
6.24.2 Lead-acid batteries	197	7.4.3 Bleeding antilock brakes	225
6.24.3 Battery rating	197	7.5 Traction control	225
6.25 Diagnostics – batteries	198	7.5.1 Introduction	225
6.25.1 Servicing batteries	198	7.5.2 Control functions	227
6.25.2 Maintenance-free	198	7.5.3 System operation	228
6.25.3 Charging	199	7.6 Diagnostics – traction control	228
6.25.4 Battery faults	200	7.6.1 Systematic testing	228
6.25.5 Testing batteries	200	7.6.2 Traction control fault diagnosis table	228
6.25.6 Battery diagnostics	202	7.7 Steering and tyres	230
6.26 Starting	204	7.7.1 Construction of a tubeless radial tyre	230
6.26.1 Starter circuit	204	7.7.2 Steering box and rack	230
6.26.2 Inertia starters	204	7.7.3 Power-assisted steering	231
6.26.3 Pre-engaged starters	205	7.7.4 Steering characteristics	232
6.26.4 Permanent magnet starters	206	7.7.5 Camber	232
6.26.5 Keyless starting system	207	7.7.6 Castor	233
6.27 Diagnostics – starting	208	7.7.7 Swivel axis inclination	234
6.27.1 Circuit testing procedure	208	7.7.8 Tracking	234
6.27.2 Starting fault diagnosis table	210	7.7.9 Scrub radius	235
6.28 Charging	210	7.8 Diagnostics – steering and tyres	236
6.28.1 Introduction	210	7.8.1 Systematic testing	236
6.28.2 Basic principles	211	7.8.2 Test equipment	236
6.28.3 Rectification of AC to DC	211	7.8.3 Four-wheel alignment	236
6.28.4 Regulation of output voltage	212	7.8.4 Test results	237
6.28.5 Charging circuits	213	7.8.5 Tyres fault diagnosis table	237
		7.8.6 Tyre inflation pressures	238

7.8.7	Steering fault diagnosis table 1	238	8.6.5	Indicators and hazard lights	273
7.8.8	Steering, wheels and tyres fault diagnosis table	239	8.6.6	Brake lights	274
7.9	Suspension	239	8.6.7	Electric horns	274
7.9.1	Introduction	239	8.6.8	Engine cooling fan motors	275
7.9.2	Suspension system layouts	239	8.7	Diagnostics – auxiliary	275
7.9.3	Front axle suspensions	240	8.7.1	Testing procedure	275
7.9.4	Rear axle suspensions	240	8.7.2	Auxiliaries fault diagnosis table	275
7.9.5	Anti-roll bar	240	8.7.3	Wiper motor and circuit testing	276
7.9.6	Springs	242	8.8	In-car entertainment, security and communications	276
7.9.7	Dampers	242	8.8.1	In-car entertainment	276
7.10	Diagnostics – suspension	242	8.8.2	Security systems	280
7.10.1	Systematic testing	242	8.8.3	Mobile communications	281
7.10.2	Test equipment	242	8.9	Diagnostics – ICE, security and communication	281
7.10.3	Test results	244	8.9.1	Testing procedure	281
7.10.4	Suspension fault diagnosis table 1	244	8.9.2	ICE, security and communication system fault diagnosis table	281
7.10.5	Suspension fault diagnosis table 2	245	8.9.3	Interference suppression	282
7.11	Active suspension	245	8.10	Body electrical systems	285
7.11.1	Active suspension operation	245	8.10.1	Electric seat adjustment	285
7.11.2	Delphi MagneRide case study	247	8.10.2	Electric mirrors	285
7.12	Diagnostics – active suspension	247	8.10.3	Electric sunroof operation	286
7.12.1	Systematic testing	247	8.10.4	Door locking circuit	286
7.12.2	Back to the black box	248	8.10.5	Electric window operation	287
8	Electrical systems	251	8.11	Diagnostics – body electrical	287
8.1	Electronic components and circuits	251	8.11.1	Testing procedure	287
8.1.1	Introduction	251	8.11.2	Body electrical systems fault diagnosis table	287
8.1.2	Components	251	8.11.3	Circuit systematic testing	287
8.1.3	Integrated circuits	253	8.12	Instrumentation	288
8.1.4	Digital circuits	253	8.12.1	Gauges	288
8.1.5	Electronic component testing	254	8.12.2	Digital instrumentation	291
8.2	Multiplexing	255	8.12.3	Vehicle condition monitoring	292
8.2.1	Overview	255	8.12.4	Trip computer	293
8.2.2	Controller area network	256	8.12.5	Displays	293
8.2.3	CAN data signal	258	8.13	Diagnostics – instruments	294
8.2.4	Local interconnect network	259	8.13.1	Testing procedure	294
8.2.5	FlexRay	260	8.13.2	Instrumentation fault diagnosis table	294
8.3	Diagnostics – multiplexing	261	8.13.3	Black box technique for instrumentation	294
8.4	Lighting	264	8.14	Heating, ventilation and air conditioning	294
8.4.1	External lights	264	8.14.1	Ventilation and heating	294
8.4.2	Lighting circuits	264	8.14.2	Heating system – water-cooled engine	294
8.4.3	Gas discharge lighting	265	8.14.3	Heater blower motors	297
8.4.4	LED lighting	267	8.14.4	Electronic heating control	297
8.5	Diagnostics – lighting	267	8.14.5	Air conditioning introduction	298
8.5.1	Testing procedure	267	8.14.6	Air conditioning overview	299
8.5.2	Lighting fault diagnosis table	269	8.14.7	Automatic temperature control	299
8.5.3	Headlight beam setting	269	8.14.8	Seat heating	299
8.6	Auxiliaries	270	8.14.9	Screen heating	300
8.6.1	Wiper motors and linkages	270			
8.6.2	Wiper circuits	271			
8.6.3	Two-motor wiper system	273			
8.6.4	Headlight wipers and washers	273			

Contents

8.15	Diagnostics – HVAC	300	9.3.3	Epicyclic gearbox operation	318
8.15.1	Testing procedure	300	9.3.4	Constantly variable transmission	319
8.15.2	Air conditioning fault diagnosis table	302	9.3.5	Electronic control of transmission	320
8.15.3	Heating and ventilation fault diagnosis table	302	9.3.6	Direct shift gearbox	321
8.15.4	Air conditioning receiver	302	9.4	Diagnostics – automatic transmission	323
8.16	Cruise control	302	9.4.1	Systematic testing	323
8.16.1	Introduction	302	9.4.2	Test equipment	323
8.16.2	System description	303	9.4.3	Test results	323
8.16.3	Components	303	9.4.4	Automatic gearbox fault diagnosis table 1	324
8.17	Diagnostics – cruise control	303	9.4.5	Automatic gearbox fault diagnosis table 2	324
8.17.1	Systematic testing	303	9.4.6	ECAT fault diagnosis table	324
8.17.2	Cruise control fault diagnosis table	304	9.4.7	Automatic transmission stall test	324
8.18	Airbags and belt tensioners	304	10	Learning activities and simulations	325
8.18.1	Introduction	304	10.1	Introduction	325
8.18.2	Components and circuit	306	10.2	Knowledge check questions	325
8.18.3	Seat belt tensioners	307	10.2.1	Chapter 1 Introduction	325
8.19	Diagnostics – airbags and belt tensioners	308	10.2.2	Chapter 2 Diagnostic techniques	325
8.19.1	Systematic testing	308	10.2.3	Chapter 3 Tools and equipment	326
8.19.2	Airbags and belt tensioners fault diagnosis table	308	10.2.4	Chapter 4 Sensors, actuators and oscilloscope diagnostics	326
8.19.3	Deactivation and activation procedures	308	10.2.5	Chapter 5 On-board diagnostics	326
9	Transmission systems	311	10.2.6	Chapter 6 Engine systems	326
9.1	Manual transmission	311	10.2.7	Chapter 7 Chassis systems	326
9.1.1	Clutch	311	10.2.8	Chapter 8 Electrical systems	326
9.1.2	Manual gearbox	312	10.2.9	Chapter 9 Transmission systems	327
9.1.3	Drive shafts and wheel bearings	314	10.3	Vehicle system diagnostic simulations	327
9.1.4	Final drive and differential	314	10.3.1	Introduction	327
9.1.5	Four-wheel drive systems	315	10.3.2	Starting diagnostics	327
9.2	Diagnostics – manual transmission	315	10.3.3	Charging diagnostics	330
9.2.1	Systematic testing	315	10.3.4	Interior lighting diagnostics	332
9.2.2	Test equipment	316	10.3.5	Exterior lighting diagnostics	334
9.2.3	Test results	316	10.3.6	Screen wiper diagnostics	335
9.2.4	Manual transmission fault diagnosis table 1	316	10.4	Software	339
9.2.5	Manual gearbox fault diagnosis table 2	316	10.5	Summary	339
9.2.6	Clutch fault diagnosis table	317		Glossary of abbreviations and acronyms	341
9.2.7	Drive shafts fault diagnosis table	317		Index	347
9.2.8	Final drive fault diagnosis table	317			
9.3	Automatic transmission	317			
9.3.1	Introduction	317			
9.3.2	Torque converter operation	317			