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December 2012

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16. Abstract  
These tests were conducted on the subject 2013 BMW 328i in accordance with the specifications of the Office of Crash Avoidance Standards most current Test Procedure in docket NHTSA-2006-26555 to confirm the performance of a lane departure warning system. The vehicle passed the requirements of the test for all three lane marking types and for both directions.

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The purpose of the testing reported herein was to confirm the performance of a Lane Departure Warning (LDW) system installed on a 2013 BMW 328i. The LDW system for this vehicle provides a tactile alert implemented via a vibration felt in the steering wheel. The vehicle passed the requirements of the test for all three lane marking types and for both directions.

The test procedure is described in detail in the NHTSA Document "LANE DEPARTURE WARNING SYSTEM CONFIRMATION TEST" from March of 2010. Its purpose is to confirm the performance of Lane Departure Warning (LDW) systems installed on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lb. Current LDW technology relies on sensors to recognize a lane delimiting edge line. As such, the test procedures described in the document rely on painted or taped lines or Botts Dots being present on the test course to emulate those found on public roadways. Although it is impossible to predict what technologies could be used by future LDW systems (e.g., magnetic markers, RADAR reflective striping, ultra violet paint, infra red, etc.), it is believed that minor modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of alternative or more advanced LDW systems.
Section II
DATA SHEETS
# LANE DEPARTURE WARNING

## DATA SHEET 1: TEST SUMMARY

### 2013 BMW 328i

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1 – Continuous White Line</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Test 2 – Dashed Yellow Line</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Test 3 – Botts Dots</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>Pass</strong></td>
<td></td>
</tr>
</tbody>
</table>

**VIN:** WBA3A5C58DF3xxxx  
**Test Date:** 12/11/2012  
**Lane Departure Warning setting:** Nominal
TEST VEHICLE INFORMATION

VIN:  WBA3A5C58DF3xxxx
Body Style:  Sedan     Color:  Blue
Date Received:  Odometer Reading:  20 mi
Engine:  2 L Inline 4
Transmission:  Automatic
Final Drive:  Rear

Is the vehicle equipped with:

ABS  X  Yes  ___  No
Adaptive Cruise Control  X  Yes  ___  No
Collision Mitigating Brake System  ___  Yes  X  No

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by:  Bayerische Motoren Werke AG
Date of manufacture:  7/2012

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard:  Front:  225/45R18
                                              Rear:  225/45R18
Recommended cold tire pressure:  Front:  220 kPa (32 psi)
                                              Rear:  240 kPa (35 psi)
LANE DEPARTURE WARNING
DATA SHEET 2: GENERAL TEST AND VEHICLE PARAMETER DATA

(2013 BMW 328i)

TIRES

Tire manufacturer and model: *Pirelli Cinturato P7*

Front tire size: 225/45R18

Rear tire size: 225/45R18

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle:

- [ ] All options listed on the “window sticker” are present on the test vehicle.
- [x] Tires and wheel rims are the same as listed.
- [x] There are no dents or other interior or exterior flaws.
- [x] The vehicle has been properly prepared and is in running condition.
- [x] Verify that spare tire, jack, lug wrench, and tool kit (if applicable) is located in the vehicle cargo area.
GENERAL INFORMATION

Test date: 12/11/2012

AMBIENT CONDITIONS

Air temperature: 16.7 °C (62 F)

Wind speed: 1.5 m/s (3.5 mph)

Wind speed \( \leq 10 \text{ m/s (22 mph)} \)

Tests were not performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.

Tests were conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5000 meters). The tests were not conducted with the vehicle oriented into the sun during very low sun angle conditions, where the sun is oriented 15 degrees or less from horizontal, and camera “washout” or system inoperability results.

VEHICLE PREPARATION

Verify the following:

All non consumable fluids at 100 % capacity: X

Fuel tank is full: X

Tire pressures are set to manufacturer’s recommended cold tire pressure:

Front: 220 kPa (32 psi)

Rear: 240 kPa (35 psi)
## WEIGHT

Weight of vehicle as tested including driver and instrumentation

<table>
<thead>
<tr>
<th></th>
<th>Left Front</th>
<th>Right Front</th>
<th>Left Rear</th>
<th>Right Rear</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>410.5 kg (905 lb)</td>
<td>415.0 kg (915 lb)</td>
<td>425.9 kg (939 lb)</td>
<td>425.0 kg (937 lb)</td>
<td>1676.5 kg (3696 lb)</td>
</tr>
</tbody>
</table>

2013 BMW 328i
How is the Forward Collision Warning presented to the driver? (Check all that apply)

- Warning light
- Buzzer or audible alarm
- Vibration
- Other

Describe the method by which the driver is alerted. For example, if the warning is a light, where is it located, its color, size, words or symbol, does it flash on and off, etc. If it is a sound, describe if it is constant beep or a repeated beep. If it is a vibration, describe where it is felt (e.g., pedals, steering wheel), the dominant frequency (and possibly magnitude), the type of warning (light, audible, vibration, or combination) etc.

A vibration felt at the steering wheel is used to alert the driver to a lane departure. The primary frequency of the vibration is approximately 50Hz. The duration of the vibration is approximately 2 seconds.
Is the vehicle equipped with a switch whose purpose is to render LDW inoperable?  

X Yes  

No

If yes please provide a full description including the switch location and method of operation, any associated instrument panel indicator, etc.

A switch which toggles the LDW system on and off is located on the lower left side of the dashboard (to the left of the steering wheel). The switch lights up when the system is active. The switch has an image of the top view of a car crossing a lane line.

Is the vehicle equipped with a control whose purpose is to adjust the range setting or otherwise influence the operation of LDW?  

X No

If yes please provide a full description
Are there other driving modes or conditions that render LDW inoperable or reduce its effectiveness?  

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

If yes please provide a full description.

- **Heavy fog, rain, snowfall**
- In the event of worn, poorly visible, merging, diverging, or multiple lane markings, such as in construction areas
- When lane markings are covered in snow, ice, dirt, or water
- In tight curves or on narrow lanes
- When the lane markings are covered by objects
- When driving very close to the vehicle in front of you
- When driving towards bright lights
- When the windshield in front of the interior rear view mirror is fogged over, dirty, or covered with stickers, etc.
- During the calibration process of the camera immediately after vehicle shipment
Section III
TEST PROCEDURES

A. Test Procedure Overview

Each LDW test involved one of three lane marking types: solid white lines, dashed yellow lines, or Botts Dots. Lane departures were done both to the left and to the right, and each test condition was repeated five times, as shown in Table 1.

Table 1. – LDW Test Matrix

<table>
<thead>
<tr>
<th>Lane Geometry</th>
<th>Line Type</th>
<th>Departure Direction</th>
<th>Number of Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>Solid</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Dashed</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td>Botts Dots</td>
<td>L</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

Prior to the start of a test series involving a given lane marking type and departure direction combination, the accuracy of the distance to lane marking measurement was verified. This was accomplished by driving the vehicle to the approximate location at which the lane departure would occur and placing the tire at the lane marking edge of interest (i.e., distance to lane marking = 0). The real-time display of distance to the lane marking was then observed to verify that the measured distance was within the tolerance (5 cm). If the measured distance was found to be greater than the tolerance, the instrumentation setup was checked and corrected, if necessary. If the measured distance was found to be within the tolerance, the instrumentation setup was considered appropriate and the test series was begun.

To begin the maneuver, the vehicle was accelerated from rest to a test speed of 72.4 km/h (45 mph), while being driven in a straight line parallel to the lane marking of interest, with the centerline of the vehicle approximately 1.83 m (6.0 ft) from the lane edge (i.e., such that the vehicle would pass through the center of the start gate). The test speed was achieved at least 60 m (200 ft) before the start gate was reached. Striking any start gate cones was not permitted, and any run in which a cone was struck was considered to be invalid. Also, during the initialization and test phases, the test driver avoided using turn
signals and avoided applying any sudden acceleration, sudden steering or sudden braking, and any use of the turn signals, sudden acceleration, sudden steering or sudden braking invalidated the test trial.

Data collection began with the vehicle at least 60 m (200 ft) from the start gate, which was configured using a pair of non-reflective, low-contrast color traffic cones. A second set of cones, placed 6 m (20 ft) longitudinally before the start gate, was used to guide the driver into the start gate. The lateral width between the cone pairs was 20 cm (8 in) greater than the width of the vehicle, and the centerline of each pair was laterally offset from the lane marking by 1.8 m (6 ft).

Once the driver passed the gate, the driver manually input sufficient steering to achieve a lane departure with a target lateral velocity of 0.5 m/s with respect to the lane line. As shown in Fig 1, two additional non-reflective cones were used to guide the driver in making this steering maneuver. Throughout the maneuver the driver modulated the throttle, or used cruise control, as appropriate, such that vehicle speed remained at constant speed. The test was considered complete when the vehicle crossed at least 1 m (3.3 ft) over the lane edge boundary.

![Figure 1. Position of Cones Used to Assist Driver](image)

Data collected included vehicle speed, position, and yaw rate. In addition to cone strikes, vehicle speed and yaw rate data were used to identify invalid runs as described in Section C below. Data from trials where speed or yaw rate were outside of the performance specification were not considered valid.

**B. Lane Delineation Markings**

The Office of Crash Avoidance Standards’ Test Procedure for the confirmation of a lane departure warning system contains a requirement that all lane markings
meet USDOT specifications as described in the Manual on Uniform Traffic Control Devices (MUTCD) and be considered in “very good condition”.

1. Lane Marker Width

The width of the edge line marker was 10 to 15 cm (4 to 6 in). This is considered to be a normal width for longitudinal pavement markings under Section 3A.05 of the MUTCD.

2. Line Marking Color and Reflectivity

Lane marker color and reflectivity met all applicable standards. These standards include those from the International Commission of Illumination (CIE) for color and the American Society for Testing and Materials (ASTM) on lane marker reflectance.

3. Line Styles

The tests described in this document required the use of three lane line configurations: continuous solid white, discontinuous dashed yellow, and discontinuous with raised pavement markers.

- Continuous White Line
  A continuous white line is defined as a white line that runs for the entire length of the test course.

- Dashed Yellow Line
  As stated in the Manual on Uniform Traffic Control Devices (MUTCD), and as shown in Figure 2, a discontinuous dashed yellow line is defined as by a series of 3 m (10 ft) broken (dashed) yellow line segments, spaced 9.1 m (30 ft) apart.

- Raised Pavement Marker Line (Botts Dots)
  California Standard Plans indicates raised pavement markers are commonly used in lieu of painted strips for marking roads in California. Other states, mainly in the southern part of the United States, rely on them as well. These markers may be white or yellow, depending on the specific application, following the same basic colors of their analogous white and yellow painted lines. Following the California 2006 Standard Plans, three types of raised pavement markings are used to form roadway lines. It is believed that these types of roadway markings are the hardest for an LDW sensor system to process. Type A and Type AY are non-reflective circular domes that are approximately 10 cm (4 in) in diameter and approximately 1.8 cm (0.7
in) high. Type C and D are square markings that are retro reflective in two directions measuring approximately 10 x 10 x 5 cm (4 x 4 x 0.5 in), and Type G and H that are the same as C and D only retro reflective in a single direction.

For the tests described in this document, raised pavement markers were set up following California Standard Plan A20A, Detail 4 as shown in Figure 3. Note that in this figure, the squares are Type D yellow reflectors and the circles are yellow Type AY discs.

Figure 2. MUTCD Discontinuous Dashed Line Specifications

Figure 3. California Standard Plan A20A, Detail 4
C. Test Validity

1. Speed

All LDW tests were conducted at 72.4 km/h (45 mph). Test speed was monitored and a test was considered valid if the test speed remained within ± 2 km/h (± 1.2 mph) of the 72.4 km/h (45 mph) target speed. It was required that the speed must remain within this window from the start of the test until any part of the vehicle crossed a lane line by 1 m (3.3 ft) or more.

2. Lateral Velocity

All tests were conducted with a lateral velocity of 0.1 to 0.6 m/s (0.3 to 2.0 ft/s), measured with respect to the lane line at the time of the alert. To assist the test driver in being able to efficiently establish the target lateral velocity, cones were positioned in the manner shown in Figure 1.

3. Yaw Rate

It was required that the magnitude of the vehicle’s yaw rate could not exceed 1.0 deg/sec at any time during lane departure maneuver, from the time the vehicle passes through the start gate to the instant the vehicle has crossed a lane line by 1 m (3.3 ft).

D. Pass/Fail Criteria

The measured test data were used to determine the pass/fail outcome for each trial. The outcome was based on whether the LDW produced an appropriate alert during the maneuver. In the context of this test procedure, a lane departure is said to occur when any part of the two dimensional polygon used to represent the test vehicle breaches the inboard lane line edge (i.e., the edge of the line closed to the vehicle before the departure occurs). In the case of tests performed in this procedure, the front corner of the polygon, defined as the intersection of center of the front wheels (longitudinally) with the outboard edge of the front tire (laterally), crossed the line edge first. So, for example, if the vehicle departed its lane to the left, the left front corner of the polygon would first breach the lane line edge.

For an individual trial to be considered a “pass”:

- Test speed, lateral velocity, and yaw rate validity conditions must be satisfied.
- The LDW alert must not occur when the lateral position of the vehicle
is greater than 0.75 m (2.5 ft) from the lane line edge (i.e., prior to the lane departure).

- The LDW alert must occur before the lane departure exceeds 0.3 m (1.0 ft).

For an overall “Pass” the LDW system must satisfy the pass criteria for 3 of 5 individual trials for each combination of departure direction and lane line type (60 percent), and pass 20 of the 30 trials overall (66 percent).

E. Instrumentation

Table 2 lists the sensors, signal conditioning and data acquisition equipment used for these tests.
<table>
<thead>
<tr>
<th>Type</th>
<th>Output</th>
<th>Range</th>
<th>Accuracy, Other Primary Specs</th>
<th>Mfr, Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire Pressure Gauge</td>
<td>Vehicle Tire Pressure</td>
<td>0-100 psi 0-690 kPa</td>
<td>0.5 psi 3.45 kPa</td>
<td>Ashcroft, D1005PS</td>
</tr>
<tr>
<td>Platform Scales</td>
<td>Vehicle Total, Wheel, and Axle Load</td>
<td>8000 lb 35.6 kN</td>
<td>±1.0% of applied load</td>
<td>Intercomp, SWII</td>
</tr>
<tr>
<td>Differential Global Positioning System</td>
<td>Position, Velocity</td>
<td>Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots</td>
<td>Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h</td>
<td>Trimble GPS Receiver, 5700 (base station and in-vehicle)</td>
</tr>
<tr>
<td>Multi-Axis Inertial Sensing System</td>
<td>Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles</td>
<td>Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots Accel: ±100 m/s² Angular Rate: ±100 deg/s Angular Disp: ±180 deg</td>
<td>Position: ±2 cm Velocity: 0.05 km/h Accel: ≤0.01% of full range Angular Rate: ≤0.01% of full range Roll/Pitch Angle: ±0.03 deg Heading Angle: ±0.1 deg</td>
<td>Oxford Technical Solutions (OXTS), Inertial+</td>
</tr>
<tr>
<td>Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)</td>
<td>Distance and Velocity to lane markings (LDW) and POV (FCW)</td>
<td>Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec</td>
<td>Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02 m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec</td>
<td>Oxford Technical Solutions (OXTS), RT-Range</td>
</tr>
</tbody>
</table>
Table 2. Test Instrumentation and Equipment (Cont’d)

<table>
<thead>
<tr>
<th>Type</th>
<th>Output</th>
<th>Range</th>
<th>Accuracy, Other Primary Specs</th>
<th>Mfr, Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Acquisition System</td>
<td>Record Time; Position; Velocity; Distance to lane markings; Headway distance; Closing Velocity; Lateral, Longitudinal, and Vertical Accels; Roll, Yaw, and Pitch Rates; Roll, Yaw and Pitch Angles.</td>
<td>Sufficient to meet or exceed individual sensors</td>
<td>Sound digitized at 10 kHz, all other channels digitized at 100 Hz. Accuracy is sufficient to meet or exceed individual sensors</td>
<td>SoMat, eDaq ECPU processor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SoMat, High level Board EHLS</td>
</tr>
<tr>
<td>Microphone</td>
<td>Sound (to measure time at alert)</td>
<td>Max SPL: 139 dB/SPL Frequency Response: 40 Hz – 20 kHz</td>
<td>≤ 3 dB over Freq. Resp. Range</td>
<td>Sennheiser, e614</td>
</tr>
<tr>
<td>Light Sensor</td>
<td>Light intensity (to measure time at alert)</td>
<td>Spectral Bandwidth: 440-800 nm Rise time &lt; 10 msec</td>
<td></td>
<td>DRI designed and developed Light Sensor</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>Acceleration (to measure time at alert)</td>
<td>± 5g</td>
<td>≤ 3% of full range</td>
<td>Silicon Designs, 2210-005</td>
</tr>
<tr>
<td>Coordinate Measurement Machine</td>
<td>Inertial Sensing System Coordinates</td>
<td>0-8 ft 0-2.4 m</td>
<td>± .0020 in. ± .051 mm (Single point articulation accuracy)</td>
<td>Faro Arm, Fusion</td>
</tr>
</tbody>
</table>
As part of the pre-test instrumentation verification process, the tonal frequency of the audible warning or the vibration frequency of the tactile warning (if present) was determined through use of the PSD (Power Spectral Density) function in Matlab. This was accomplished in order to identify the center frequency around which a band-pass filter was applied to subsequent audible or tactile warning data so that the beginning of such warnings could be programmatically determined. The bandpass filter used for these warning signals was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 3.

Table 3. Audible and Tactile Warning Filter Parameters

<table>
<thead>
<tr>
<th>Warning Type</th>
<th>Filter Order</th>
<th>Peak-to-Peak Ripple</th>
<th>Minimum Stop Band Attenuation</th>
<th>Pass-Band Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audible</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>3 dB</td>
<td>60 dB</td>
<td>Identified Center Frequency ± 5%</td>
</tr>
<tr>
<td>Tactile</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>3 dB</td>
<td>60 dB</td>
<td>Identified Center Frequency ± 20%</td>
</tr>
</tbody>
</table>
APPENDIX A

Photographs
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Figure A1. Front View of Subject Vehicle
Figure A2. Rear View of Subject Vehicle
Figure A3. Window Sticker (Monroney Label)
Figure A4. Vehicle Certification Label

MFD BY BAYERISCHE MOTOREN WERKE AG

07-2012

GVWR 4453 lbs 2020 kg
GAWR FRONT 2061 lbs 935 kg
GAWR REAR 2513 lbs 1140 kg

THIS VEHICLE CONFORMS TO ALL APPLICABLE U.S. FEDERAL MOTOR VEHICLE SAFETY, BUMPER AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.

WBA3A5C58DF35

TYPE: PASSENGER CAR
A89/1
7315814
Figure A5. DGPS and Inertial Measurement Unit Installed in Subject Vehicle
Figure A6. Data Acquisition System Installed in Subject Vehicle
Figure A7. Computer Installed in Subject Vehicle
Figure A8. Sensor for Detecting Haptic Alert
Figure A9. LDW On-Off Switch
APPENDIX B

Excerpts from Owner’s Manual
Cockpit

Vehicle equipment

All standard, country-specific and optional equipment that is offered in the model series is described in this chapter. Therefore, equipment is also described that is not available in a vehicle, e.g., because of the selected optional equipment or country variant. This also applies for safety-related functions and systems.

All around the steering wheel

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Low beams 86

Online Edition for Part no. 01 40 2 608 633 - 11 09 490

B-2
Continued driving with a flat tire

If continuing to drive with a damaged tire:

1. Avoid sudden braking and steering maneuvers.
2. Do not exceed a speed of 50 mph/80 km/h.
3. Check the air pressure in all four tires at the next opportunity.

If the tire inflation pressure in all four tires is correct, the Flat Tire Monitor may not have been initialized. In this case, initialize the system.

Possible driving distance with complete loss of tire inflation pressure:

The possible driving distance after a loss of tire inflation pressure depends on the cargo load and the driving style and conditions.

For a vehicle containing an average load, the possible driving distance is approx. 50 miles/80 km.

When the vehicle is driven with a damaged tire, its handling characteristics change, e.g., reduced lane stability during braking, a longer braking distance, and altered self-steering properties. Adjust your driving style accordingly. Avoid abrupt steering maneuvers or driving over obstacles, e.g., curbs, potholes, etc.

Because the possible driving distance depends on how the vehicle is used during the trip, the actual distance may be smaller or greater depending on the driving speed, road conditions, external temperature, cargo load, etc.

Continued driving with a flat tire

Drive moderately and do not exceed a speed of 50 mph/80 km/h.

A loss of tire inflation pressure results in a change in the handling characteristics, e.g., reduced lane stability during braking, a longer braking distance and altered self-steering properties.

Final tire failure

Vibrations or loud noises while driving can indicate the final failure of the tire. Reduce speed and stop; otherwise, pieces of the tire could come loose and cause an accident. Do not continue driving, and contact your service center.

Lane departure warning

The concept

Starting at a specific speed, this system alerts you when the vehicle on streets with lane markings is about to leave the lane. Depending on the country-specific version of the vehicle, the speed is between 35 mph/55 km/h and 45 mph/70 km/h. When switching on the system below this speed, a message appears in the instrument cluster.

The steering wheel begins vibrating gently in the event of warnings. The time of the warning may vary depending on the current driving situation.

The system does not provide a warning if the turn signal is set before leaving the lane.

Switching on/off

Press the button.

- On: the LED lights up.
- Off: the LED goes out.

The state is stored for the remote control currently in use.
Display

Lines, arrow 1: the system is activated.

Arrows, arrow 2: at least one lane marking was detected and warnings can be issued.

Issued warning

If you leave the lane and if a lane marking has been detected, the steering wheel begins vibrating.

If the turn signal is set before changing the lane, a warning is not issued.

End of warning

The warning ends:

- Automatically after approx. 3 seconds.
- When returning to your own lane.
- When braking hard.
- When using the turn signal.

System limits

⚠ Personal responsibility

The system cannot serve as a substitute for the driver’s personal judgment of the course of the road and the traffic situation.

In the event of a warning, do not jerk the steering wheel, as you may lose control of the vehicle.

The system may not be fully functional in the following situations:

- In heavy fog, rain or snowfall.
- In the event of worn, poorly visible, merging, diverging, or multiple lane markings such as in construction areas.

- When lane markings are covered in snow, ice, dirt or water.
- In tight curves or on narrow lanes.
- When the lane markings are covered by objects.
- When driving very close to the vehicle in front of you.
- When driving toward bright lights.
- When the windshield behind the interior rearview mirror is fogged over, dirty or covered with stickers, etc.
- During the calibration process of the camera immediately after vehicle shipment.

Camera

The camera is located near the base of the mirror.

Keep windshield clean and clear in the area in front of the interior rear view mirror.
Driving comfort

- Certain sitting positions.
- Objects on the cover of the Head-up Display.
- Sunglasses with certain polarization filters.
- Wet roads.
- Unfavorable light conditions.

If the image is distorted, check the basic settings.

Switching on/off
1. "Settings"
2. "Head-up display"
3. "Head-up display"
   Switch the Head-up Display ON/OFF as required.

Display

1. Lane departure warning
2. Active Cruise Control
3. Desired speed
4. Navigation system
5. Speed

The collision warning, Night Vision pedestrian warning, or Check Control messages are displayed briefly if needed.

Selecting displays in the Head-up Display
1. "Settings"
2. "Head-up display"
3. "Display information"
4. Select the desired displays in the Head-up Display.
   The settings are stored for the remote control currently in use.

Setting the brightness
The brightness is automatically adjusted to the ambient light.
The basic setting can be adjusted manually.
1. "Settings"
2. "Head-up display"
3. "Brightness"
4. Turn the controller.
   The brightness is adjusted.

When the low beams are switched on, the brightness of the Head-up Display can be additionally influenced using the instrument lighting, refer to page 99.
The setting is stored for the remote control currently in use.

Adjusting the height
1. "Settings"
2. "Head-up display"
3. "Height"
4. Turn the controller.
   The height is adjusted.
The setting is stored for the remote control currently in use.

Setting the rotation
1. "Settings"
2. "Head-up display"
3. "Rotation"
4. Turn the controller.
   Rotation is set.
The setting is stored for the remote control currently in use.
APPENDIX C

Run Log
<table>
<thead>
<tr>
<th>Run</th>
<th>Lane Marking Type</th>
<th>Departure Direction</th>
<th>Valid Run?</th>
<th>Distance at Tactile Alert (ft)</th>
<th>Pass/Fail</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Botts Right</td>
<td>Y</td>
<td>0.73</td>
<td>Pass</td>
<td></td>
<td></td>
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<td>2</td>
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<td>Pass</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
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<td></td>
<td></td>
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<td>4</td>
<td></td>
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<td>Object in lane</td>
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<td>5</td>
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<td>6</td>
<td></td>
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<td>15</td>
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<td>0.49</td>
<td>Pass</td>
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<td>Run</td>
<td>Lane Marking Type</td>
<td>Departure Direction</td>
<td>Valid Run?</td>
<td>Distance at Tactile Alert (ft)</td>
<td>Pass/Fail</td>
<td>Notes</td>
</tr>
<tr>
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<td>------------</td>
<td>-----------------------------</td>
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<tr>
<td>16</td>
<td>Solid</td>
<td>Left</td>
<td>Y</td>
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<td>25</td>
<td></td>
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<td>0.52</td>
<td>Pass</td>
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<td>26</td>
<td></td>
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<td>0.5</td>
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<td>Distance at Tactile Alert (ft)</td>
<td>Pass/Fail</td>
<td>Notes</td>
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<td>Pass</td>
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<tr>
<td>35</td>
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<td>Y</td>
<td>0.73</td>
<td>Pass</td>
<td></td>
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<td>36</td>
<td></td>
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<td>Y</td>
<td>0.7</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Dashed</td>
<td>Left</td>
<td>Y</td>
<td>0.69</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
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<td>Y</td>
<td>0.53</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
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<td>Y</td>
<td>0.58</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>40</td>
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<td>0.47</td>
<td>Pass</td>
<td></td>
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<tr>
<td>41</td>
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<td>Y</td>
<td>0.49</td>
<td>Pass</td>
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</tbody>
</table>
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Time History Plots
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Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from the Subject Vehicle, as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color code for data envelopes.

Time History Plot Description

Time history figures include the following sub-plots:

- Event – indicates timing of warning issued by LDW system. Depending on the type of LDW alert or instrumentation used to measure the alert, this can be any of the following:
  - Filtered and rectified sound signal
  - Filtered and rectified acceleration (e.g., steering wheel vibration)
  - Light sensor signal
  - Discrete on/off value
- Speed (mph) – speed of the Subject Vehicle
- Yaw Rate (deg/sec) – yaw rate of the Subject Vehicle
- Dist to Lane Edge (ft) – lateral distance (in lane coordinates) from the outer front tire bulge to the inside edge of the lane marking of interest for a given test (a positive value indicates the vehicle is completely within the lane while a negative value indicates that the outer front tire bulge has crossed over the inner lane marking edge)
- Lateral Velocity (ft/sec) – lateral velocity (in lane coordinates) of the outer front tire bulge
- Bird’s Eye View – Indicates the position of the Subject Vehicle with respect to the lane marking of interest for a given test. Green rectangles represent the Subject Vehicle’s position at approximately 2 second intervals, while the yellow rectangle indicates the position of the Subject Vehicle at the time of LDW warning issuance.
Envelopes and Thresholds

Each of the time history plot figures can contain either green or yellow envelopes and/or black threshold lines. These envelopes and thresholds are used to programmatically and visually determine the validity of a given test run. Envelope and threshold exceedances are indicated with either red shading or red asterisks, and red text is placed to the right side of the plot indicating the type of exceedance.

Green envelopes indicate that the time-varying data should not exceed the envelope boundaries at any time within the envelope. Exceedances of a green envelope are indicated by red shading in the area between the measured time-varying data and the envelope boundaries.

Yellow envelopes indicate that the time-varying data should not exceed the envelope only at the right end. Exceedances at the right extent of a yellow envelope are indicated by red asterisks. Data within the boundaries at the right extent of a yellow envelope are indicated by green circles.

Color Codes

Color codes have been adopted to easily identify the types of data, envelopes and thresholds used in the plots.

Color codes can be broken into three categories:

1. Validation envelopes and thresholds
2. Instantaneous samplings
3. Text

1. Validation envelope and threshold color codes:
   - Green envelope = time varying data must be within the envelope at all times in order to be valid
   - Yellow envelope = time varying data must be within limits at right end
   - Black threshold (Solid) = time varying data must not exceed this threshold in order to be valid
   - Black threshold (Dashed) = for reference only – this can include warning level thresholds which are used to determine the timing of the alert

2. Instantaneous sampling color codes:
   - Green circle = passing or valid value at a given moment in time
   - Red asterisk = failing or invalid value at a given moment in time
3. Text color codes:
   • Green = passing or valid value
   • Red = failing or invalid value

   Examples of time history plots (including passing, failing and invalid runs) are shown in Figure D1 through Figure D3. Actual time history data plots for the vehicle under consideration are provided subsequently.
Figure D1. Example Time History for Lane Departure Warning Test, Passing

GPS Fix Type: RTK Fixed
Figure D2. Example Time History for Lane Departure Warning Test, Failing, No Warning Issued
Figure D3. Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate

GPS Fix Type: RTK Fixed
Figure D4. Time History for Run 1, Botts Dots, Right Departure, Haptic Warning
GPS Fix Type: RTK Fixed

Figure D5. Time History for Run 2, Botts Dots, Right Departure, Haptic Warning
GPS Fix Type: RTK Fixed

Figure D6. Time History for Run 3, Botts Dots, Right Departure, Haptic Warning
Figure D7. Time History for Run 5, Botts Dots, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D8. Time History for Run 6, Botts Dots, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D9. Time History for Run 7, Botts Dots, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D10. Time History for Run 8, Botts Dots, Right Departure, Haptic Warning
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Figure D12. Time History for Run 10, Botts Dots, Left Departure, Haptic Warning
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GPS Fix Type: RTK Fixed
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GPS Fix Type: RTK Fixed
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GPS Fix Type: RTK Fixed
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Figure D32. Time History for Run 31, Dashed Line, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D33. Time History for Run 32, Dashed Line, Right Departure, Haptic Warning
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Figure D35. Time History for Run 34, Dashed Line, Right Departure, Haptic Warning
Figure D36. Time History for Run 35, Dashed Line, Right Departure, Haptic Warning
Figure D37. Time History for Run 36, Dashed Line, Right Departure, Haptic Warning
Figure D38. Time History for Run 37, Dashed Line, Left Departure, Haptic Warning
Figure D39. Time History for Run 38, Dashed Line, Left Departure, Haptic Warning
Figure D40. Time History for Run 39, Dashed Line, Left Departure, Haptic Warning
Figure D41. Time History for Run 40, Dashed Line, Left Departure, Haptic Warning
Figure D42. Time History for Run 41, Dashed Line, Left Departure, Haptic Warning
Figure D43. Time History for Run 42, Dashed Line, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D44. Time History for Run 43, Dashed Line, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed