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Vehicle Automatic Lower Beam Activation System Test Procedure Development

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16. Abstract

This report describes the development of a draft test procedure for measuring the performance of vehicle automatic lower beam headlamp activation systems and testing of a small set of systems. These systems are used to automatically activate lower beam headlamps – often called low-beam headlights – of a vehicle based on ambient light levels. When the ambient illumination level decreases to a specific value, such as at dusk, the system automatically activates the lower beam headlamps. Similarly, when the ambient illumination level increases to a specific value, the lower beam headlamps automatically deactivate.

This research examined the current state of performance of automatic lower beam headlamp activation systems and developed a means for measuring system performance. The main objectives were (1) to develop a draft test procedure that could assess the operation of automatic lower beam headlamp activation systems by measuring the ambient light level and response times of automatic lower beam activation and deactivation and (2) use the draft test procedure to measure these values for a small set of test vehicles. The developed draft test procedure drew from UNECE Regulation No. 48. A lamp with adjustable light level setting was used to control the artificial ambient light level cast on the tested light sensor. Through this effort, a laboratory-based method for simulating ambient sunlight coming from a realistic direction and measuring that ambient illumination at a vehicle's exterior windshield surface was identified. Test procedure steps, as well as equipment, test environment, and procedures were documented.

Testing using the developed draft laboratory test procedure was performed on five light vehicles. Results showed a range of values for both the ambient illumination level values and response times for headlamp activation and deactivation across vehicles. The draft test procedure was also performed on one of the tested vehicles a second time in outdoor, natural sunlight conditions for comparison with laboratory results. Comparing the outdoor test results for a single vehicle with the same vehicle's indoor test results confirmed that the indoor test could replicate those of testing performed under natural lighting conditions for that vehicle. Overall, the developed draft test procedure was found to be effective for assessing the performance of a vehicle automatic lower beam activation system for the vehicles tested.

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Executive Summary

This report describes development of a draft test procedure for measuring the performance of vehicle automatic lower beam headlamp activation systems and testing of a small set of systems. These systems automatically activate lower beam headlamps based on ambient light levels. When the ambient illumination level decreases to a specific value, such as at dusk, the system automatically activates the lower beam headlamps. Similarly, when the ambient illumination level increases to a specific value, the lower beam headlamps automatically deactivate. While some headlighting systems will automatically activate lower beam headlamps in conditions of precipitation in daylight, this work did not address that condition.

This research sought to gather information to better the understanding of the current state of automatic headlamp activation system performance and develop a means for measuring system performance. The main objectives were (1) to develop a draft test procedure that could assess the operation of automatic headlamp activation systems by measuring the ambient light level and response times of automatic lower beam activation and deactivation (i.e., how long after the stimulus light level was reached did the system respond) and (2) use the draft test procedure to measure these values for a small set of test vehicles. The developed draft test procedure drew from UNECE Regulation No. 48 (2016). A lamp with adjustable light level setting was used to control the artificial ambient light level cast on the tested system's light sensor. Through this effort, a laboratory-based method for simulating ambient sunlight coming from a realistic direction and measuring that ambient illumination at a vehicle's exterior windshield surface were identified. Test procedure steps, as well as equipment, test environment, and procedures were documented.

The draft test procedure was used to test five 2022 model year passenger cars. Test results showed a range of values for both the ambient illumination level values and response times for headlamp activation and deactivation. These observed values document the performance of existing systems. Most measured values met UNECE Regulation No. 48 requirements. The draft test procedure was also performed on one of the test vehicles a second time in outdoor, natural sunlight conditions for comparison with lab results. Comparing the outdoor test results with the same vehicle's indoor test results confirmed that the indoor test could replicate those of testing performed under natural lighting conditions. Overall, the draft test procedure was found to be useful for assessing performance of vehicle automatic lower beam headlamp activation systems.

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Introduction

Per FMVSS No. 108, lower beams, or beams provided by lower beam headlamps, are "intended to illuminate the road and its environs ahead of the vehicle when meeting or closely following another vehicle" (49 CFR 571.111). Lower beams are "also referred to as "Passing Beam" and "Dipped Beam" in ECE regulation," where "dipped" refers to the beam being directed downward to illuminate the area in front of the vehicle at close range. Automatic lower beam headlamp activation systems are used to automatically control activation of a vehicle's lower beam headlamps based on the ambient light level to ensure that these lamps are illuminated when ambient conditions warrant it. When the ambient illumination level decreases to the extent that visibility is reduced, such as at dusk, this system automatically turns on the lower beam headlamps. Similarly, when the ambient illumination level increases to a particular level, the lower beam headlamps automatically turn off.

Background

Automatic lower beam activation capability has been available in some form on passenger vehicles since the 1950's. Early systems such as GM's Twilight Sentinel were available on luxury models. Currently, many new U.S. passenger car models have automatic lower beam headlamp activation systems, but there are no requirements for their performance in Federal Motor Vehicle (FMVSS) No. 108, *Lamps, reflective devices, and associated equipment* (49 CFR 571.108, 2007). However, with a mixed fleet where some vehicles have automatic lower beam headlamp activation systems and others do not, it is possible that drivers may inadvertently drive without headlamps turned on in conditions when they should be used. For example, drivers who are accustomed to lower beam headlamps turning on automatically may not realize a vehicle they have newly purchased, rented, or borrowed does not have automatic lower beam headlamp activation system or may not think to take action to turn on the headlamps.

Several regulatory agencies around the world have made these systems standard on new vehicles. UNECE .NO. 48 (2016) has mandated these systems since 2016, and as of 2020, new vehicles sold in Japan are required to have these systems. These systems ensure that lower beams are active in low ambient lighting conditions, increasing visibility for the driver and conspicuousness of the vehicle. While NHTSA is not aware of any study that has examined lower beam use rate that would suggest that drivers do not consistently turn them on, with the introduction of daytime running lamps (DRLs) and constantly illuminated instrument panel gauges, it is possible that these illumination sources may cause drivers to believe their lower beam headlamps are on when they are not.

Objectives and Scope

This research sought to gain better understanding of the current state of performance of systems that automatically turn on or off lower beam headlamps in response to ambient lighting conditions and develop a way to measure system performance. The main objectives were (1) to develop a draft test procedure for assessing operation of automatic headlamp activation systems by measuring the ambient light level and response times of automatic lower beam activation and deactivation and (2) use the draft test procedure to measure these values for a small set of test vehicles. Such a draft test procedure would measure the ambient light level and response time of automatic lower beam activation and deactivation. It should be noted this work did not address lower beam headlamp automatic activation for conditions of precipitation in daylight.

One objective of this research effort investigated whether automatic lower beam activation system testing could be performed in an indoor laboratory with controlled lighting simulating daylight and darkness. To develop the draft test procedure, a method (e.g., simulating ambient sunlight coming from a realistic direction) was identified for measuring ambient illumination at the vehicle windshield. Equipment, test environment requirements, and procedures were documented.

Once developed and documented, the draft test procedure was applied to a small set of test vehicles to determine the ambient illumination level at which each vehicle's automatic headlamp activation system turned on its lower beam headlamps.

Method

This section describes development of the specified draft test procedure, equipment used, and test approach.

Test Procedure Development

The draft test procedure details were adapted from Annex 13 of UNECE No. 48 (2016), which describes the required conditions for automatic switching of dipped-beam headlamps, referred to in FMVSS No. 108 (2022) as lower beam headlamps. Annex 13 states the ranges of ambient light levels outside the vehicle at which an automatic lower beam headlamp activation system must turn "dipped-beam" headlamps on or off. It also states that illuminance must be measured on a horizontal surface with a cosine corrected sensor located at the same height as the vehicle light sensor. Annex 13 states that when the ambient light is 7,000 lux[1] or greater the dipped-beam headlamps shall be off, when the ambient light is 1,000 lux or less the dipped-beam headlamps shall be on, and at any value in between the headlamp status is left to the manufacturer's discretion. Annex 13 also states the response time for activation shall be no more than 2 seconds and the response time for deactivation shall be more than 5 seconds and no more than 300 seconds. The range of observed ambient light level was chosen based on the ambient light requirements of UNECE No. 48, which range from 1,000 lux to 7,000 lux. UNECE No. 48 does not specify a test procedure for assessing automatic switching of dipped-beam headlamps, by states in Annex 13, "Compliance with these conditions shall be demonstrated by the applicant, by simulation, or other means of verification accepted by Type Approval Authority."

The test procedure was developed with the assumption that it would be performed on fully assembled production vehicles. While it may be possible to perform such a test procedure using relevant vehicle components, it would be challenging. Vehicle components needed would include the system light sensor (mounted behind the windshield), windshield, and likely at least a portion of the vehicle's roof to ensure that the ambient source casts its light onto the components in a realistic way. The positions and orientations and special relationships of these components and the ambient light source likely affect the systems performance and, therefore, would be important to accurately represent in any test procedure. The position and orientation of the illuminance receptor head used to measure of the ambient light level were considered important in order to match the system light sensor's orientation and distance from the ambient light source.

Test Equipment and Instrumentation

The two primary pieces of equipment needed for testing were an illuminance meter and an ambient light source with controllable light output level.

[1] "Lux: The amount of light that is cast on a surface is called illuminance, which is measured in lux. This can be thought of as light intensity within a specific area. Lumens: The total output of visible light from a light source is measured in lumens. Typically, the more lumens a light fixture provides, the brighter it is. One lux is equal to one lumen per square meter (lux = lumens/m^2). Essentially, as light travels from the emitter, it will disperse throughout an area. The further the light has to travel the more it will be dispersed. Therefore, the amount of lux in an area or on a surface can vary depending upon the distance the light travels and the angle at which it is dispersed" (see Banner Engineering Corp., n.d.).

The Konica Minolta T-10A[2] was chosen as the illuminance meter for its ability to record measurements from two or more receptor heads at once, which facilitated measuring the output of the ambient light and headlamps simultaneously. The receptor heads for this illuminance meter are cosine corrected, which follows the requirement in UNECE No. 48 for an illuminance measuring device. UNECE No. 48 notes that the ambient light is measured outside the vehicle with a light sensor positioned on the same horizontal plane as the vehicle's automatic lower beam headlamp activation system light sensor. For this reason, the illuminance receptor head measuring the ambient light level was placed outside the vehicle, at the same orientation, and as close to the light sensor as possible.

A second illuminance receptor head, connected in series and on the same time scale as the first receptor head, was used to determine when the lower beams of the test vehicle activated. The distance this sensor was from the front of the vehicle was deemed to be not critical so long as it was able to capture the lower beam activation and deactivation. For this effort, a distance of 3 feet (0.914 m) was chosen.

The ambient light source[3] was chosen for its easily adjustable light output intensity using controlled adjustments, as described below. The controlled adjustments were needed to accurately and finely reduce or increase the lamp's light output and ambient light levels during testing. In order to determine the ambient light level at lower beam activation and deactivation and measure the response time of the lower beam activation system, the output of the light source was incrementally decreased with each new light level held for a period of time. The ambient light source was able to change to any 1% increment of its maximum output. A step size of 5% changes in light output and a hold time of 1 minute were chosen to keep testing duration reasonable while still capturing the vehicle's response. This approach resulted in a full test cycle of lower beam activation and deactivation taking around 40 minutes to complete.

The ambient light source was also remotely controllable. This allowed the person performing the test to be away from the immediate area of the test vehicle and not interfere with the test procedure.

The color temperature of the light source was also adjustable from 2,700K to 6,500K. UNECE No. 48 does not specify requirements of a light source, so the light source was set to the highest color temperature possible of 6,500K. Although the color temperature of sunlight can be lower at sunrise and sunset, a temperature of 6,500K more closely matches daylight conditions. UNECE-compliant vehicles are required to have their lower beam headlamps switched on when the ambient light level is under 1,000 lux and switched off when the ambient light exceeds 7,000 lux.

To find the best distance between the light source and the sensor, the minimum and maximum light source output was measured at several distances. After some trial and error, it was found that at a distance of 2.5 feet (0.762 m), the range of possible illumination from the light source was approximately 500 lux to 7,500 lux, which encompassed the 1,000- to 7,000 lux range of UNECE-required values.

[2] Konica Minolta Sensing Americas Inc., Ramsey, NJ. See Konica Minolta (n.d.).

[3] The light source used for this effort was a Novostella 100W Smart tunable white LED flood light, Shenzhen Ustellar Technology Ltd., Shenzhen, Guangdong, China.

The following table on the next page lists the instrumentation used for obtaining data measurements, where equivalent options could be substituted.

Table 1. Test Equipment and Instrumentation

Item	Quantity	Purpose
Konica Minolta T-10A Illuminance Meter	1	Main hub for collecting lux measurements from headlamps and overhead lights. Permitted simultaneous measurements from multiple illuminance receptor heads. Specifications include cosine correction characteristics: “Within ±1% at 10°; Within ±2% at 30°; Within ±6% at 50°; Within ±7% at 60°; Within ±25% at 80°”[2]
T-10 Illuminance Receptor Heads (RH)	2	Additional receptor heads for taking all required measurements
Stands for Receptor Heads	2	Holds receptor heads at appropriate measurement height and location
CAT5 Ethernet Cabling	-	Connects illuminance meter with receptor heads for synchronized data collection
Laptop	1	Connects to illuminance meter, records data collection
Novostella 100W Smart Tunable White LED Flood Lights	1	Used to simulate outdoor lighting conditions. Lamp output range included the UNECE required values of 1,000 lux to 7,000 lux.
Boom Arm	1	Used to position flood lights above the vehicle
Smartphone	1	Used to control the flood lights via Bluetooth

Test Environment

Testing was conducted in an indoor laboratory area in which ambient lighting level could be controlled to simulate daylight and darkness at the location of vehicles’ automatic lower beam headlamp activation system sensor.

Test Procedure

The following is an outline of steps to set up and execute this draft test procedure using the equipment listed previously. These steps could be carried out by a single person.

Test Preparation and Setup

1) The test vehicle battery voltage was confirmed to be within normal operating range. The headlamps, windshield, and light sensor coverings were wiped clean to ensure they were free of dirt or other substances that might impact system performance.
2) The test vehicle was positioned in the controlled test environment.
3) The system’s light sensor location on the vehicle was determined, noting both its position and orientation.

4) The cosine corrected receptor heads were set up in their respective locations for illuminance measurement.
   a) Receptor head (RH) #1 measured the ambient light level.
   b) RH #2 measured the test vehicle's lower beam headlamp output.
   c) Both receptor heads were connected in series to the Konica Minolta T-10A illuminance meter.
   d) Illuminance receptor heads were attached to the appropriate mounting fixtures.
      i) RH #1 was adjusted such that a perpendicular axis going through the center of the RH hemisphere was in the same direction as the perpendicular axis through the face of the light sensor.
      ii) RH #2 was vertical, with the sensor facing the front of the vehicle.
   e) RH #1 was positioned on the same horizontal plane as the test vehicle's light sensor. RH #1 was located as close as possible to the vehicle's light sensor without obstructing it.
   f) RH #2 was located 3 feet (0.914 meters) longitudinally from the center of the front-most point of the vehicle, laterally in line with the optical center of the driver-side lower beam, and at the same height as the optical center of the driver-side lower beam. The RH was facing the vehicle.
5) Set up the ambient light source.
   a) The light source was positioned such that a perpendicular axis going through the face of the light source ran in the same direction as a perpendicular axis through the face of light sensor.
   b) The light source was placed 2.5 feet (0.762 meters) away from the light sensor.

The following diagram shows the general test setup. The positioning of the illuminance receptor head at the exterior of the windshield (RH #1) and the height of the stimulus light source depended on the location and orientation of a test vehicle's light sensor as described in points 4 and 5 above. For the tested vehicles, the light sensor locations and orientations were visually apparent.

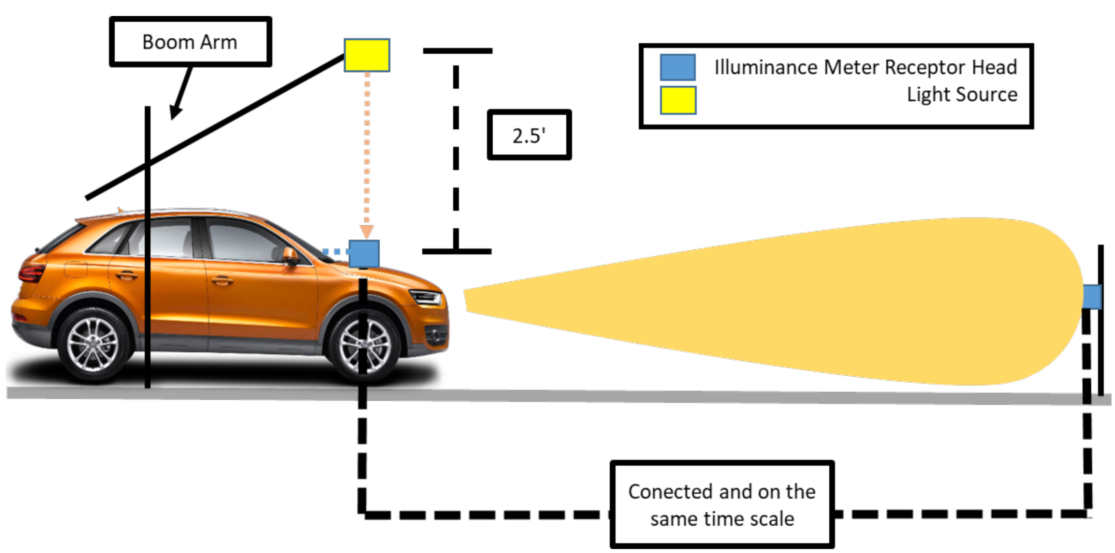

Figure 1. Illustration of Test Setup

Lower Beam Activation Test

1) Before testing, all other light sources within the test environment were turned off and the ambient light level was recorded via the illuminance meter.
2) The ambient light source was turned on at maximum output.
3) The test vehicle's headlighting system control was set to its automatic setting.
4) The test vehicle's engine was turned on.
5) The data collection and recording began.
   a. After at least 1 minute, the ambient light source's output was decreased by 5%
      i. This step (decreasing by increments of 5% each minute) was repeated until the lower beams were activated, or the output was 0%.

Lower Beam Deactivation Test

1) Before testing, all other light sources were turned off and the ambient light level was recorded.
2) The ambient light source was turned on at minimum output.
3) The test vehicle's headlighting system control was set to its automatic setting.
4) The test vehicle's engine was turned on.
5) Data collection and recording began.
   a. After at least 1 minute, the ambient light source's output was increased by 5%.
      i. This step (increasing by increments of 5% each minute) was repeated until the lower beam was deactivated, or the output was 100%.

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Results

Test Vehicles

The vehicle models tested for this effort are listed in the table below.

Table 2. Test Vehicle Information

Model Year	Make and Model	Trim	VIN (First 10 digits)	Light Sensor Type	Light Sensor Location and Orientation
2022	Chevrolet Equinox	Limited	2GNAXXEV4N	Light sensor	On top of the dashboard near the bottom of the windshield
2022	Hyundai Tucson	Limited	5NMJECAE0NH	Light sensor	Near top of the windshield, at a 25° angle from horizontal
2022	Subaru Outback	Touring	4S4BTAPC3N	Light sensor	On top of the dashboard near the bottom of the windshield
2022	Tesla Model Y	-	7SAYGDEE6NF	Forward-facing camera	Near top of the windshield, facing the forward direction of the vehicle
2022	Toyota Camry	SE	4T1G11AKXNU	Light sensor	On top of the dashboard near the bottom of the windshield

Analysis Method

For analysis of the automatic headlamp activation systems' performance, illuminance data was plotted versus time. The headlamps activating or deactivating was signified by a large and instantaneous change in the measured value of illuminance for receptor head (RH #2). The limit for the light sensor activation or deactivation was then identified using the overhead illuminance receptor head (RH #1) output (illuminance reading of light level cast on the windshield) right before the significant change in RH #2 measured value (the change in the illuminance reading of the headlamp). The time for lower beam activation or deactivation can then be determined by the time between the last detected RH #1 light level drop and the RH #2 change. The following figure shows a sample of the lower beam activation data output where, in this example, the limit for activation is 2700 lux and the time for activation is 19.8 seconds. Lower beam deactivation data analysis is similar to lower beam activation except with increasing ambient light and the deactivation being marked by a sudden decrease in the reading of RH #2 that measured the headlamp light output.

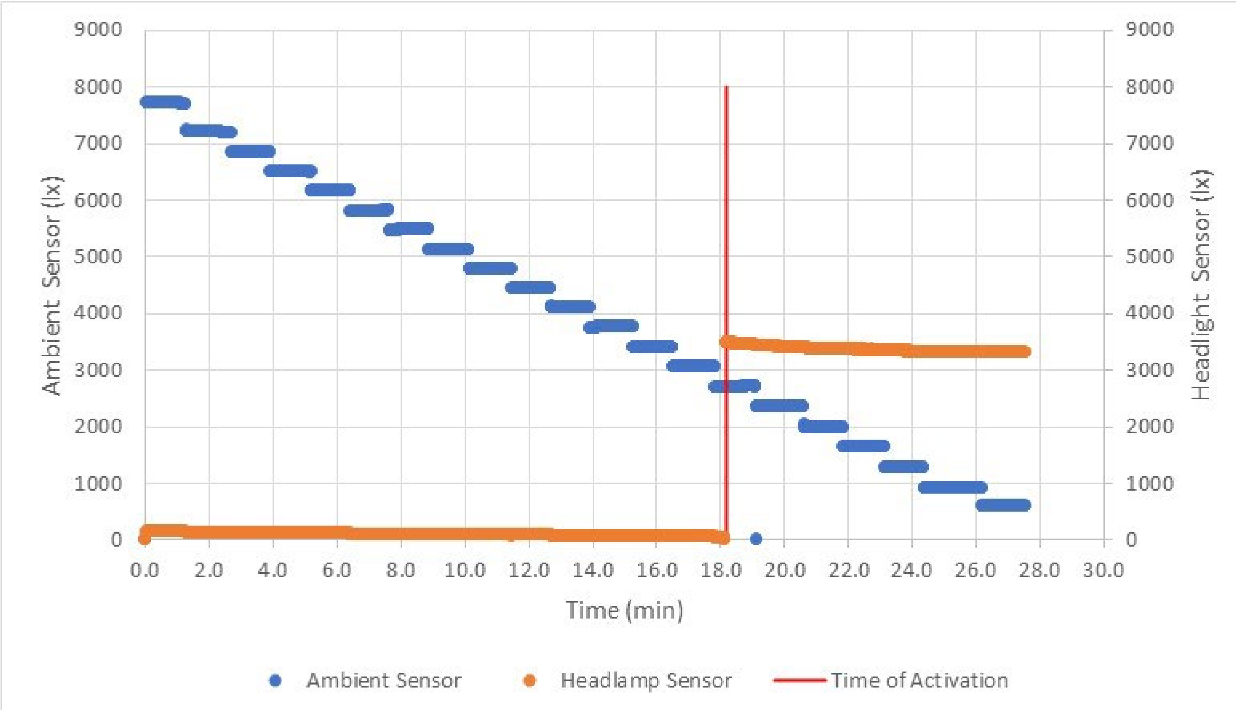

Figure 2. Lower Beam Activation Data Output Example

Test Results

Test results reported for each vehicle include both lower beam activation and deactivation measured values for the time of activation or deactivation of the headlamps and the illuminance value at the time of headlamp activation or deactivation. As the design criteria for these values were not known, it therefore could not be determined if the values measured using this test procedure reflected expected values.

Lower Beam Activation

The following table shows the test results for the light level at which the lower beams were automatically activated and the activation time.

Table 3. Lower Beam Activation Results

Make	**Chevy**	**Hyundai**	**Subaru**	**Tesla**	**Toyota**
Model	**Equinox**	**Tucson**	**Outback**	**Model Y**	**Camry**
Activation Time (s)	25.6	10.4	19.8	3.5	19.8
Ambient Light Illuminance of Activation (lux)	1,140	4,240	2,700	529	2,550

Figures 3 to 7 illustrate the stimulus and headlamp output illuminance levels and timing of lower beam activation for the tested vehicles.

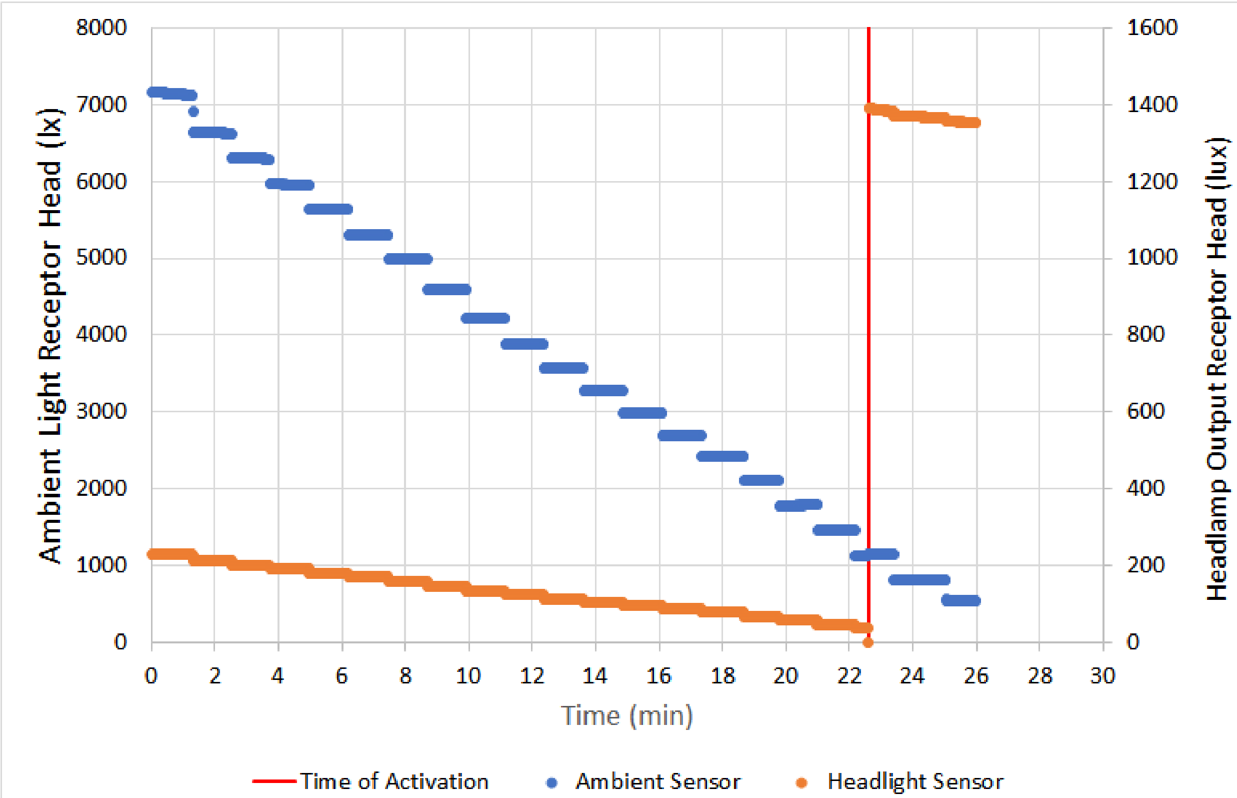

Figure 3. 2022 Chevrolet Equinox Lower Beam Activation

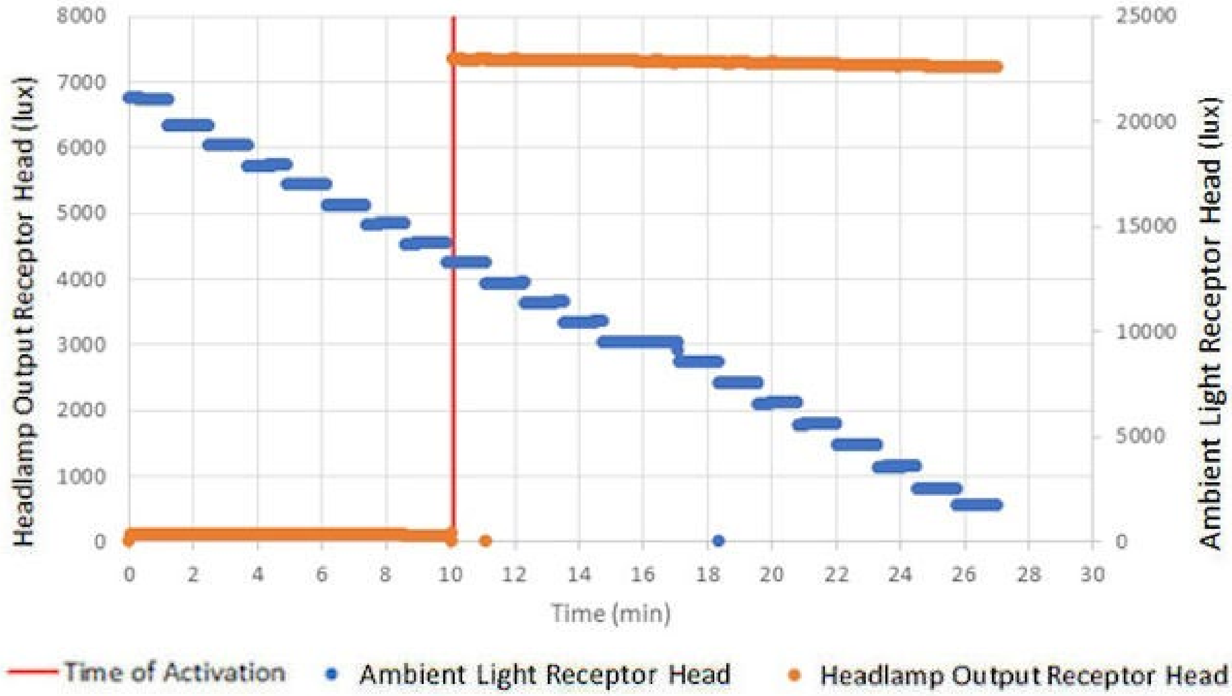

Figure 4. 2022 Hyundai Tucson Lower Beam Activation

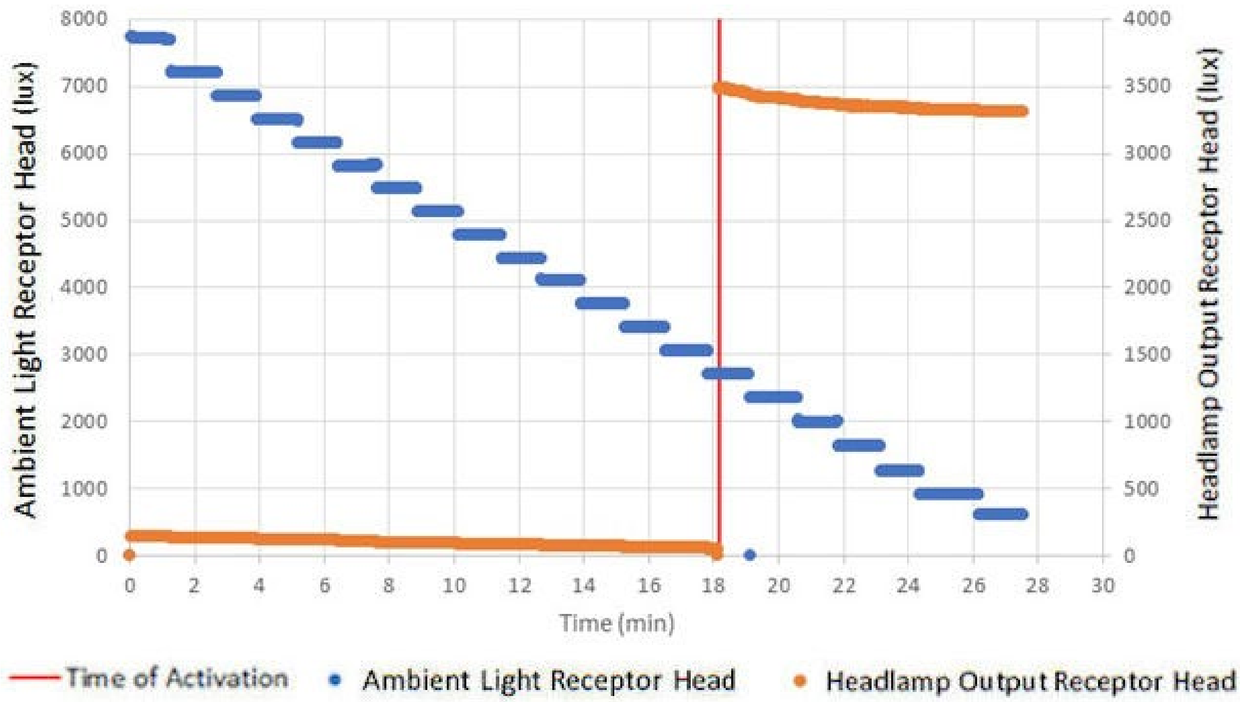

Figure 5. 2022 Subaru Outback Lower Beam Activation

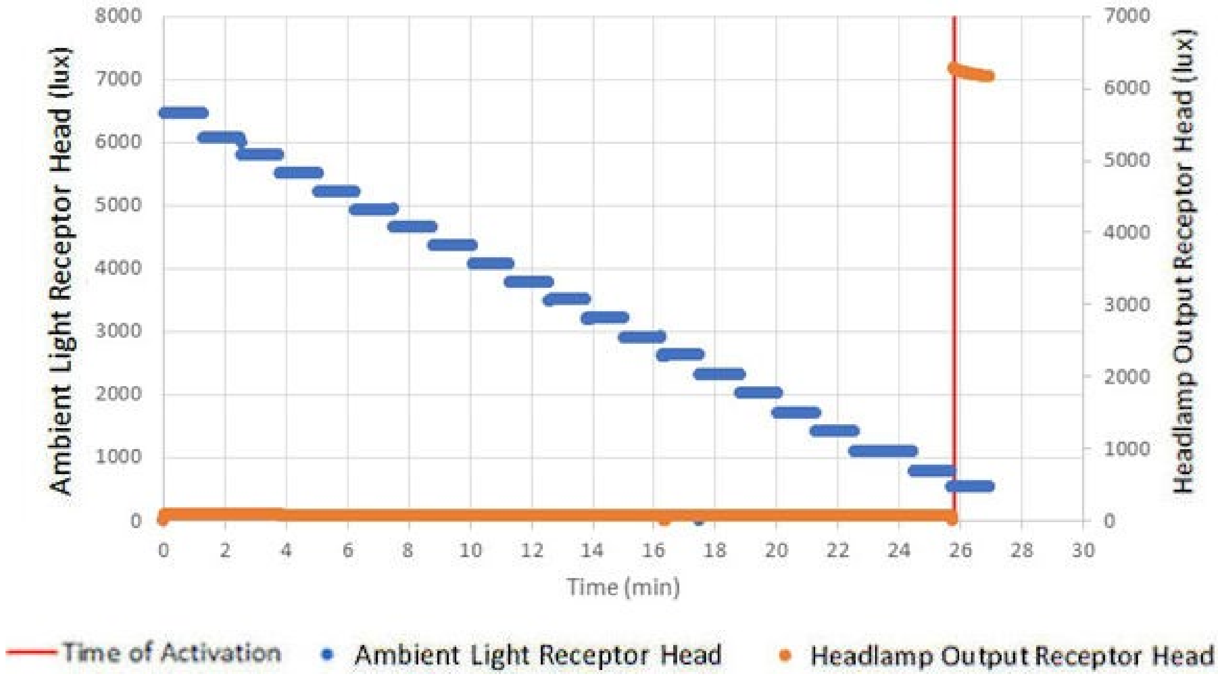

Figure 6. 2022 Tesla Model Y Lower Beam Activation

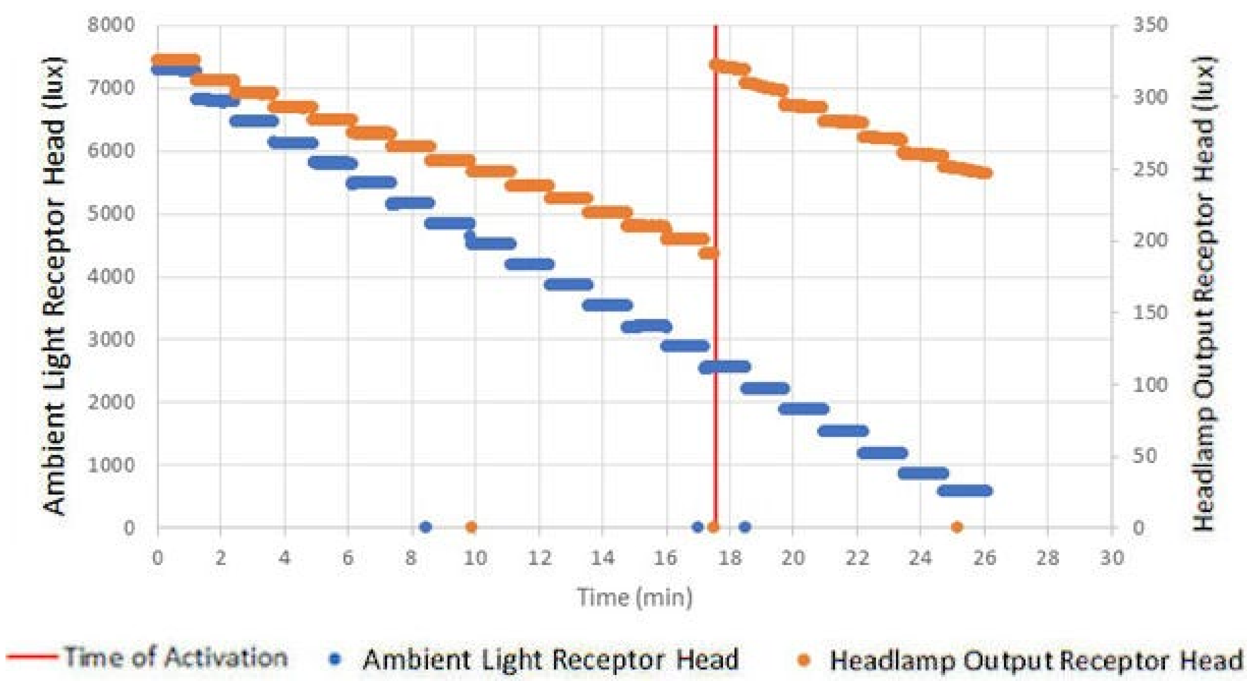

Figure 7. 2022 Toyota Camry Lower Beam Activation

Headlamp Deactivation

The following table shows the test results for the light level at which lower beam deactivation occurred and the deactivation time.

Table 4. Lower Beam Deactivation Results

Make	**Chevy**	**Hyundai**	**Subaru**	**Tesla**	**Toyota**
Model	**Equinox**	**Tucson**	**Outback**	**Model Y**	**Camry**
Deactivation Time (s)	24.4	N/A	19.7	9.3	16.3
Ambient Light Illuminance of Deactivation (lux)	2,176	> 7,000	4,180	2,051	6,500

Figures 8 through 12 below illustrate the stimulus and headlamp output illuminance levels and timing of lower beam deactivation for the tested vehicles.

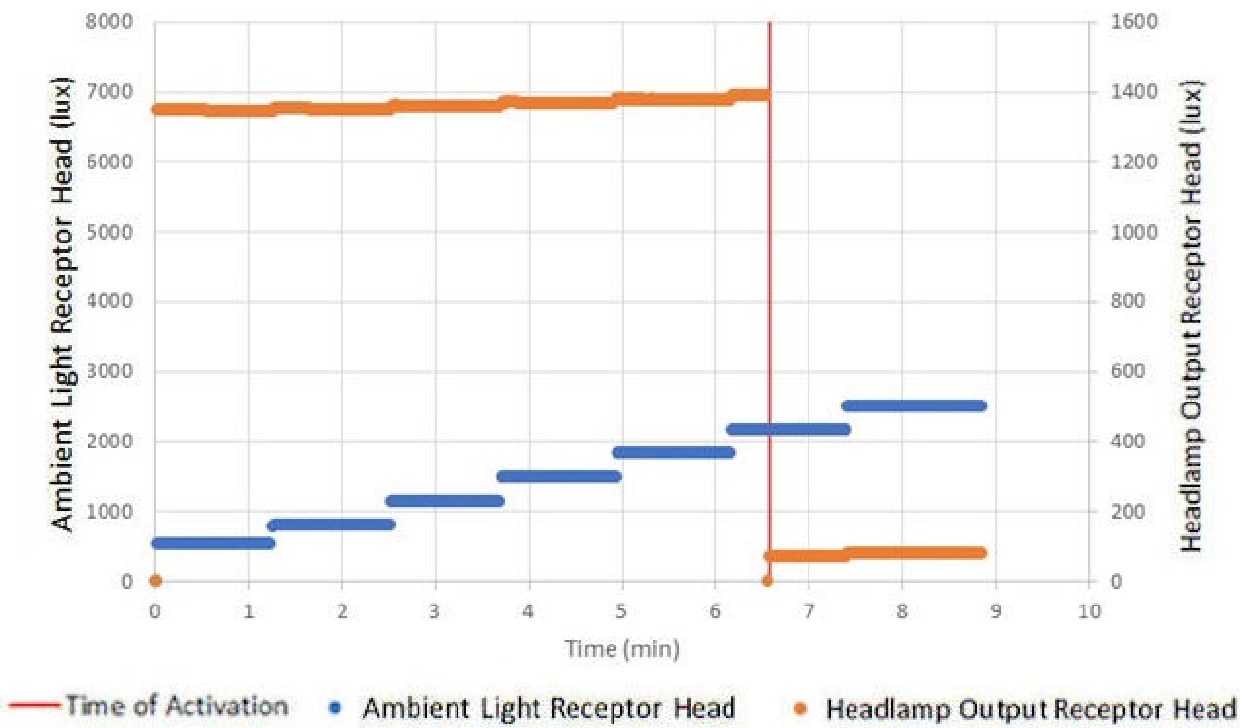

Figure 8. 2022 Chevrolet Equinox Lower Beam Deactivation

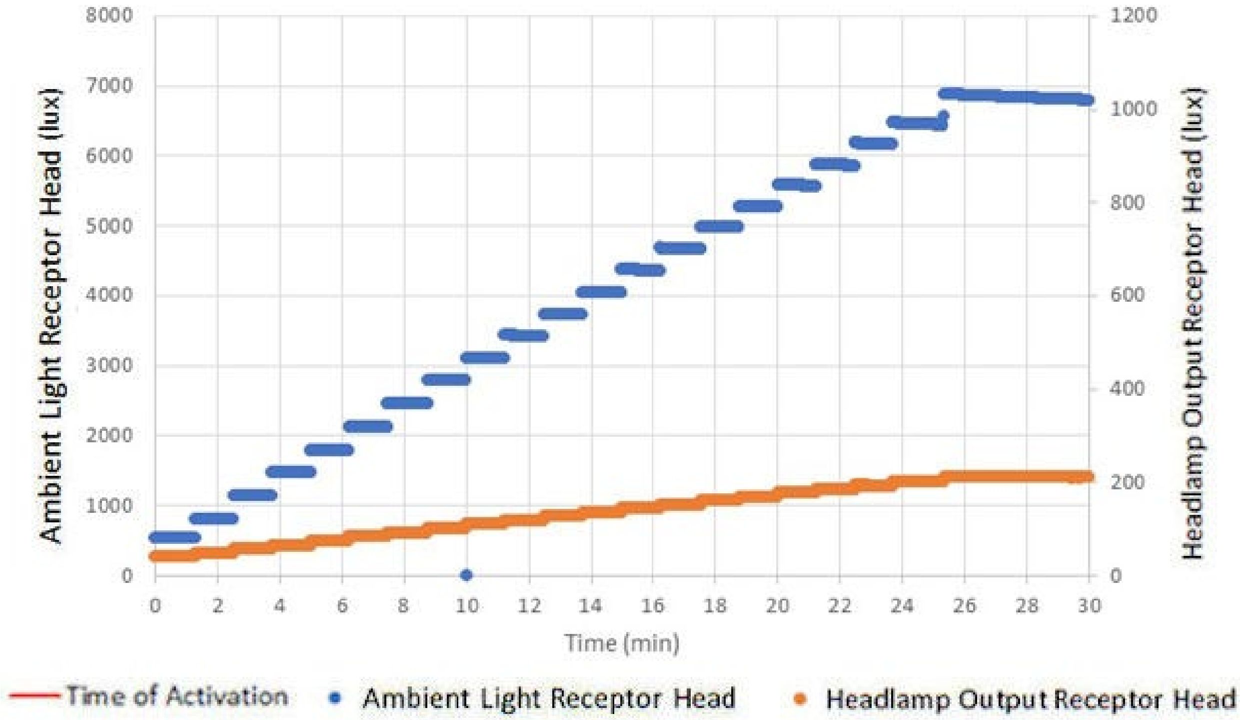

Figure 9. 2022 Hyundai Tucson Lower Beam Deactivation

The lower beam deactivation characteristics were not able to be recorded for the 2022 Hyundai Tucson Limited. The lower beams were not observed to change state even at the maximum output of the ambient light source (approximately 7,000 lux). The lower beam activation for this vehicle also occurred at a higher illuminance value than any of the other tested vehicles. The light sensor location was confirmed by the manufacturer to be the sensor tested.

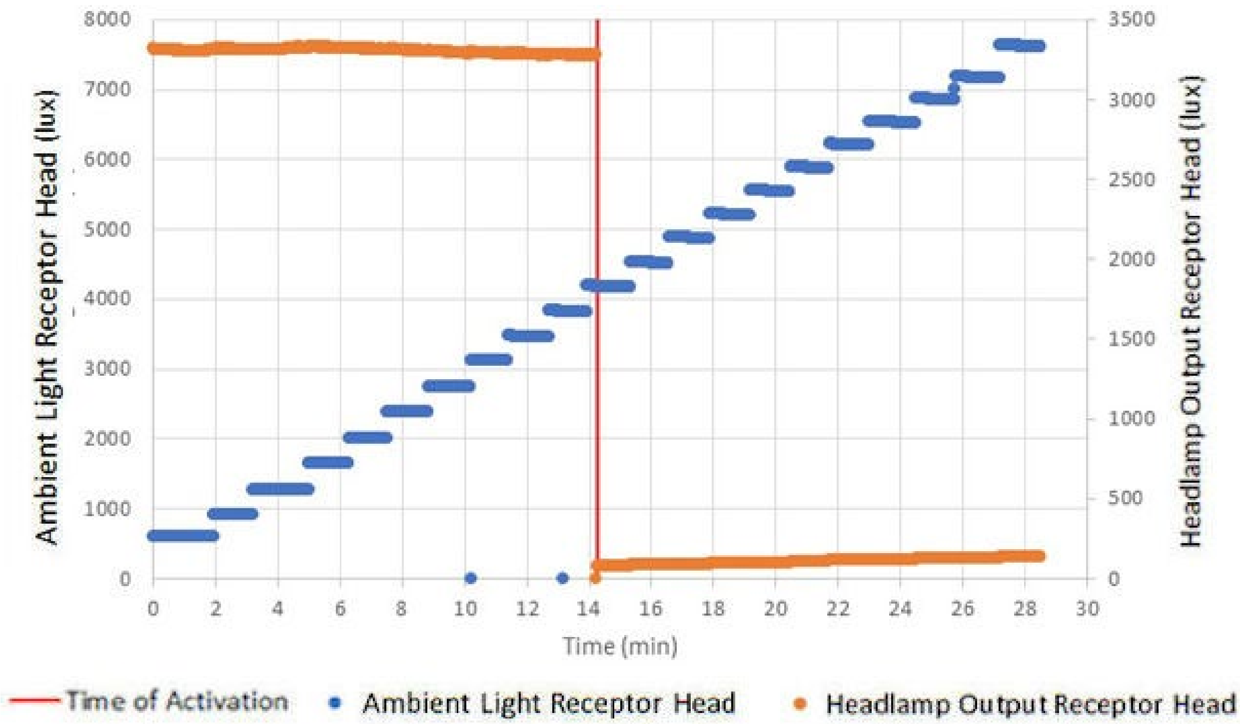

Figure 10. 2022 Subaru Outback Lower Beam Deactivation

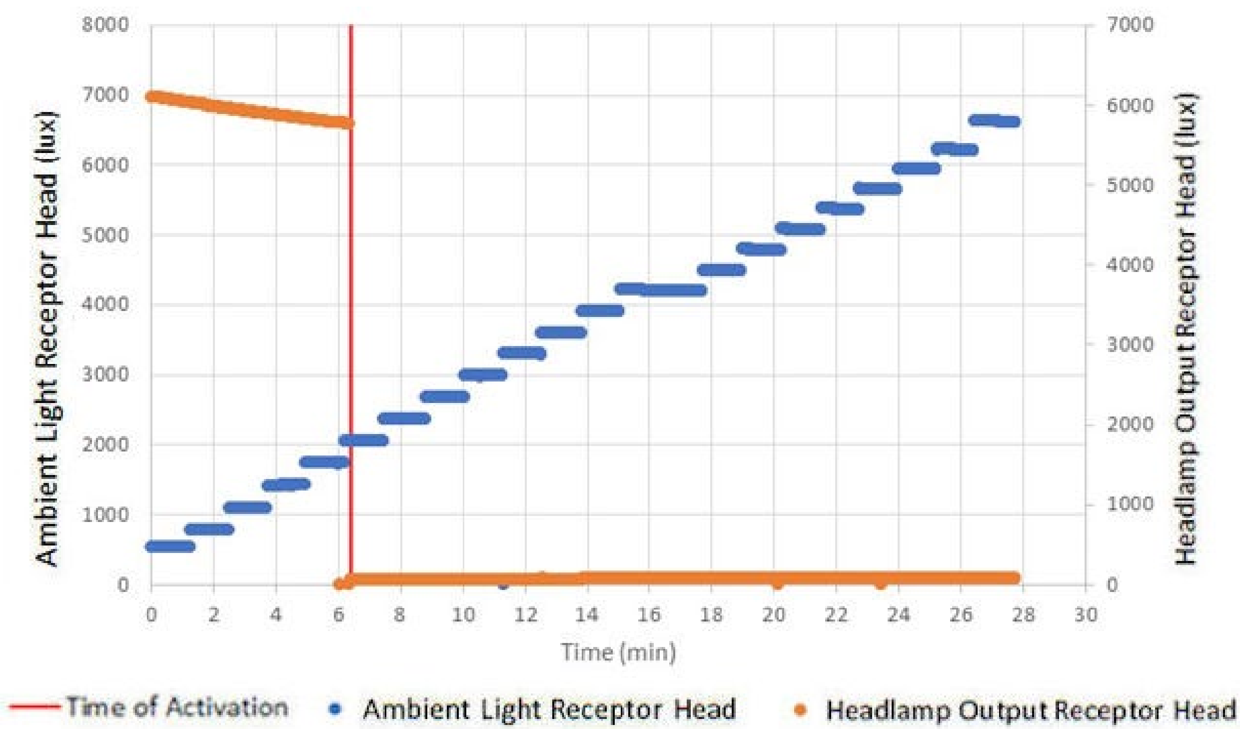

Figure 11. 2022 Tesla Model Y Lower Beam Deactivation

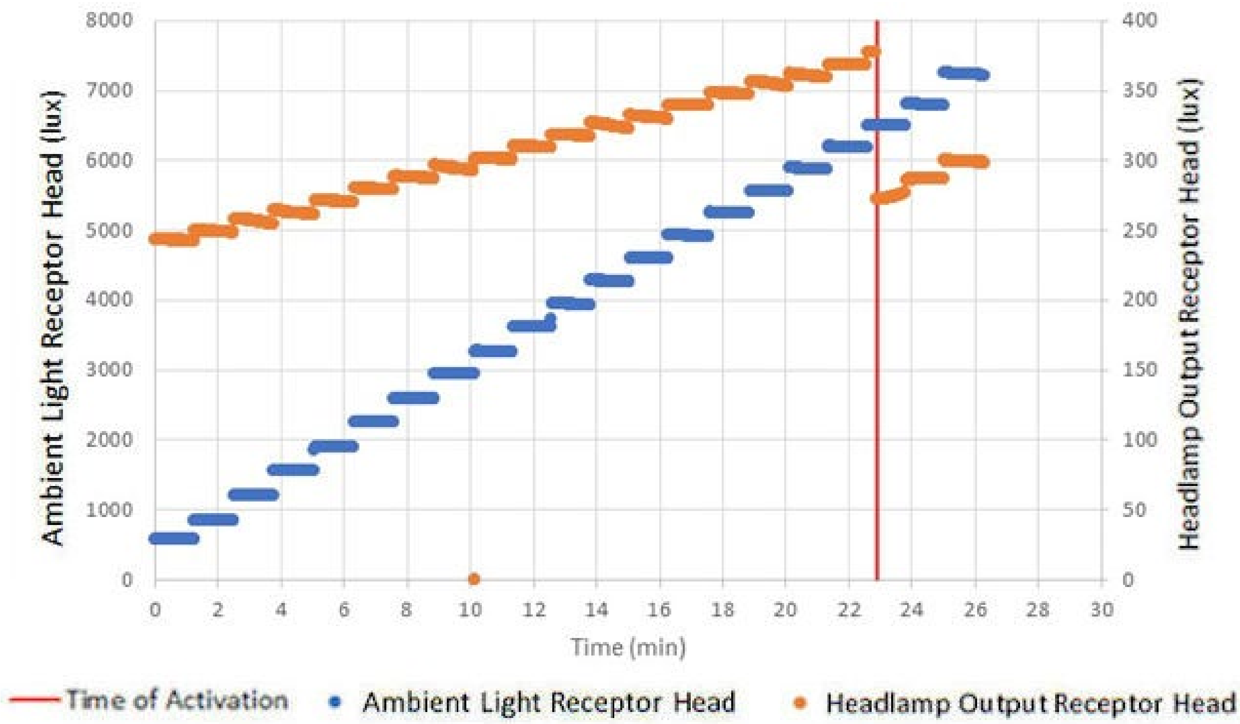

Figure 12. 2022 Toyota Camry Lower Beam Deactivation

Outdoor Lower Beam Activation Testing

To assess the validity of the indoor draft test procedure, an outdoor test was performed with the same draft test procedure except the light source was removed and the outdoor ambient lighting level was recorded. The test was performed at dusk on the Chevrolet Equinox for lower beam activation. The outdoor ambient light level was constantly changing over time in a way that was not incremental, so the measured indoor activation time was used to find the ambient light value that would have first triggered the lower beam activation. With the indoor test result value for activation known, data recording was able to be started close to the time at which activation was likely to occur, resulting in a short data collection period of approximately 5 minutes. Without that value being known, the test duration would have been longer. The results showed that the outdoor test produced similar results to the indoor test.

Table 5. Outdoor Testing Results

Make	Model	Illuminance of Indoor Lower Beam Activation (lux)	Illuminance of Outdoor Lower Beam Activation (lux)	Activation Delta (lux)
Chevrolet	Equinox	1,140	1,201	61

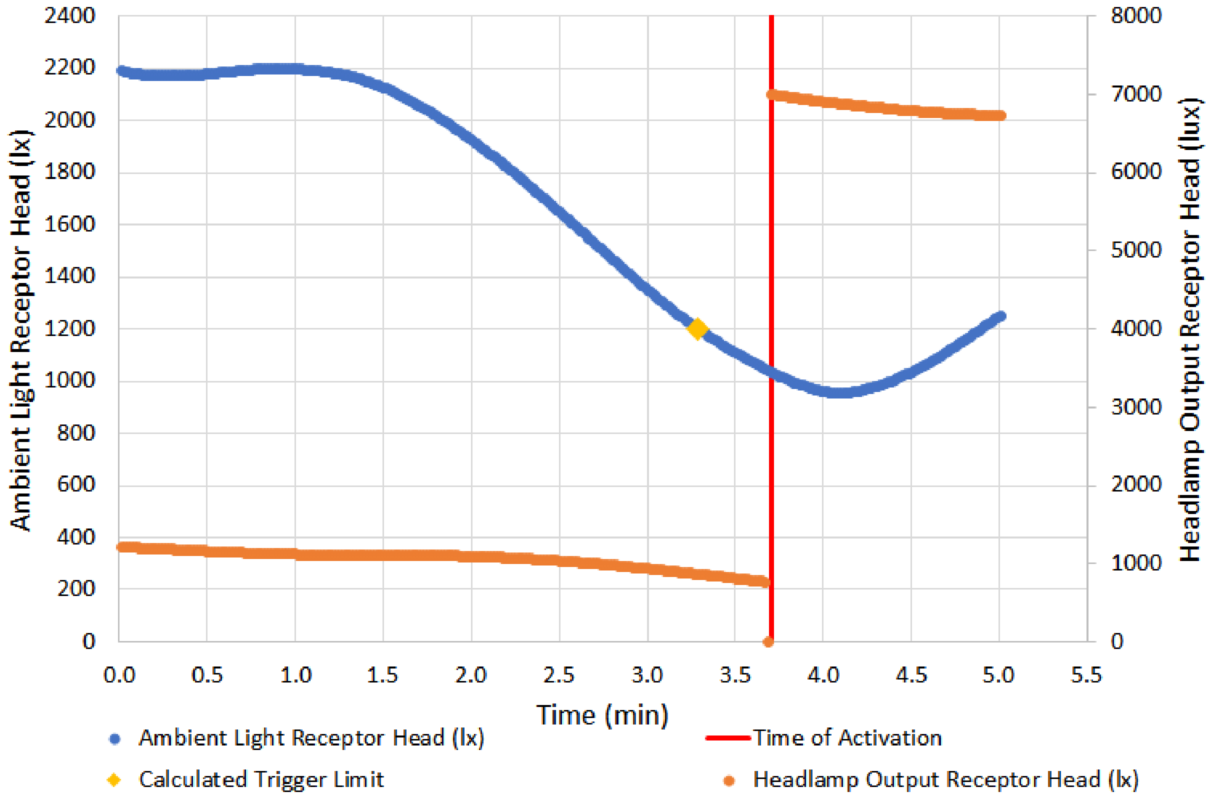

Figure 13. 2022 Chevrolet Equinox Outdoor Lower Beam Activation

Discussion

Draft Test Procedure Development

The draft test procedure developed for measuring the performance of an automatic lower beam headlamp activation system demonstrates strong potential that could be further refined. The setup was simple and easy to carry out. The procedure was able to measure both the ambient light levels at activation and deactivation of the lower beam as well as the time it takes the vehicle to do so after being exposed to the qualifying stimuli. The outdoor testing under natural ambient light conditions showed similar measured illuminance as was observed for the artificial ambient light source used for indoor testing.

Since the light level was measured at the exterior of the windshield, the test procedure can be used regardless of the windshield properties and any original equipment treatments. The light sensor would need to be able to accurately detect the ambient light level through the windshield. To improve the draft test procedure, additional specifications regarding the maximum allowable distance between the illuminance receptor head positioned at the exterior of the windshield and the vehicle's light sensor should be determined.

It should also be noted that not all possible relevant test procedure related questions were addressed in this effort. Test procedure repeatability, an important factor, was not examined in this effort. Some environmental conditions that may be relevant to system performance were also not examined. For example, while some headlighting systems will automatically activate lower beam headlamps in conditions of precipitation in daylight, this work did not address that condition. The test procedure development effort also did not consider how the system may perform in the scenario of a vehicle driving into and out of a dark tunnel in daylight conditions, where quick system responsiveness would be appropriate.

Only one vehicle tested was not able to have the deactivation illuminance recorded because the value exceeded the output of the ambient light source. This value exceeded the UNECE No. 48 minimum required value for lower beam deactivation of 7,000 lux. To mitigate this issue, a light source with a higher output level could be used provided it is able to resolve to small enough steps in output.

The draft test procedure could easily be adapted with a few adjustments to a test that more directly determined whether lower beam activation and deactivation requirements are met. Instead of changing the ambient light in increments, it could be instantly changed to the limit values. Then the state of the lower beams could be observed and the response time could be measured in a similar manner to the draft test procedure.

Test Results

The range of ambient illuminance over which the lower beams activated and deactivated differed across vehicles, as did the time for activation and deactivation.

The light level of lower beam activation ranged from 4,240 lux to 529 lux, with all but the Tesla Model Y activating above 1,000 lux which is the limit stated in UNECE No. 48. The light level of lower beam deactivation ranged from more than 7,000 lux to 2051 lux, with all but the Hyundai Tucson deactivating above 7,000 lux which is the UNECE No. 48 limit for lower beam deactivation. The vehicle response time for lower beam activation ranged from 25.6 seconds to 3.5 seconds, which is greater than the maximum limit of 2 seconds stated in UNECE No. 48.

However, all but one of these vehicles activated before the 1,000 lux limit which, according to UNECE No. 48, would fall in the range of the manufacturer's discretion. The vehicle response time for lower beam deactivation ranged from greater than 60 seconds to 9.3 seconds, all of which except the Hyundai Tucson are within the range of response times of 5 seconds to 300 seconds stated in UNECE No. 48. These results illustrate that most vehicles sold for the U.S. market are adhering to existing standards in the global market.

The lower beam deactivation characteristics were not able to be recorded for the 2022 Hyundai Tucson Limited. The lower beams were not observed to change state even at the maximum output of the ambient light source (approximately 7,000 lux). The lower beam activation for this vehicle also occurred at a higher illuminance value than any of the other tested vehicles. The light sensor location was confirmed by the manufacturer to be the sensor tested.

Summary

As indicated above, the main objective of this effort was to develop a draft test procedure for measuring automatic headlamp activation system's performance. The draft test procedure would measure the ambient light level and response time of automatic lower beam activation and deactivation.

A draft test procedure was developed that could be performed in a laboratory setting and involved using an output-controllable light source to vary the ambient illumination level exposed to the automatic headlamp activation and deactivation system's light sensor and measuring both the stimulus light level and the lower beam headlamp output using an illuminance meter. The developed draft test procedure is relatively simple and easy to perform. The validity of the draft test procedure was assessed by performing the test procedure outdoors for one test vehicle. The result obtained by this test procedure aligned with the result obtained by the indoor draft test procedure. However, it should be noted that repeatability, an important factor, was not examined for this test procedure. This test procedure development also did not consider all scenarios, such as the scenario of a vehicle driving into and out of a dark tunnel in daylight conditions.

This draft test procedure could be adapted to a test that more directly assesses required conditions based on ambient light levels. Such a test procedure would involve the same setup, except instead of continuously lowering the ambient light level in small increments, the light level could instantaneously either decrease to a lower beam activation limit or increase to a lower beam deactivation limit and observe whether the headlamps responded correctly. Response time could be measured in the same manner as described in the draft test procedure. This draft test procedure provides a basis for further development.

Test results obtained by applying the draft test procedure to a small set of vehicles showed differing values for both the activation and deactivation ambient light values and response times. These values provide some information about the performance of existing systems. An additional test performed outside with the procedure showed a strong correlation with results obtained in a laboratory environment.

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