



BSI Standards Publication

Road vehicles — Ergonomic and performance aspects of Camera Monitor Systems — Requirements and test procedures

National foreword

This British Standard is the UK implementation of ISO 16505:2019+A1:2021. It supersedes [BS ISO 16505:2019](#), which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO text carry the number of the ISO amendment. For example, text altered by ISO amendment 1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee AUE/1, Vehicle Lighting & Visibility.

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Published by BSI Standards Limited 2021

ISBN 978 0 539 06568 8

ICS 13.180; 43.040.10

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2019.

Amendments/corrigenda issued since publication

Date	Text affected
31 August 2021	Implementation of ISO amendment 1:2021

INTERNATIONAL STANDARD

ISO
16505

Second edition
2019-07-15

Road vehicles — Ergonomic and performance aspects of Camera Monitor Systems — Requirements and test procedures

*Véhicules routiers — Aspects ergonomiques et de performance des
caméras embarquées — Exigences et procédures d'essai*



Reference number
ISO 16505:2019(E)
Documents
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 35, *Lighting and visibility*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This second edition cancels and replaces the first edition ([ISO 16505:2015](http://www.iso.org/iso/16505:2015)), of which it constitutes a minor revision.

The main changes compared to the previous edition are as follows:

- [6.1](#) has been added, and all subsequent subclauses in [Clause 6](#) have been renumbered, in order to align with the subclause structure in [Clause 7](#).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to give minimum safety, ergonomic, and performance requirements and test methods for Camera Monitor Systems (CMS) to replace mandatory inside and outside rearview mirrors for road vehicles (e.g. classes I to IV as defined in UN Regulation No. 46). This document can follow updates of referred national regulations that influence the included contents.

Where possible, the requirements established for a CMS providing a specific legally prescribed field of view are based on the properties of conventional state of the art mirror systems providing that field of view.

The CMS is treated as a functional system in regard to requirement definitions and performance tests.

This document outlines general requirements and test methods regarding the basic aspects of CMS; e.g. intended use, operating readiness, field of view, magnification, etc.

Furthermore, this document outlines requirements and test methods regarding the necessary object size and resolution provided by the CMS. Besides the properties of the mirror system to be replaced, those requirements are also based on physical aspects of the human operator (e.g. visual acuity).

The given requirements follow the assumption, that the CMS provides an ideal mapping of the real-world scene. To correspond to reality, this document also provides requirements and test methods for all relevant parameters that worsen the ideal mapping (e.g. isotropy or artefacts).

Finally, this document gives requirements and test methods regarding the aspects of time behaviour and failure behaviour.

All requirements are established to be as generic as possible, i.e. that these are possible to apply to any of the covered rearview mirrors. If additional or specific information is required for certain mirrors, these are provided in separate annexes.

This document declares that CMS replacing legally prescribed mirrors have to be considered as safety-relevant systems and therefore, relevant safety standards (e.g. ISO 26262) have to be considered.

Road vehicles — Ergonomic and performance aspects of Camera Monitor Systems — Requirements and test procedures

1 Scope

This document gives minimum safety, ergonomic, and performance requirements for Camera Monitor Systems to replace mandatory inside and outside rearview mirrors for road vehicles (e.g. classes I to IV as defined in UN Regulation No. 46). It addresses Camera Monitor Systems (CMS) that will be used in road vehicles to present the required outside information of a specific field of view inside the vehicle. These specifications are intended to be independent of different camera and display technologies unless otherwise stated explicitly. Advanced driver assistance systems (ADAS), such as parking aids, are not part of this document.

NOTE 1 Mirror classes V and VI (as defined in UN Regulation No. 46) are not in scope of this document since the requirements are already defined in UN Regulation No. 46.

NOTE 2 The definitions and requirements in this document are formulated with regard to a system structure, where one camera captures one legally prescribed field of view and one monitor displays one legally prescribed field of view. Of course, also other system structures (e.g. with one monitor displaying two legally prescribed fields of view) are within the scope of this document. For those systems, either the system supplier or the vehicle manufacturer has to prove that the resulting system fulfils the requirements given in [Clause 6](#).

NOTE 3 Whenever the phrases “field of view” or “field of vision” are used, then both have the same meaning and are to be used in parallel.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 Vehicle related terms and definitions

3.1.1 vehicle

vehicle with a combustion engine and/or electric driving motor, intended for use on the road, with or without external body components added, having a permissible maximum mass of at least 400 kg and a maximum design speed equal to or exceeding 50 km/h

Note 1 to entry: Vehicles of categories M1, M2, M3, N1, N2 and N3 (see UN Regulation No. 46).

[SOURCE: ISO 13043:2011, 3.1]

3.1.2 vehicle coordinate system

positive x-axis pointing into the opposite of the forward movement direction of the vehicle, the z-axis being orthogonal to the ground plane pointing upwards and the y-axis pointing to the right seen in forward movement direction thus forming a right-handed coordinate system

3.1.3 driver's ocular points

points that are uniquely defined for each vehicle

Note 1 to entry: See [Figure 1](#).

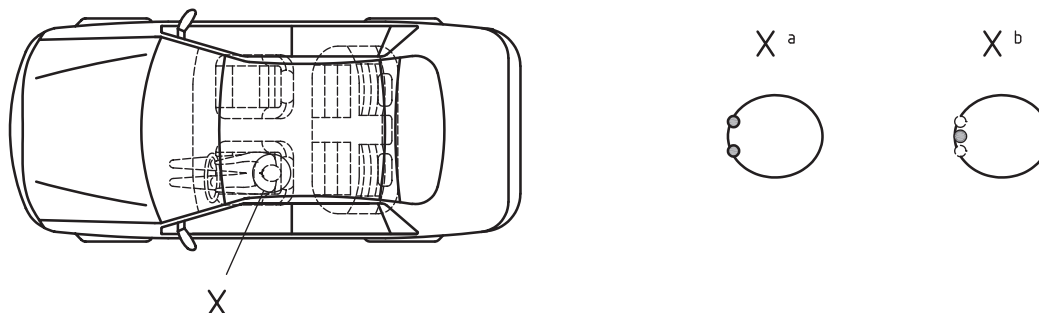
Note 2 to entry: These points are related to data given by the vehicle manufacturer following definitions of the responsible national body.

EXAMPLE $\boxed{A_1}$ "The driver's ocular points" means two points 65 mm apart and 635 mm vertically above point *R* of the driver's seat as defined in UN Regulation No. 46, Annex 8. The straight line joining these points runs perpendicular to the vertical longitudinal median plane of the vehicle. The centre of the segment joining the two ocular points is in a vertical longitudinal plane which has to pass through the centre of the driver's designated seating position, as specified by the vehicle manufacturer. $\boxed{A_1}$

3.1.4 driver ocular reference point

ORP
middle point between the two ocular points of the driver

Note 1 to entry: See [Figure 1](#).



$\boxed{A_1}$ Key $\boxed{A_1}$

- a Ocular points.
- b Ocular reference point.

Figure 1 — Driver ocular reference point

EXAMPLE $\boxed{A_1}$ The two ocular points of the driver uses 635 mm vertically above point *R*, as defined in the UN Regulation No. 46, paragraph 12.1, as shown in the example given in *driver's ocular points* ([3.1.3](#)). $\boxed{A_1}$

3.2 Mirror related terms and definitions

3.2.1 mirror

device with a reflective surface mounted to the bodywork of a vehicle

Note 1 to entry: It is used to see the required outside information of a specific field of view by indirect vision.

Note 2 to entry: The definitions from *mirror distance to driver ocular reference point* ([3.2.2](#)) to *mirror angular resolution* ([3.2.28](#)) assume an ideal mirror and do not deal with artefacts like low quality surface, dirt, etc.

3.2.2

mirror distance to driver ocular reference point

distance from the driver ocular reference point to the centre of the mirror

Note 1 to entry: See [Figure 2](#).

Note 2 to entry: It is denoted as a_{mirror} and is measured in metres.

Note 3 to entry: The mirror distance to driver ocular reference point influences the resolution and the magnification requirements for a CMS replacing a mirror. The designed resolution and magnification of a CMS should take into account that this distance is usually lower than the maximum values given in the following subclauses.

3.2.3

maximum mirror distance to driver ocular reference point

<driver side>maximum value for a_{mirror} as found in existing homologated vehicles for the given mirror class on the driver side

Note 1 to entry: It is denoted as $a_{mirror/driver/max}$ and is measured in metres:

- for UN Regulation No. 46 class I mirrors, this value is defined as $a_{mirror/driver/max} = 1,05$ m;
- for UN Regulation No. 46 class II mirrors, this value is defined as $a_{mirror/driver/max} = 1,7$ m;
- for UN Regulation No. 46 class III mirrors, this value is defined as $a_{mirror/driver/max} = 1,2$ m;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $a_{mirror/driver/max} = 1,7$ m.

Note 2 to entry: The above values represent the maximum distances for mass produced vehicles of MY 2013 (based upon 2013 survey).

Note 3 to entry: See [B.6.2](#) for more information on the values for class II and class IV mirrors.

3.2.4

maximum mirror distance to driver ocular reference point

<passenger side>maximum value for a_{mirror} as found in existing homologated vehicles for the given mirror class on the passenger side

Note 1 to entry: It is denoted as $a_{mirror/passenger/max}$ and is measured in metres:

- for UN Regulation No. 46 class II mirrors, this value is defined as $a_{mirror/passenger/max} = 2,6$ m;
- for UN Regulation No. 46 class III mirrors, this value is defined as $a_{mirror/passenger/max} = 1,9$ m;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $a_{mirror/passenger/max} = 2,6$ m;
- for main mirrors on cab-over-engine type trucks according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $a_{mirror/passenger/max} = 2,5$ m;
- for main mirrors on motor vehicles with a passenger capacity of 11 persons or more according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $a_{mirror/passenger/max} = 2,5$ m.
- for mirrors on the other vehicle category in Japan refer to Article 44 of Japanese Safety Regulations for Road Vehicles.

Note 2 to entry: The above values represent the maximum distances for mass produced vehicles of MY 2013 (based upon 2013 survey).

Note 3 to entry: See [B.6.3](#) for more information on the values for class II and class IV mirrors.

Note 4 to entry: According to Article 44 of Japanese Safety Regulations for Road Vehicles main mirror means “Those mirrors used mainly for observing obstacles showing up around the rear portion on the left side of the vehicle”. See [Figures B.5](#), [B.6](#), and [B.7](#).

3.2.5

mirror viewing angle

total angle between the ray leaving the eye-point and reaching an object after being reflected from the mirror surface, i.e. two times the angle between the driver's line of sight and the surface normal of the mirror

Note 1 to entry: See [Figure 3](#).

Note 2 to entry: It is denoted as β_{mirror} and is measured in degrees.

3.2.6

minimum mirror viewing angle

<driver side>minimum value for β_{mirror} as found in existing homologated vehicles for the given mirror class on the driver side

Note 1 to entry: It is denoted as $\beta_{\text{mirror/driver/min}}$ and is measured in degrees:

- for UN Regulation No. 46 class I mirrors, this value is defined as $\beta_{\text{mirror/driver/min}} = 20^\circ$;
- for UN Regulation No. 46 class II mirrors, this value is defined as $\beta_{\text{mirror/driver/min}} = 55^\circ$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $\beta_{\text{mirror/driver/min}} = 30^\circ$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $\beta_{\text{mirror/driver/min}} = 55^\circ$.

Note 2 to entry: The above values represent the minimum angles for mass produced vehicles of MY 2013 (based upon 2013 survey) regarding the required field of view.

3.2.7

maximum mirror viewing angle

<driver side>maximum value for β_{mirror} as found in existing homologated vehicles for the given mirror class on the driver side

Note 1 to entry: It is denoted as $\beta_{\text{mirror/driver/max}}$ and is measured in degrees:

- for UN Regulation No. 46 class I mirrors, this value is defined as $\beta_{\text{mirror/driver/max}} = 65^\circ$;
- for UN Regulation No. 46 class II mirrors, this value is defined as $\beta_{\text{mirror/driver/max}} = 75^\circ$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $\beta_{\text{mirror/driver/max}} = 65^\circ$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $\beta_{\text{mirror/driver/max}} = 125^\circ$.

Note 2 to entry: The above values represent the maximum angles for mass produced vehicles of MY 2013 (based upon 2013 survey) regarding the required field of view.

3.2.8

minimum mirror viewing angle

<passenger side>minimum value for β_{mirror} as found in existing homologated vehicles for the given mirror class on the passenger side

Note 1 to entry: It is denoted as $\beta_{\text{mirror/passenger/min}}$ and is measured in degrees:

- for UN Regulation No. 46 class II mirrors, this value is defined as $\beta_{\text{mirror/passenger/min}} = 80^\circ$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $\beta_{\text{mirror/passenger/min}} = 55^\circ$;
- for UN Regulation No. 46 class IV, this value is defined as $\beta_{\text{mirror/passenger/min}} = 80^\circ$;
- for main mirrors on cab-over-engine type trucks according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $\beta_{\text{mirror/passenger/min}} = 54^\circ$;
- for main mirrors on motor vehicles with a passenger capacity of 11 persons or more according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $\beta_{\text{mirror/passenger/min}} = 50,5^\circ$.

- for mirrors on the other vehicle category in Japan refer to Article 44 of Japanese Safety Regulations for Road Vehicles.

Note 2 to entry: The above values represent the minimum angles for mass produced vehicles of MY 2013 (based upon 2013 survey) regarding the required field of view.

Note 3 to entry: According to Article 44 of Japanese Safety Regulations for Road Vehicles, main mirror means “Those mirrors used mainly for observing obstacles showing up around the rear portion on the left side of the vehicle”. See [Figures B.5, B.6, and B.7](#).

3.2.9

maximum mirror viewing angle

<passenger side>maximum value for β_{mirror} as found in existing homologated vehicles for the given mirror class on the passenger side

Note 1 to entry: It is denoted as $\beta_{mirror/passenger/max}$ and is measured in degrees:

- for UN Regulation No. 46 class II mirrors, this value is defined as $\beta_{mirror/passenger/max} = 95^\circ$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $\beta_{mirror/passenger/max} = 85^\circ$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $\beta_{mirror/passenger/max} = 150^\circ$;
- for main mirrors on cab-over-engine type trucks according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $\beta_{mirror/passenger/max} = 111^\circ$;
- for main mirrors on motor vehicles with a passenger capacity of 11 persons or more according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $\beta_{mirror/passenger/max} = 64^\circ$.
- for mirrors on the other vehicle category in Japan refer to Article 44 of Japanese Safety Regulations for Road Vehicles.

Note 2 to entry: The above values represent the maximum angles for mass produced vehicles of MY 2013 (based upon 2013 survey) regarding the required field of view.

Note 3 to entry: According to Article 44 of Japanese Safety Regulations for Road Vehicles main mirror means “Those mirrors used mainly for observing obstacles showing up around the rear portion on the left side of the vehicle”. See [Figures B.5, B.6, and B.7](#).

3.2.10

distance from mirror to object

distance from the mirror to an object being viewed by the driver

Note 1 to entry: See [Figure B.14](#).

Note 2 to entry: It is denoted as d_{object} and is measured in meters.

3.2.11

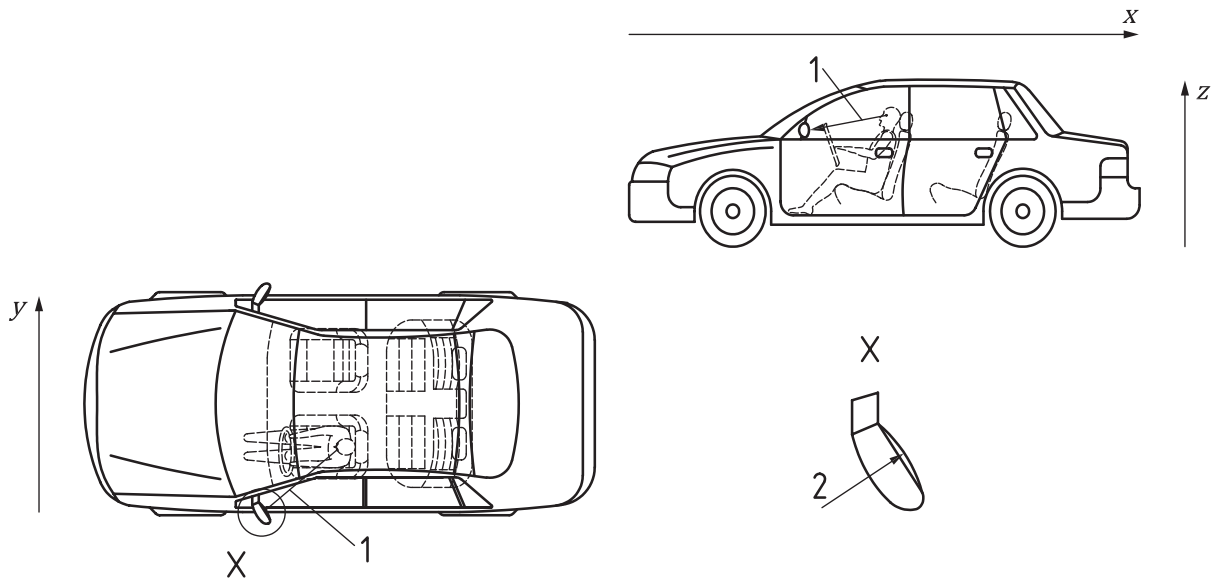
mirror radius of curvature

radius of the sphere that specifies the shape of a spherical mirror surface

Note 1 to entry: See [Figure 2](#).

Note 2 to entry: For convex spherical mirrors with the reflective layer on the convex surface, this value is positive.

Note 3 to entry: It is denoted as r_{mirror} and is measured in metres.



Key

- 1 a_{mirror}
- 2 r_{mirror}

Figure 2 — Mirror radius of curvature

3.2.12

mirror minimum allowed radius of curvature

minimum allowed value for r_{mirror} as defined by the responsible national body

Note 1 to entry: It is denoted as $r_{mirror/min}$ and is measured in metres.

Note 2 to entry: The values given below are examples:

- for UN Regulation No. 46 class I spherical convex mirrors, this value is defined as $r_{mirror/min} = 1,2$ m;
- for UN Regulation No. 46 class II spherical convex mirrors, this value is defined as $r_{mirror/min} = 1,2$ m;
- for UN Regulation No. 46 class III spherical convex mirrors, this value is defined as $r_{mirror/min} = 1,2$ m;
- for UN Regulation No. 46 class IV spherical convex mirrors, this value is defined as $r_{mirror/min} = 0,3$ m;
- for main mirrors on cab-over-engine type trucks according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $r_{mirror/min} = 0,6$ m;
- for main mirrors on motor vehicles with a passenger capacity of 11 persons or more according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is defined as $r_{mirror/min} = 0,6$ m;
- for mirrors on the other vehicle category in Japan refer to Article 44 of Japanese Safety Regulations for Road Vehicles;
- FMVSS 111 only allows for plane mirrors where $r_{mirror/min}$ is infinite on the driver side; however, on the passenger side of the vehicle, FMVSS 111 defines a spherical convex mirror with a minimum radius of $r_{mirror/min} = 0,889$ m.

Note 3 to entry: According to Article 44 of Japanese Safety Regulations for Road Vehicles, main mirror means “Those mirrors used mainly for observing obstacles showing up around the rear portion on the left side of the vehicle”. See [Figures B.5](#), [B.6](#), and [B.7](#).

3.2.13

mirror angular size

angle under which the driver perceives the mirror

Note 1 to entry: See *mirror horizontal angular size* (3.2.14) and *mirror vertical angular size* (3.2.15) for details and differentiation between horizontal and vertical direction.

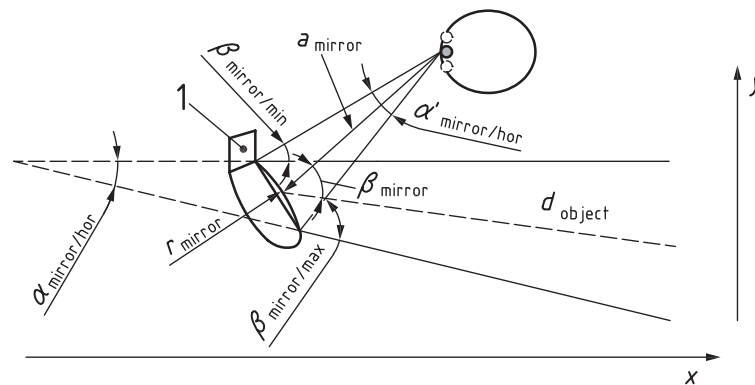
3.2.14

mirror horizontal angular size

angle between the lines from the ORP to the left and right edge (in y-direction) of the reflective mirror surface

Note 1 to entry: See Figure 3.

Note 2 to entry: It is denoted as $\alpha'_{\text{mirror/hor}}$ and is measured in degrees.



Key

1 mirror

Figure 3 — Mirror horizontal angular size (bird's eye view)

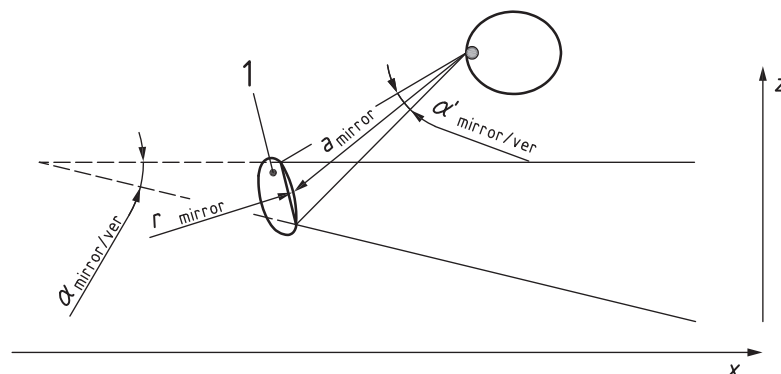
3.2.15

mirror vertical angular size

angle between the lines from the ORP to the top and bottom edge in (z-direction) of the reflective mirror surface

Note 1 to entry: See Figure 4.

Note 2 to entry: It is denoted as $\alpha'_{\text{mirror/ver}}$ and is measured in degrees.



Key

1 mirror

Figure 4 — Mirror vertical angular size (side view)

3.2.16

field of view

space defined by all rays of light (lines from object points to the reflective mirror surface) that are still reflected into the driver's imaginary monocular eye point at the ORP

Note 1 to entry: This space can be approximated by a pyramid with its base lying in the y-z-plane.

3.2.17

horizontal field of view

angle between the leftmost and the rightmost ray of the field of view projected to the x-y-plane

Note 1 to entry: It is denoted as $\alpha_{mirror/hor}$ and is measured in degrees.

3.2.18

minimum horizontal field of view

minimum allowed value for $\alpha_{mirror/hor}$ as defined by the responsible national body

Note 1 to entry: It is denoted as $\alpha_{mirror/hor/min}$ and is measured in degrees.

Note 2 to entry: Information on $\alpha_{mirror/hor/min}$ for different mirror classes is given in [B.2.1](#).

3.2.19

vertical field of view

angle between the topmost and the bottommost ray of the field of view projected to the x-z-plane

Note 1 to entry: It is denoted as $\alpha_{mirror/ver}$ and is measured in degrees.

3.2.20

minimum vertical field of view

minimum allowed value for $\alpha_{mirror/ver}$ as defined by the responsible national body

Note 1 to entry: It is denoted as $\alpha_{mirror/ver/min}$ and is measured in degrees.

Note 2 to entry: Information on $\alpha_{mirror/ver/min}$ for different mirror classes is given in [B.2.2](#).

3.2.21

mirror magnification factor

relationship between the correct size of an object and its perceived size when seen through the mirror

Note 1 to entry: It is dependent on the distance from the ORP to the mirror a_{mirror} (see [3.2.2](#)), the radius of the mirror r_{mirror} (see [3.2.11](#)), the distance to the object d_{object} (see [3.2.10](#)), and the mirror viewing angle β_{mirror} (see [3.2.5](#)). It is denoted as M_{mirror} .

Note 2 to entry: For convex spherical rearview mirrors, the magnification factor is below 1, i.e. objects in a rearview mirror appear smaller than they really are. For plane mirrors with unit magnification, the magnification factor is equal to 1, i.e. there is no magnification.

Note 3 to entry: For a formula describing the magnification factor variation over the mirror, refer to [B.3](#).

3.2.22

mirror average magnification factor

average value for the magnification based on a mirror with minimum radius $r_{mirror/min}$ and maximum distance to the ORP $a_{mirror/max}$

Note 1 to entry: It is denoted as $M_{mirror/avg}$.

Note 2 to entry: It is derived as the average over the relevant range of viewing angles β_{mirror} at the horizontal centre line of the mirror and distances d_{object} .

Note 3 to entry: See *mirror average magnification factor (driver side)* ([3.2.23](#)) and *mirror average magnification factor (passenger side)* ([3.2.24](#)) for details and differentiation between driver and passenger side.

3.2.23

mirror average magnification factor

<driver side>average magnification factor for M_{mirror} as found in existing homologated vehicles for the given mirror class on the driver side

Note 1 to entry: It is denoted as $M_{mirror/driver/avg}$:

- for UN Regulation No. 46 class I mirrors, this value is defined as $M_{mirror/driver/avg} = 0,33$;
- for UN Regulation No. 46 class II mirrors, this value is defined as $M_{mirror/driver/avg} = 0,23$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $M_{mirror/driver/avg} = 0,31$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $M_{mirror/driver/avg} = 0,065$;
- for an FMVSS 111 plane driver mirror, this value is $M_{mirror/driver/avg} = 1$.

Note 2 to entry: The above values were derived from mass produced vehicles of MY 2013 (based upon 2013 survey).

Note 3 to entry: For detailed information how these values were derived, refer to [B.3](#).

Note 4 to entry: For additional recommendations concerning commercial vehicles, refer to [A.3.3](#).

3.2.24

mirror average magnification factor

<passenger side>average magnification factor for M_{mirror} as found in existing homologated vehicles for the given class on the passenger side

Note 1 to entry: It is denoted as $M_{mirror/passenger/avg}$:

- for UN Regulation No. 46 class II mirrors, this value is defined as $M_{mirror/passenger/avg} = 0,15$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $M_{mirror/passenger/avg} = 0,20$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $M_{mirror/passenger/avg} = 0,036$;
- for an FMVSS 111 passenger mirror, this value is defined as $M_{mirror/passenger/avg} = 0,17$;
- for main mirrors on cab-over-engine type trucks according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is $M_{mirror/passenger/avg} = 0,088$;
- for main mirrors on motor vehicles with a passenger capacity of 11 persons or more according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is $M_{mirror/passenger/avg} = 0,10$;
- for mirrors on the other vehicle category in Japan refer to Article 44 of Japanese Safety Regulations for Road Vehicles.

Note 2 to entry: The above values were derived from mass produced vehicles of MY 2013 (based upon 2013 survey).

Note 3 to entry: For detailed information how these values were derived, refer to [B.3](#).

Note 4 to entry: For additional recommendations concerning commercial vehicles, refer to [A.3.3](#).

Note 5 to entry: According to Article 44 of Japanese Safety Regulations for Road Vehicles, main mirror means “Those mirrors used mainly for observing obstacles showing up around the rear portion on the left side of the vehicle”. See [Figures B.5](#), [B.6](#), and [B.7](#).

3.2.25

mirror minimum magnification factor

minimum value for the magnification based on a mirror with minimum radius $r_{mirror/min}$ and maximum distance to the ORP $a_{mirror/max}$; it is derived from the maximum viewing angle $\beta_{mirror/max}$ at the horizontal centre line of the mirror within the relevant range and the distance $d_{object} = \infty$

Note 1 to entry: It is denoted as $M_{mirror/min}$.

Note 2 to entry: See *mirror minimum magnification factor (driver side)* (3.2.26) and *mirror minimum magnification factor (passenger side)* (3.2.27) for details and differentiation between driver and passenger side.

3.2.26

mirror minimum magnification factor

<driver side>minimum magnification factor for M_{mirror} as found in existing homologated vehicles for the given class on the driver side

Note 1 to entry: It is denoted as $M_{mirror/driver/min}$:

- for UN Regulation No. 46 class I mirrors, this value is defined as $M_{mirror/driver/min} = 0,31$;
- for UN Regulation No. 46 class II mirrors, this value is defined as $M_{mirror/driver/min} = 0,21$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $M_{mirror/driver/min} = 0,29$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $M_{mirror/driver/min} = 0,037$;
- for an FMVSS 111 plane driver mirror, this value is $M_{mirror/driver/min} = 1$.

Note 2 to entry: The above values were derived from mass produced vehicles of MY 2013 (based upon 2013 survey).

Note 3 to entry: For detailed information how these values were derived, refer to [B.3](#).

Note 4 to entry: For additional recommendations concerning commercial vehicles, refer to [A.3.3.2](#).

3.2.27

mirror minimum magnification factor

<passenger side>minimum magnification factor for M_{mirror} as found in existing homologated vehicles for the given class on the passenger side

Note 1 to entry: It is denoted as $M_{mirror/passenger/min}$:

- for UN Regulation No. 46 class II mirrors, this value is defined as $M_{mirror/passenger/min} = 0,13$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $M_{mirror/passenger/min} = 0,19$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $M_{mirror/passenger/min} = 0,014$;
- for an FMVSS 111 passenger mirror, this value is defined as $M_{mirror/passenger/min} = 0,17$;
- for main mirrors on cab-over-engine type trucks according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is $M_{mirror/passenger/min} = 0,061$;
- for main mirrors on motor vehicles with a passenger capacity of 11 persons or more according to Article 44 of Japanese Safety Regulations for Road Vehicles, this value is $M_{mirror/passenger/min} = 0,094$.

Note 2 to entry: The above values were derived from mass produced vehicles of MY 2013 (based upon 2013 survey).

Note 3 to entry: For detailed information how these values were derived, refer to [B.3](#).

Note 4 to entry: For additional recommendations concerning commercial vehicles, refer to [A.3.3.2](#).

Note 5 to entry: According to Article 44 of Japanese Safety Regulations for Road Vehicles, main mirror means "Those mirrors used mainly for observing obstacles showing up around the rear portion on the left side of the vehicle". See [Figures B.5](#), [B.6](#), and [B.7](#).

3.2.28

mirror angular resolution

parameter that describes the ability of a mirror to resolve small details in a reflected scene

Note 1 to entry: In principle, a mirror can resolve an unlimited amount of detail. Nevertheless, in combination with the human eye, the angular resolution of a driver seeing through the rear view mirror of a vehicle is limited by the angular resolution of the human eye. The smaller the angular resolution of the human eye, the smaller the details can be that are still resolved by the driver, i.e. in contrast to the pixel resolution of cameras smaller values for the angular resolution indicate a higher quality vision.

3.2.29

visual acuity of the human eye

ability of the human eye and human visual system to resolve small details; it is different for each person and usually degrades with increasing age of the person

Note 1 to entry: It is measured using a Landolt C test (see [ISO 8596:2009](#)) at an optician, denoted as V_{eye} and measured in [1/arcmin].

Note 2 to entry: Usually, national bodies define a minimum visual acuity for acquiring a driver's license. A visual acuity of 1 is reached if a test person has correctly identified the direction of 60 % of the Landolt C openings, assuming that the Landolt C openings are of a size such that the openings are visible (from the test person's eye position) under an angle of 1 arcmin (see [Figure 5](#)).

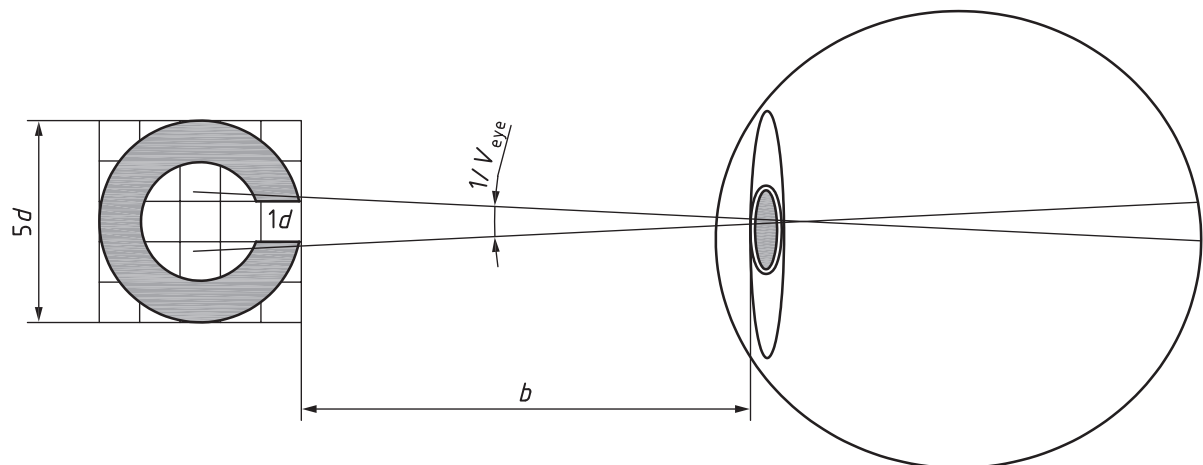


Figure 5 — Example of visual acuity of the human eye tested with Landolt C ring

3.2.30

minimum visual acuity of the human eye

minimum value of V_{eye}

Note 1 to entry: It is denoted as $V_{eye/min}$:

- for UN Regulation No. 46 class I mirrors, this value is defined as $V_{eye/min} = 0,7$;
- for UN Regulation No. 46 class II mirrors, this value is defined as $V_{eye/min} = 0,8$;
- for UN Regulation No. 46 class III mirrors, this value is defined as $V_{eye/min} = 0,7$;
- for UN Regulation No. 46 class IV mirrors, this value is defined as $V_{eye/min} = 0,8$.

Note 2 to entry: [A1](#) FeV, which is the German driver license regulation, describes the requirements for acquiring a driver license and defines in its attachment 6 clause 1.1 a minimum visual acuity of 0,7 for driver licenses for vehicles that require class I and class III mirrors according to UN Regulation No. 46. Japan defines 0,7, Netherlands defines 0,5, and Sweden defines 0,5. [A1](#)

Note 3 to entry: In Sweden, Germany, Japan, and Netherlands, driving licenses for C/CE (heavy truck/heavy truck with trailer), D/DE (heavy bus/heavy bus with trailer) type of vehicles, as well as for taxis; minimum 0,8 in binocular acuity is required. Glasses or contact lenses may be used to achieve this acuity.

Note 4 to entry: There may be differences depending on the market where the vehicle is to be driven.

3.3 Camera related terms and definitions

3.3.1

camera

device used to capture colour images of a specific field of view; it mainly consists of two relevant items: imager and lens

Note 1 to entry: The following definitions assume an ideal camera and do not deal with artefacts like image blur, wrong focus, lens distortion, etc. The tests defined in 7.8 make sure that these artefacts are reduced to a minimum.

3.3.2

camera optical axis

virtual line that defines the path along which light propagates through the system; for a system composed of simple lenses, the axis passes through the centre of curvature of each surface, and coincides with the axis of rotational symmetry

3.3.3

camera reference orientation

orientation of a camera of a CMS where the optical axis of the camera is pointing along the positive x-axis of the vehicle [the camera is looking backwards with the *camera imager* (3.3.7) lying in the y-z-plane] and the camera's upper side normal is parallel to the positive z-axis of the vehicle

Note 1 to entry: It helps to simplify the definition of further parameters of the camera (see Figure 6). See also *vehicle coordinate system* (3.1.2) for coordinate convention used.

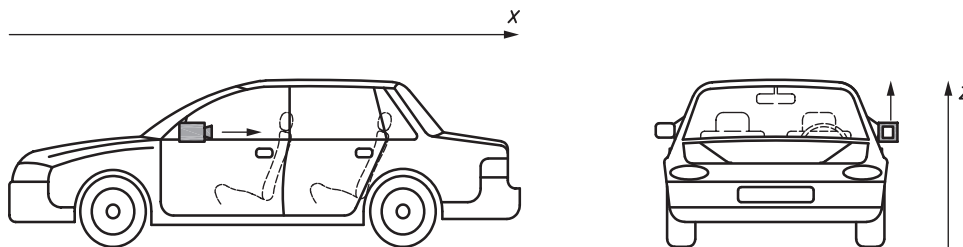


Figure 6 — Camera reference orientation

3.3.4

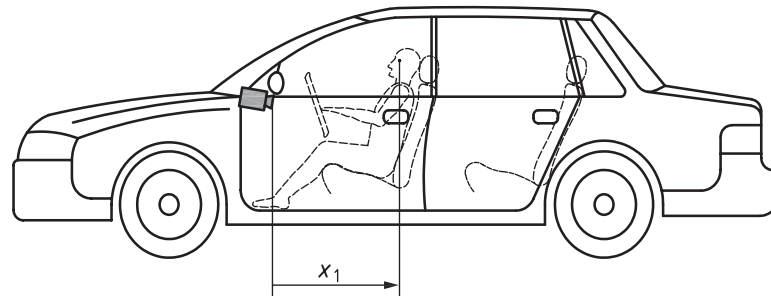
camera distance to driver ocular reference point in x-direction

distance from the centre of the *entrance pupil of the camera* (3.3.13) to the *driver ocular reference point* (3.1.4) in x-direction when mounted to the vehicle; it is specific for each vehicle, even if the camera itself is the same for each vehicle

Note 1 to entry: See Figure 7.

Note 2 to entry: It is denoted as x_{camera} and is measured in metres.

Note 3 to entry: For camera positions forward of the ORP, x_{camera} has to be a positive value while for camera positions rear of the ORP, x_{camera} has to be a negative value.



Key

X_1 x_{camera}

Figure 7 — Distance to driver ocular reference point in x-direction

3.3.5

camera distances in y-direction

displacement from the outermost point of the same side of the vehicle to the entrance pupil of a camera replacing side mirrors in y-direction is denoted as y_{camera} , and displacement from the longitudinal centre x-z-plane to the entrance pupil of a camera replacing the interior centre mirror in y-direction is denoted as y'_{camera}

Note 1 to entry: Distances are measured in metres (see [Figure 8](#)).

Note 2 to entry: For camera positions located outboard of the outermost point of the vehicle, y_{camera} has to be a positive value while for camera positions located inboard of the outermost point of the vehicle, y_{camera} has to be a negative value.

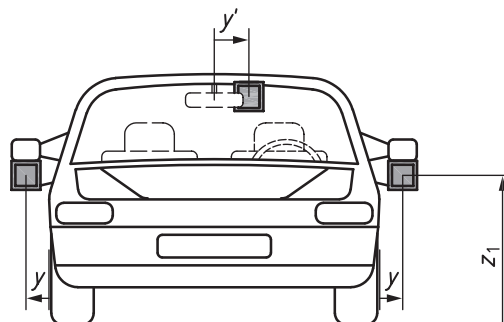
Note 3 to entry: For camera positions located in positive y-direction, y'_{camera} has to be a positive value while for camera positions located in negative y-direction, y'_{camera} has to be a negative value.

3.3.6

camera height above road surface

distance from the road surface to the centre of the *entrance pupil of the camera* ([3.3.13](#)) in z-direction when mounted to the vehicle; it is specific for each vehicle, even if the camera itself is the same for each vehicle

Note 1 to entry: It is denoted as z_{camera} and is measured in metres.



Key

y y_{camera}

y' y'_{camera}

z_1 z_{camera}

Figure 8 — Height above road surface

Note 2 to entry: For some vehicles (e.g. heavy trucks), different chassis variants and/or wheel dimensions are common depending on what type of transport the vehicle is intended for. It is important to be aware of this as the actual height above road surface will influence the requirement fulfilment by the CMS. Often, there will be worst case variants to consider.

3.3.7

camera imager

rectangular device that transforms electromagnetic radiation (irradiance) mostly of visible wavelength into electric currents; it is subdivided into a matrix of smaller (usually squared) active areas

3.3.8

camera pixel

smallest active area in a matrix of several active areas forming an imager

Note 1 to entry: It is an abbreviated term for picture element.

EXAMPLE For a Bayer pattern imager, it is either the green, blue, or red filtered pixel.

3.3.9

camera resolution

measure of the ability of a camera system to depict picture detail

Note 1 to entry: The specification hereinafter will assume a camera orientation where the imager axes are parallel to the coordinate axes when CMS camera is fixed to the body of the vehicle. For all other CMS systems composed of a different configuration, those specifications shall meet the same or increased perceptibility to the specification cited herein, under above consideration.

3.3.10

camera horizontal pixel resolution

number of pixels of the imager in y-direction for a *camera in reference orientation* (3.3.3)

Note 1 to entry: It is denoted as $N_{camera/hor}$; this is not necessarily the scanning direction of the imager.

3.3.11

camera vertical pixel resolution

number of pixels of the imager in z-direction for a *camera in reference orientation* (3.3.3)

Note 1 to entry: It is denoted as $N_{camera/ver}$.

3.3.12

camera lens

optical device of one or more optical elements that collects the incident light reflected or emitted from the scene and focuses the target scene image on to the surface of the imager

3.3.13

camera entrance pupil

optical image of the physical aperture stop seen through the front lens of the system; it is also defined as the vertex of the camera's field of view; it is influenced by the lens and is also sometimes called the "projection centre" or "centre of projection"; for simplicity, it is approximated by the centre of the outermost lens surface

Note 1 to entry: It is denoted as EP_{camera} and is a coordinate triplet given in metres.

3.3.14

camera field of view

space defined by all rays of light (lines from the centre of the entrance pupil of a camera to object points) that are projected onto the imager; for a camera fulfilling the recommendation of minimum geometric distortion, this space can be approximated by a pyramid with its apex lying in the centre of the entrance pupil and its base lying in the y-z-plane for a *camera in reference orientation* (3.3.3)

Note 1 to entry: See 6.8.6.

3.3.15

camera horizontal field of view

angle between the leftmost and the rightmost ray of the field of view projected to the x-y-plane for a camera in reference orientation (3.3.3)

Note 1 to entry: It is denoted as $\alpha_{camera/hor}$ and measured in degrees. It is sometimes also called the horizontal opening angle of a camera.

Note 2 to entry: See Figure 9.

3.3.16

camera vertical field of view

angle between the topmost and the bottommost ray of the field of view projected to the x-z-plane for a camera in reference orientation (3.3.3)

Note 1 to entry: It is denoted as $\alpha_{camera/ver}$ and measured in degrees. It is sometimes also called the vertical opening angle of a camera.

Note 2 to entry: See Figure 9.

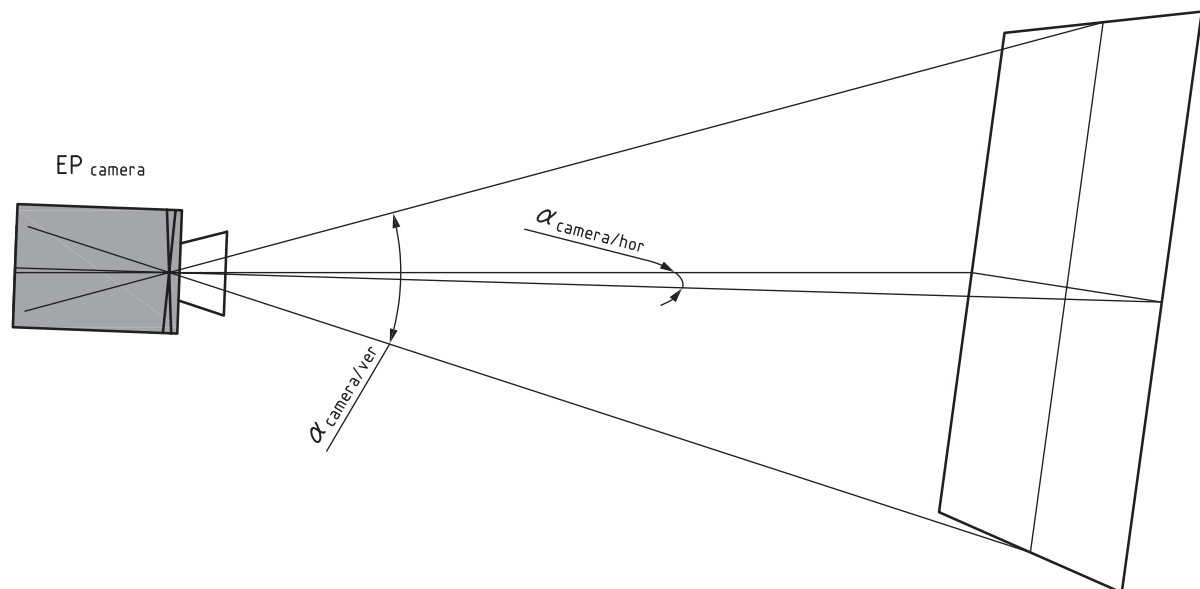


Figure 9 — Horizontal and vertical camera field of view

3.3.17

camera angular resolution

parameter describing the ability of a camera to resolve small details in a captured scene; it does not only take into account the mere resolution of the imager but also relating it to the field of view that the camera is capturing; the smaller the angular resolution of a camera, the smaller the details that can be resolved by the camera, i.e. in contrast to the pixel resolution, smaller values for the angular resolution indicate a more detailed camera image

3.4 Monitor related terms and definitions

3.4.1

monitor

device for displaying images; it either consists of a matrix of active areas that radiate light of different wavelengths or is a (usually diffuse) reflector that is illuminated in different wavelengths and in a matrix of specific points by a projector

Note 1 to entry: The following definitions assume an ideal monitor and do not deal with artefacts like pixel defects etc. The tests defined in Clause 7 ensure that these artefacts are kept to a minimum.

3.4.2 monitor coordinate system

spherical coordinate system (a_{monitor} , θ_{monitor} , ϕ_{monitor}) of the monitor; it is mainly used for evaluation of the viewing angle dependent visual performance of the monitor; the origin of the spherical coordinate system is placed in the centre of the active area of the monitor

[SOURCE: ISO 9241-302:2008, 3.3.19, modified]

Note 1 to entry: See [Figure 10](#).

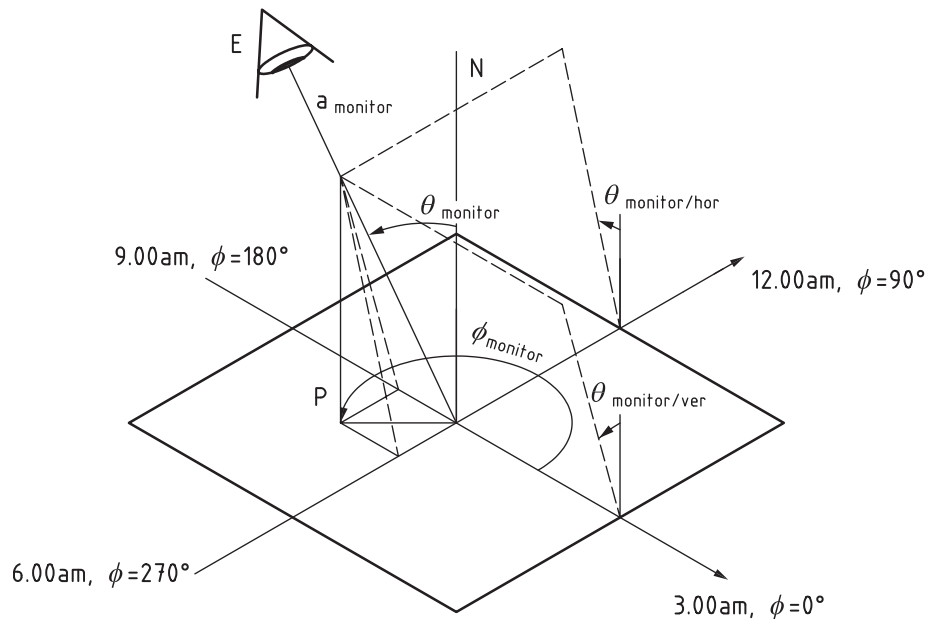


Figure 10 — Monitor spherical coordinate system

3.4.3 monitor viewing direction

direction from which the monitor is viewed; it is a line from the mid-eye point of the viewer to the centre of the monitor coordinate system

Note 1 to entry: The mid-eye point is the actual middle point between the driver's eyes. This point varies with the driver's head movement.

3.4.4 monitor viewing distance

distance of the mid-eye point of the viewer to the centre of the monitor coordinate system

Note 1 to entry: It is denoted as a_{monitor} and is measured in metres.

3.4.5 monitor viewing inclination angle

inclination angle of the monitor viewing direction in monitor coordinates

Note 1 to entry: It is denoted as θ_{monitor} and is measured in degrees.

Note 2 to entry: See [Figure 10](#).

Note 3 to entry: From the *monitor horizontal viewing angle* ([3.4.7](#)) and the *monitor vertical viewing angle* ([3.4.8](#)), this value can be derived as:

$$\theta_{\text{monitor}} = \arctan \sqrt{\tan^2 \theta_{\text{monitor/hor}} + \tan^2 \theta_{\text{monitor/ver}}} \quad (1)$$

3.4.6

monitor viewing azimuthal angle

azimuthal angle of the monitor viewing direction in monitor coordinates; it is measured counterclockwise and starting at 3 o'clock

Note 1 to entry: 3 o'clock is the right edge and 12 o'clock is the upper edge of the monitor as seen from the driver.

Note 2 to entry: It is denoted as $\Phi_{monitor}$ and is measured in degrees.

Note 3 to entry: See [Figure 10](#).

Note 4 to entry: From the *monitor horizontal viewing angle* ([3.4.7](#)) and the *monitor vertical viewing angle* ([3.4.8](#)), this value can be derived as:

$$\Phi_{monitor} = \arctan \left(\frac{\tan \theta_{monitor/ver}}{\tan \theta_{monitor/hor}} \right) \quad (2)$$

3.4.7

monitor horizontal viewing angle

monitor viewing inclination angle projected onto the plane defined by the monitor surface normal and the 12 o'clock direction

Note 1 to entry: It is denoted as $\theta_{monitor/hor}$ and is measured in degrees:

$$\theta_{monitor/hor} = \arctan \left[\tan(\theta_{monitor}) \cdot \cos(\Phi_{monitor}) \right] \quad (3)$$

Note 2 to entry: See [Figure 10](#) and [Figure 12](#).

3.4.8

monitor vertical viewing angle

monitor viewing inclination angle projected onto the plane defined by the monitor surface normal and the 3 o'clock direction

Note 1 to entry: It is denoted as $\theta_{monitor/ver}$ and is measured in degrees:

$$\theta_{monitor/ver} = \arctan \left[\tan(\theta_{monitor}) \cdot \sin(\Phi_{monitor}) \right] \quad (4)$$

Note 2 to entry: See [Figure 10](#) and [Figure 12](#).

3.4.9

monitor design viewing direction

specific monitor viewing direction allocated to the ORP and the specific vehicle design (i.e. monitor placement and rotation) indicated by the index "D"

3.4.10

monitor design viewing distance

distance of the ORP to the centre of the monitor coordinate system

Note 1 to entry: It is denoted as $a_{monitor/D}$ and is measured in metres.

3.4.11

monitor design viewing inclination angle

monitor viewing inclination angle derived from the monitor design viewing direction

Note 1 to entry: It is denoted as $\theta_{monitor/D}$ and is measured in degrees.

3.4.12

monitor design viewing azimuthal angle

monitor viewing azimuthal angle derived from the monitor design viewing direction

Note 1 to entry: It is denoted as $\Phi_{monitor/D}$ and is measured in degrees.

3.4.13

monitor design horizontal viewing angle

monitor horizontal viewing angle derived from the monitor design viewing direction

Note 1 to entry: It is denoted as $\theta_{\text{monitor/hor/D}}$ and is measured in degrees.

Note 2 to entry: See [Figure 10](#) and [Figure 12](#).

3.4.14

monitor design vertical viewing angle

monitor vertical viewing angle derived from the monitor design viewing direction

Note 1 to entry: It is denoted as $\theta_{\text{monitor/ver/D}}$ and is measured in degrees.

Note 2 to entry: See [Figure 10](#) and [Figure 12](#).

3.4.15

monitor pixel

smallest distinct able area on the monitor displaying a specific colour usually by additive mixing of the three primary colours (red, green, and blue) in different intensities

3.4.16

monitor defined size

portion of the monitor active area displaying at least the required field of view

Note 1 to entry: The monitor active area, as well as the displayed camera image, may extend beyond this area.

Note 2 to entry: The monitor defined size is defined by the system manufacturer.

Note 3 to entry: See *monitor defined horizontal size* ([3.4.17](#)) and *monitor defined vertical size* ([3.4.18](#)) for details and differentiation between horizontal and vertical size.

3.4.17

monitor defined horizontal size

portion of the monitor active area displaying at least the required horizontal field of view along the axis from 9 o'clock to 3 o'clock according to [Figure 11](#)

Note 1 to entry: It is denoted as $W_{\text{monitor/hor}}$ and is measured in metres.

3.4.18

monitor defined vertical size

portion of the monitor active area displaying at least the required vertical field of view along the axis from 6 o'clock to 12 o'clock according to [Figure 11](#)

Note 1 to entry: It is denoted as $H_{\text{monitor/ver}}$ and is measured in metres.

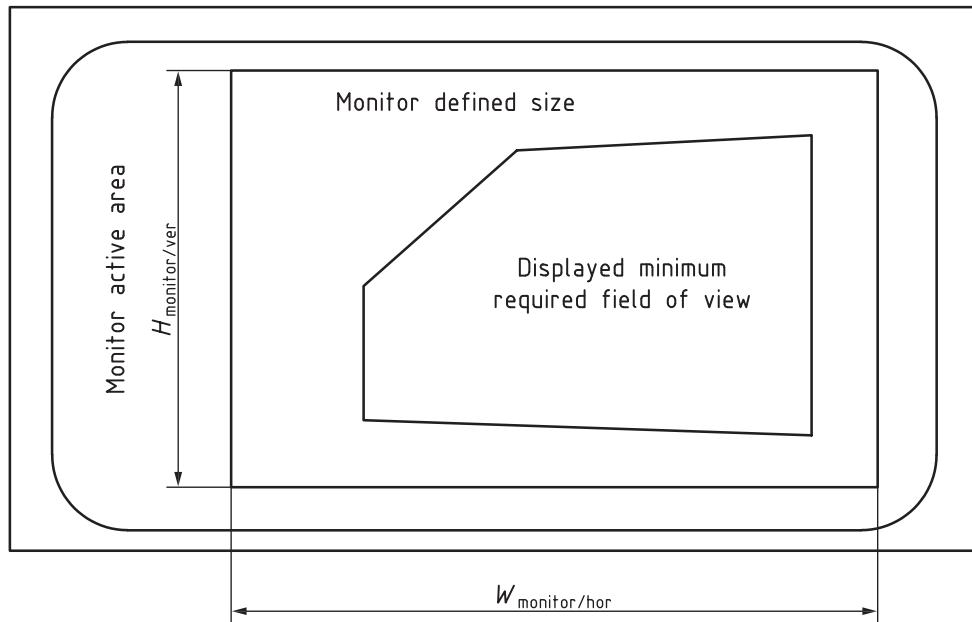


Figure 11 — Example of monitor defined size

3.4.19

monitor angular size

angle under which the driver would perceive the monitor defined size for $\theta_{monitor} = 0^\circ$ and $a_{monitor} = a_{monitor}/D$

Note 1 to entry: See *monitor horizontal angular size* (3.4.20) and *monitor vertical angular size* (3.4.21) for details and differentiation between horizontal and vertical angular size.

3.4.20

monitor horizontal angular size

angle between the lines from the ORP to the left and right edge of the monitor defined horizontal size for $\theta_{monitor} = 0^\circ$ and $a_{monitor} = a_{monitor}/D$

$$\alpha'_{monitor/hor} = 2 \arctan \left(\frac{W_{monitor/hor}}{2a_{monitor}/D} \right) \quad (5)$$

3.4.21

monitor vertical angular size

angle between the lines from the ORP to the top and bottom edge of the monitor defined vertical size for $\theta_{monitor} = 0$ and $a_{monitor} = a_{monitor}/D$

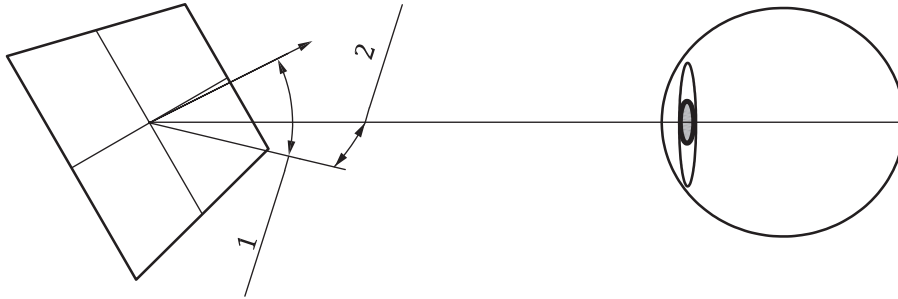
$$\alpha'_{monitor/ver} = 2 \arctan \left(\frac{H_{monitor/ver}}{2a_{monitor}/D} \right) \quad (6)$$

3.4.22

monitor design angular size

actual angular size of the monitor defined size as perceived from the driver in the specific vehicle design (i.e. seen from the monitor design viewing direction $\theta_{monitor} = \theta_{monitor}/D$, $\phi_{monitor} = \phi_{monitor}/D$, and $a_{monitor} = a_{monitor}/D$)

Note 1 to entry: See *monitor design horizontal angular size* (3.4.23) and *monitor design vertical angular size* (3.4.24) for details and differentiation between horizontal and vertical angular size.



Key

- 1 $\theta_{monitor/ver}$
- 2 $\theta_{monitor/hor}$

Figure 12 — Perspective view of horizontal and vertical viewing angle

3.4.23

monitor design horizontal angular size

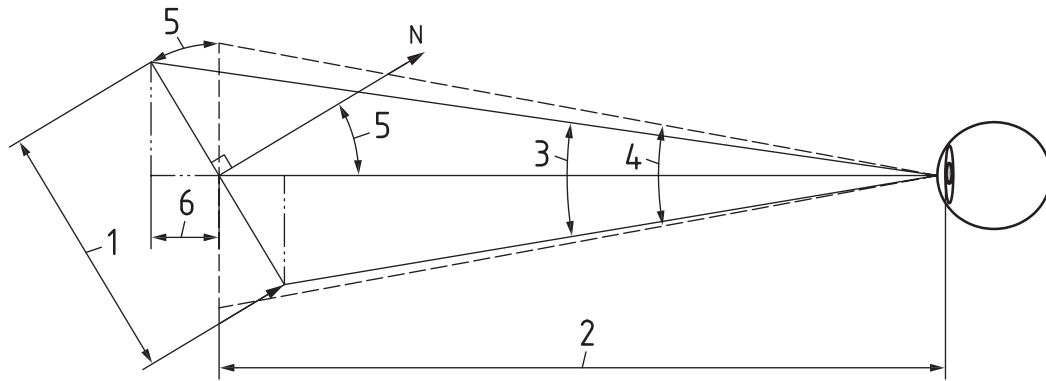
actual angular size of the monitor defined size as perceived from the driver in the specific vehicle design measured in the direction of the horizontal extent of the monitor

$$\alpha'_{monitor/hor/D} = \arctan \left\{ \frac{\frac{1}{2} \cdot W_{monitor/hor} \cdot \cos(\theta_{monitor/hor/D})}{a_{monitor/D} + \left[\frac{1}{2} \cdot W_{monitor/hor} \cdot \sin(\theta_{monitor/hor/D}) \right]} \right\} \quad (7)$$

$$+ \arctan \left\{ \frac{\frac{1}{2} \cdot W_{monitor/hor} \cdot \cos(\theta_{monitor/hor/D})}{a_{monitor/D} - \left[\frac{1}{2} \cdot W_{monitor/hor} \cdot \sin(\theta_{monitor/hor/D}) \right]} \right\}$$

Note 1 to entry: For $W_{monitor/hor} \ll a_{monitor/D}$, [Formula \(7\)](#) can be simplified to $\alpha'_{monitor/hor/D} = \cos(\theta_{monitor/hor/D}) \cdot \alpha'_{monitor/hor}$.

Note 2 to entry: See [Figure 13](#).



Key

- 1 $W_{\text{monitor}/\text{hor}}$, horizontal size of the monitor, tilted at centre
- 2 $a_{\text{monitor}/D}$
- 3 $\alpha'_{\text{monitor}/\text{hor}/D}$
- 4 $\alpha'_{\text{monitor}/\text{hor}}$, horizontal angular size of the monitor as seen from $\theta_{\text{monitor}/\text{hor}} = 0$
- 5 $\theta_{\text{monitor}/\text{hor}/D}$
- 6 $\frac{1}{2} W_{\text{monitor}/\text{hor}} \cdot \sin(\theta_{\text{monitor}/\text{hor}/D})$

Figure 13 — Monitor design horizontal angular size

3.4.24

monitor design vertical angular size

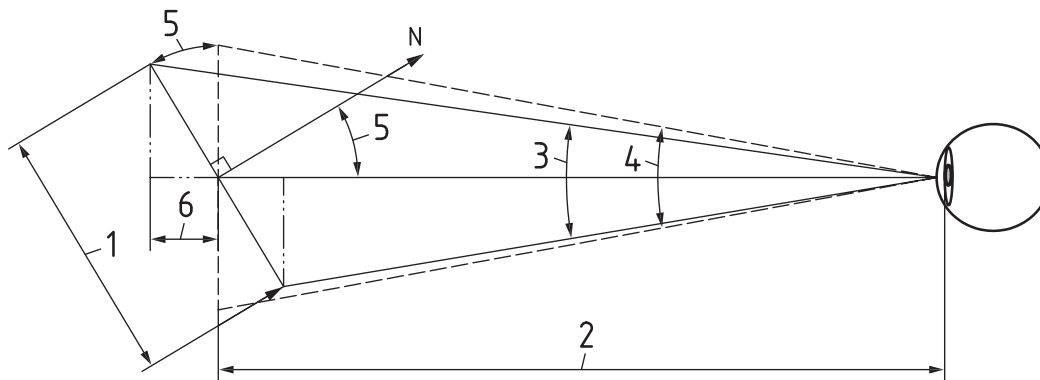
actual angular size of the monitor defined size as perceived from the driver in the specific vehicle design measured in direction of the vertical extent of the monitor

$$\alpha'_{\text{monitor}/\text{ver}/D} = \arctan \left\{ \frac{\frac{1}{2} \cdot H_{\text{monitor}/\text{ver}} \cdot \cos(\theta_{\text{monitor}/\text{ver}/D})}{a_{\text{monitor}/D} + \left[\frac{1}{2} \cdot H_{\text{monitor}/\text{ver}} \cdot \sin(\theta_{\text{monitor}/\text{ver}/D}) \right]} \right\} \quad (8)$$

$$+ \arctan \left\{ \frac{\frac{1}{2} \cdot H_{\text{monitor}/\text{ver}} \cdot \cos(\theta_{\text{monitor}/\text{ver}/D})}{a_{\text{monitor}/D} - \left[\frac{1}{2} \cdot H_{\text{monitor}/\text{ver}} \cdot \sin(\theta_{\text{monitor}/\text{ver}/D}) \right]} \right\}$$

Note 1 to entry: For $H_{\text{monitor}/\text{ver}} \ll a_{\text{monitor}/D}$, [Formula \(8\)](#) can be simplified to $\alpha'_{\text{monitor}/\text{ver}/D} = \cos(\theta_{\text{monitor}/\text{ver}/D}) \cdot \alpha'_{\text{monitor}/\text{ver}}$.

Note 2 to entry: See [Figure 14](#).



Key

- 1 $H_{monitor/ver}$, vertical size of the monitor, tilted at centre
- 2 $a_{monitor/D}$
- 3 $\alpha'_{monitor/ver/D}$
- 4 $\alpha'_{monitor/ver}$, vertical angular size of the monitor as seen from $\theta_{monitor/ver} = 0$
- 5 $\theta_{monitor/ver/D}$
- 6 $\frac{1}{2}H_{monitor/ver} * \sin(\theta_{monitor/ver/D})$

Figure 14 — Monitor design vertical angular size

3.4.25

monitor displayed field of view

portion of the camera's field of view that is actually displayed on the monitor defined size

3.4.26

monitor horizontal percentage of displayed camera field of view

percentage of the camera's horizontal field of view that is actually visible on the monitor defined by horizontal size

Note 1 to entry: It is denoted as $p_{camera/hor}$ and is given in percent.

3.4.27

monitor vertical percentage of displayed camera field of view

$$\frac{\text{percentage of the camera's vertical field of view that is actually visible on the monitor}}{\text{vertical size}}$$

Note 1 to entry: It is denoted as $p_{camera/ver}$ and is given in percent.

3.4.28

field of view displayed in the monitor defined horizontal size

portion of the camera's field of view that is actually displayed on the monitor defined horizontal size

$$\alpha_{monitor/hor} = \alpha_{camera/hor} * p_{camera/hor} \quad (9)$$

3.4.29

field of view displayed in the monitor defined vertical size

portion of the camera's field of view that is actually displayed on the monitor defined vertical size

$$\alpha_{monitor/ver} = \alpha_{camera/ver} * p_{camera/ver} \quad (10)$$

3.4.30 monitor displayed angular resolution

parameter that describes the ability of the monitor to resolve small details in the displayed scene

Note 1 to entry: It considers the mere resolution of the monitor and its relation to the field of view, the monitor is displaying.

Note 2 to entry: The smaller the angular resolution of a monitor, the smaller the details can be that are still resolved by the monitor.

3.4.31 monitor standard isotropy range

specific vertical range of 6 ° up and 6 ° down from the *monitor design vertical viewing angle* (3.4.14), and specific horizontal range of 7 ° right and 7 ° left from the *monitor design horizontal viewing angle* (3.4.13)

Note 1 to entry: The value is derived from the eye ellipse definition given in [ISO 4513:2010](#), Table 2, with a_{monitor} equals 60 cm.

3.4.32 monitor extended isotropy range

additional 5 ° from the standard isotropy range in the vertical and horizontal directions

Note 1 to entry: This additional range covers head movements.

3.4.33 image formation time

summation of the rise time and the fall time as defined in [ISO 9241-302:2008](#), 3.4.14

3.5 Camera Monitor System based terms and definitions

3.5.1 Camera Monitor System CMS

entity used in vehicles that presents the required outside information of a specific field of view to the driver of the vehicle, replacing conventional mirror system by means of electronic image capture and display devices

Note 1 to entry: It consists of a *camera* (3.3.1) that is usually installed at the bodywork of a vehicle and a *monitor* (3.4.1) that is usually placed inside the vehicle.

3.5.2 CMS system overview

scheme that comprises the black box of a functional system and its interfaces

Note 1 to entry: See [Figure 15](#).

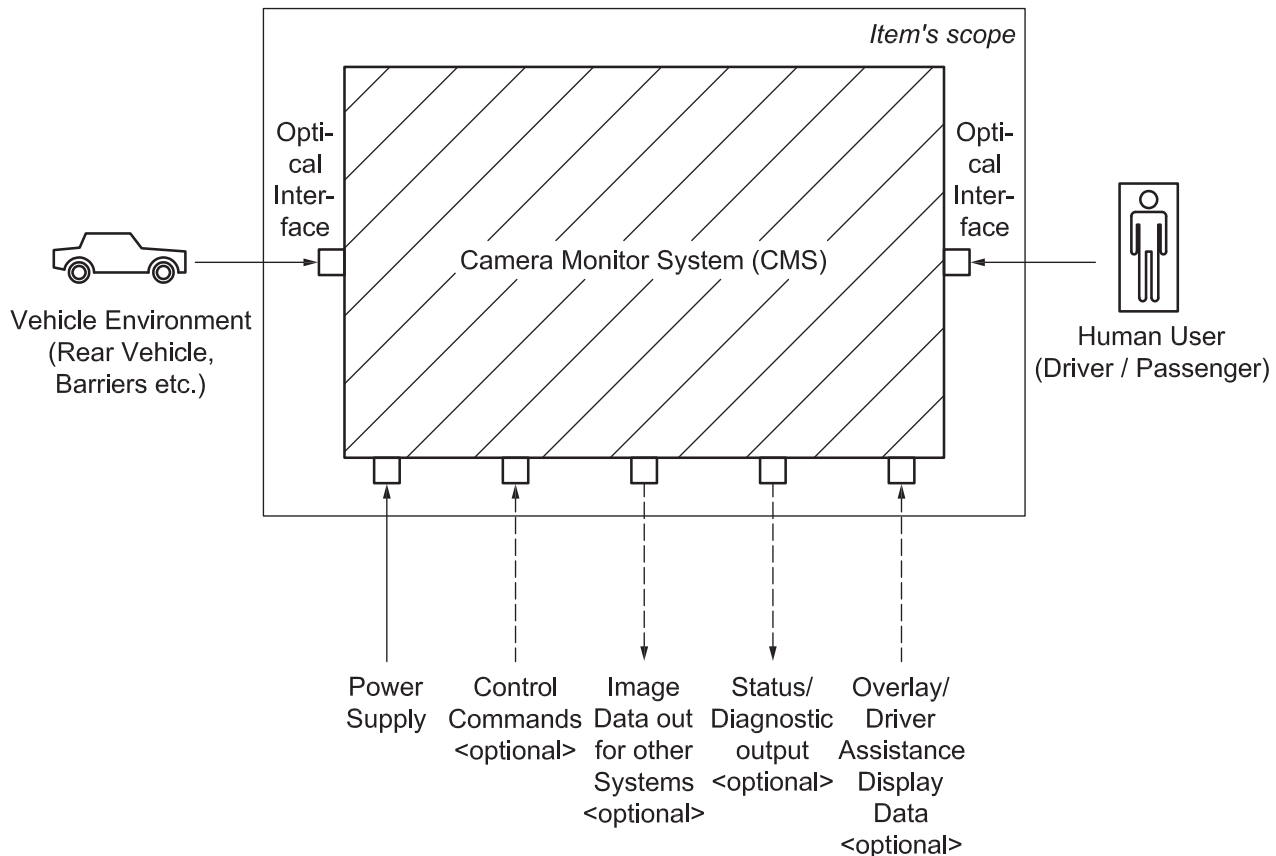


Figure 15 — System block diagram

Note 2 to entry: The external interfaces of the CMS are the following:

- captured optical signal from the vehicle's surrounding environment (technical realization: e.g. camera);
- optical image shown to the driver or a passenger (technical realization: e.g. display);
- power supply;
- control commands, e.g. on/off command (unless technically linked to the toggling of the power supply), and optionally choice of the image zoom factor, viewing area, contrast, brightness, etc.;
- optionally, image data output for other ADAS, which are not the scope of this document;
- optionally, status/diagnostic output signal (e.g. to activate warning lamp in the instrument cluster);
- optionally, overlay information or driver assistance display data from other ADAS, which are not in the scope of this document.

Note 3 to entry: The following entities are usually interacting with the CMS:

- vehicle on-board network (e.g. CAN, FlexRay, LIN, etc.);
- optionally, control elements (e.g. switches, buttons, joystick, menu entries, etc.);
- optionally, ADAS, which provide additional information on the display graphically or use images captured by the camera for their purposes.

3.5.3

CMS functional structure

system that is functionally divided in its essential parts

Note 1 to entry: See [Figure 16](#).

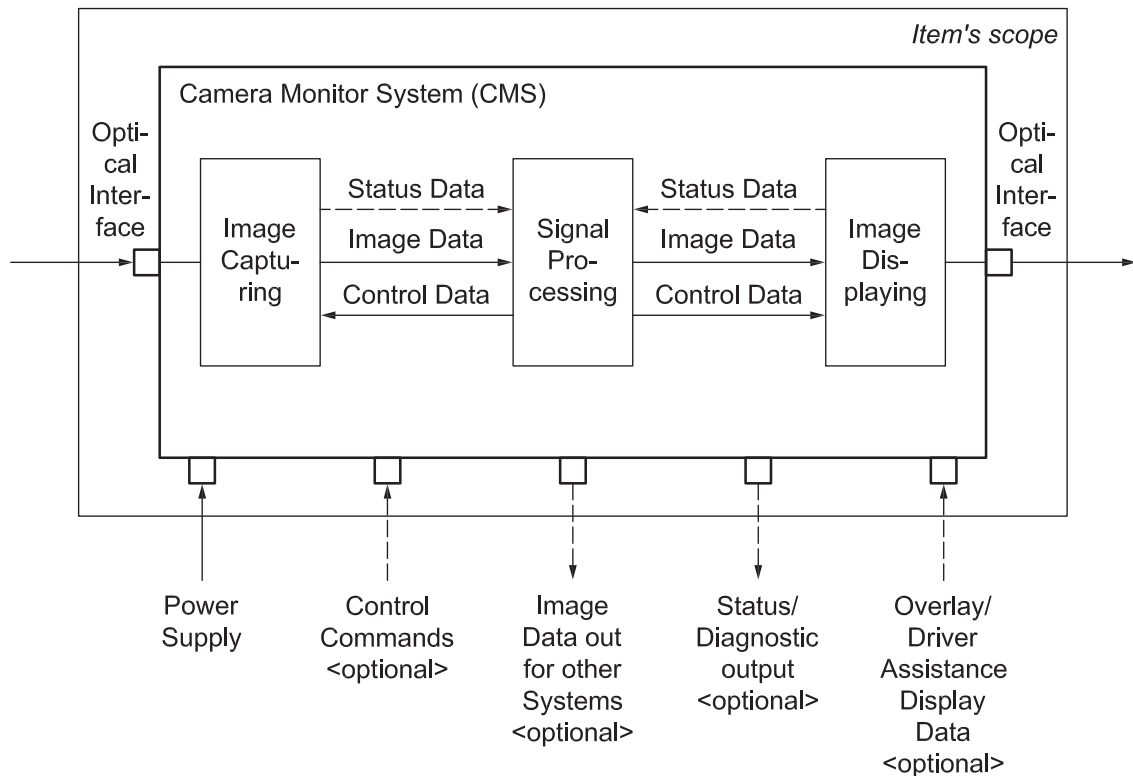


Figure 16 — CMS as white box

Note 2 to entry: A CMS is functionally divided in three essential parts:

- image capturing;
- image processing;
- image displaying, independent of different display technologies (e.g. flat screen, projection).

Note 3 to entry: The main task of the image capturing is to capture the visual surrounding field of the vehicle. It is realized by a camera, without regard to its implementation technologies.

Note 4 to entry: The image processing processes the image captured to realize display characteristics on the display unit, e.g. brightness or contrast adaptation, filtering, etc. It can be realized in hardware or software, either as a separate device, or integrated directly into the camera or in the display unit. Besides, the image processing part computes necessary controls of the camera (e.g. zoom) or display unit and also processes user inputs, if available, and optionally interface data from/to external ADAS.

Note 5 to entry: The image displaying represents the actual computed image in the vehicle on a screen or display at an appropriate viewing position for the driver. It can be realized for example by flat screen, projection, etc.

3.5.4

CMS field of view

field of view that a driver using the CMS is really able to observe; it is equal with the displayed field of view; for CMS with one camera and one monitor, this value is always less or equal to the camera field of view

3.5.5

CMS horizontal field of view

field of view that a driver using the CMS is really able to observe along the monitor defined horizontal size

Note 1 to entry: It is equal with the field of view displayed in the monitor horizontal size.

$$\alpha_{system/hor} = \alpha_{monitor/hor}$$

3.5.6

CMS vertical field of view

field of view that a driver using the CMS is really able to observe along the monitor defined vertical size

Note 1 to entry: It is equal with the field of view displayed in the monitor vertical size.

$$\alpha_{system/ver} = \alpha_{monitor/ver} \quad (12)$$

3.5.7

CMS magnification factor

defines the relationship between the angular size of an object as seen by the camera and the angular size as it is perceived by the driver on the monitor of the CMS

Note 1 to entry: It is denoted as M_{system} .

3.5.8

CMS average magnification factor

average value for the magnification of the CMS based on the relationship between $\alpha_{monitor}$, i.e. the displayed field of view, and $\alpha'_{monitor/D}$, i.e. the monitor design angular size

Note 1 to entry: It is denoted as $M_{system/avg}$.

3.5.9

CMS horizontal average magnification factor

horizontal average magnification of the scene observed through the CMS is given by:

$$M_{system/hor/avg} = \frac{\alpha'_{monitor/hor/D}}{\alpha_{monitor/hor}} \approx \cos(\theta_{monitor/hor/D}) * \left\{ \frac{2 \arctan\left(\frac{W_{monitor/hor}}{2a_{monitor/D}}\right)}{\alpha_{camera/hor} * p_{camera/hor}} \right\} \quad (13)$$

where

$\theta_{monitor/hor/D}$ is the monitor's design horizontal viewing angle (3.4.13);

$a_{monitor/D}$ is the distance of the ORP to the centre of the monitor coordinate system (see 3.4.10);

$W_{monitor/hor}$ is the monitor defined horizontal size (3.4.17);

$\alpha_{camera/hor}$ is the camera's horizontal field of view (3.3.15);

$p_{camera/hor}$ is the percentage of the camera's field of view as displayed on the monitor (see 3.4.26).

3.5.10

CMS vertical average magnification factor

vertical average magnification of the scene observed through the CMS is given by:

$$M_{system/ver/avg} = \frac{\alpha'_{monitor/ver/D}}{\alpha_{monitor/ver}} \approx \cos(\theta_{monitor/ver/D}) * \left\{ \frac{2 \arctan\left(\frac{H_{monitor/ver}}{2a_{monitor/D}}\right)}{\alpha_{camera/ver} * p_{camera/ver}} \right\} \quad (14)$$

where

$\theta_{monitor/ver/D}$ is the monitor's design vertical viewing angle (3.4.14);

- $a_{\text{monitor}/D}$ is the design distance of the monitor to the ORP (see [3.4.10](#));
- $H_{\text{monitor}/\text{ver}}$ is the *monitor defined vertical size* ([3.4.18](#));
- $\alpha_{\text{camera}/\text{ver}}$ is the *camera's vertical field of view* ([3.3.16](#));
- $p_{\text{camera}/\text{ver}}$ percentage of the camera's field of view as displayed on the monitor (see [3.4.27](#)).

3.5.11

CMS minimum magnification factor

minimum value for the magnification the CMS shows in the required field of view as defined in [6.5](#)

Note 1 to entry: It is denoted as $M_{\text{system}/\text{hor}/\text{min}}$ for horizontal direction and $M_{\text{system}/\text{ver}/\text{min}}$ for vertical direction.

3.5.12

CMS angular resolution

combination of the *camera angular resolution* ([3.3.17](#)) and the *monitor displayed angular resolution* ([3.4.30](#)); it describes the ability of the CMS as a whole to resolve small details in the displayed scene and is defined as the maximum of both values

Note 1 to entry: If the camera is not capturing a certain detail (i.e. it does not have a sufficient angular resolution), the monitor will not be able to display it, so the camera limits the angular resolution of the CMS. On the other hand, in case the monitor is displaying the camera image (i.e. the captured field of view) with less pixel resolution, it is the monitor that limits the angular resolution of the CMS, as details that are present in the camera image cannot be displayed and, thus, are not observable by the user. It has to be the maximum of both values, as smaller values for the angular resolution indicate a higher quality for the displayed scene.

3.5.13

CMS overlay

any driving-related visual information added to the original image (such as icons, labels, coloured areas, etc.) that modifies it in a way that part of the original information is hidden; overlays can be partially transparent or totally opaque and can be displayed temporary or permanently

3.6

signal to noise ratio

ratio of the usable wanted optical signal to unwanted noise

3.7

point light source

light source of very small angular extend of about 2 arcmin and has a luminance of more than 300 cd/m²

EXAMPLE Low beam headlights with a dimension of about 20 cm width in 350 m distance.

3.8

glare

condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance or by extreme contrasts

3.9

glare source

very bright light source like the sun or the headlights of a vehicle

Note 1 to entry: [Table 1](#) below shows some typical luminance values that are relevant for the case of a camera monitor system observing a road scene.

Table 1 — Typical luminance values relevant for camera monitor systems in road vehicles

Object	Luminance
Clear sky	8 000 cd/m ²
Night sky at full moon	0,1 cd/m ²

Object	Luminance
60 W light bulb	$120 \times 10^3 \text{ cd/m}^2$
TFT white	500 cd/m^2
TFT black	$0,8 \text{ cd/m}^2$
White LED	$50 \times 10^6 \text{ cd/m}^2$
Sun (clear day at noon)	$1,6 \times 10^9 \text{ cd/m}^2$

3.10

glare scenario

situation where a glare source is shining directly into the imaging system

3.11

parking situation

driving situation that includes all low speed manoeuvring with a vehicle or vehicle combination where it is important to precisely manoeuvre to the right spot ending at a certain vehicle orientation without colliding or interfering with surrounding objects

3.12

modulation transfer function

MTF

quantitative means to measure the spatial frequency capability as a modulus of the signal amplitude at which the individual black and white lines (or also described as line and space) of a test pattern are captured and transferred as output signal and reproduced on a display

Note 1 to entry: An MTF plot is obtained as signal amplitude response to the spatial frequency of the elements J1-J2, K1-K2, JS1-JS2, and KS1-KS2 of the chart shown in ISO 12233:2017, Figure I.2.

Note 2 to entry: An MTF plot can also be obtained by the discrete Fourier transform of the line-spread function, also known as the spatial frequency response (SFR), if the camera signal is not submitted to nonlinear gamma correction and/or image edge enhancement and/or image smoothing process. As this might not apply to most CMS, this method should only be used as a practical method for depth of field measurement.

3.13

MTF10

spatial frequency of the *modulation transfer function* (3.12), where an average modulation value is equal to 10 % of the modulation of its black and white reference level, given in [LW/PH] or line widths per picture height

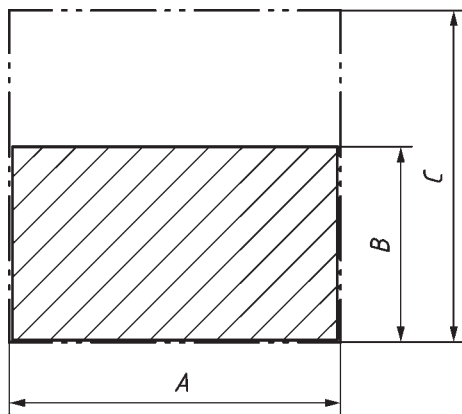
Note 1 to entry: The modulation is the difference between the black and white signal level divided by the sum of these levels. The result shows the limit visual resolution, to perceive fine details of the observed scene through the CMS. For the purpose of fast recognition of the scene, a signal drop limit of 10 % is used, instead of commonly used 5 % which is described as an example of limiting resolution in ISO 12233. The higher the frequency, the higher is the capability of the CMS system to reproduce fine details of the scene.

3.14

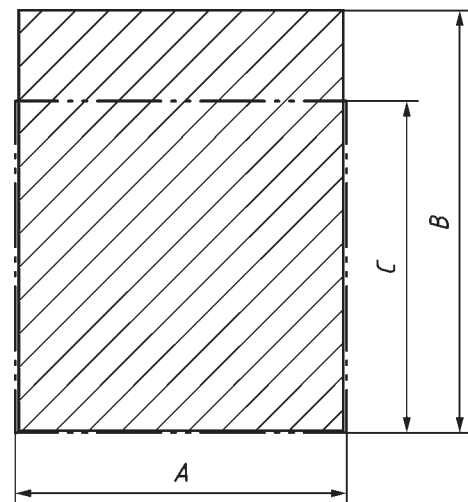
MTF10(1:1)/hor

is the horizontal spatial frequency of the CMS as measured and converted to an assumed monitor vertical size $H'_{\text{monitor/ver}} = W_{\text{monitor/hor}}$ resulting in a horizontal versus vertical output aspect ratio of 1:1 using the test procedure given in 7.5.3

Note 1 to entry: See Figure 17.



a) Landscape monitor



b) Portrait monitor

Key

- A $W_{\text{monitor}/\text{hor}}$
- B $H_{\text{monitor}/\text{ver}}$
- C $H'_{\text{monitor}/\text{ver}}$

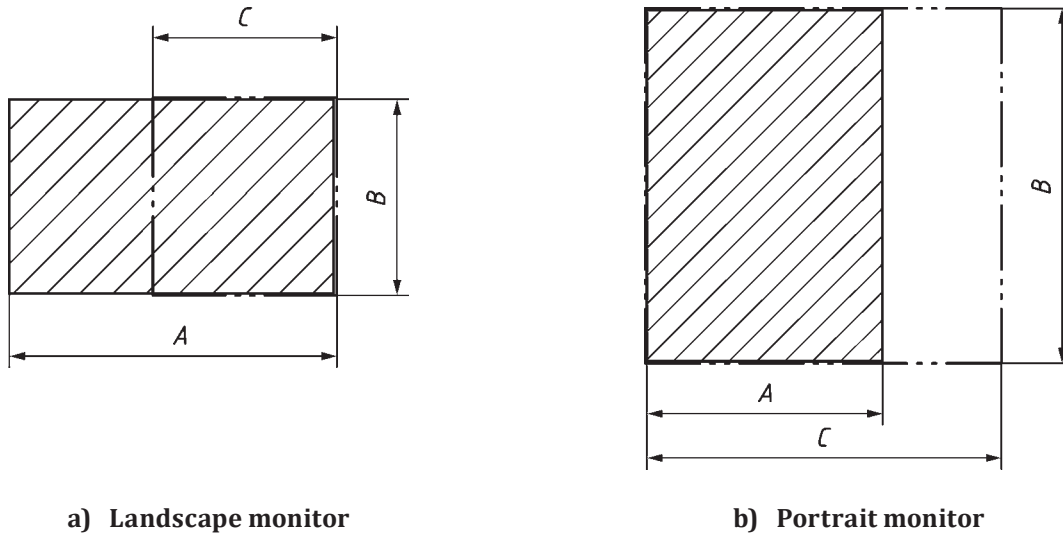
Figure 17 — Illustration of the assumed monitor dimensions of $\text{MTF10}_{(1:1)/\text{hor}}$

3.15

$\text{MTF10}_{(1:1)/\text{ver}}$

vertical spatial frequency of the CMS as measured and converted to an assumed monitor horizontal size $W'_{\text{monitor}/\text{hor}} = H_{\text{monitor}/\text{ver}}$ resulting in a horizontal versus vertical output aspect ratio of 1:1 using the test procedure given in [7.5.3](#)

Note 1 to entry: See [Figure 18](#).



Key

- A $W_{monitor/hor}$
B $H_{monitor/ver}$
C $W'_{monitor/hor}$

Figure 18 — Illustration of the assumed monitor dimensions of MTF10(1:1)/ver

3.16

MTF10_{MIN(1:1)/hor}

definition of horizontal spatial frequency requirement of resolution (MTF)

Note 1 to entry: It is denoted as MTF10_{MIN(1:1)/hor} and it is measured in line widths per picture height [LW/PH] of an assumed monitor defined size $H'_{monitor/ver} = W_{monitor/hor}$, resulting in a horizontal versus vertical output aspect ratio of 1:1; the requirement is given as observable number of lines along this assumed monitor defined size $H'_{monitor/ver} = W_{monitor/hor}$ and it is calculated as:

$$MTF10_{MIN(1:1)/hor} = \left(\frac{W_{monitor/hor}}{W_{monitor/hor/min}} \right) * M_{mirror/avg} * \alpha_{mirror/hor/min} * V_{eye/min} * 60 \frac{\text{arcmin}}{^\circ} \quad (15)$$

Note 2 to entry: The spatial frequency requirement is derived from the number of observable lines in the required field of view of a traditional mirror which is given by: $M_{mirror/avg} * \alpha_{mirror/hor/min} * V_{eye/min} * 60 \frac{\text{arcmin}}{^\circ}$. The

factor $\left(\frac{W_{monitor/hor}}{W_{monitor/hor/min}} \right)$ in [Formula \(15\)](#) reflects the size correction, as the ratio of the monitor horizontal defined size ($W_{monitor/hor}$) versus the monitor horizontal size displaying the required field of view ($W_{monitor/hor/min}$), compensating for the different size in the monitor defined size measurement.

In a distortion free CMS with a constant magnification throughout the entire monitor defined size, the following approximation applies $\left(\frac{W_{monitor/hor}}{W_{monitor/hor/min}} \right) \approx \left(\frac{\alpha_{monitor/hor}}{\alpha_{mirror/hor/min}} \right)$. For such a system, the calculation formula of the measurable value MTF10_{MIN(1:1)/hor} can be simplified as:

$$MTF10_{MIN(1:1)/hor} = M_{mirror/avg} * \alpha_{monitor/hor} * V_{eye/min} * 60 \frac{\text{arcmin}}{^\circ}$$

Note 3 to entry: For the adaptation of resolution measurement according to [ISO 12233](#), the measurable value given for a squared aspect ratio 1:1 with length equal to monitor defined size, has to be corrected to take into account the actual measuring monitor size, according to different aspect ratio or to wider measuring field of view. For details of measurement using the monitor defined size, see [D.4](#), or see [D.5](#) for measurement using a partially cropped square image.

Note 4 to entry: Concerning the resolution MTF requirements, $M_{mirror/avg}$ has to be 0,33 for the FMVSS 111 interior mirror and 0,31 for the driver side exterior mirror.

3.17

MTF10_{MIN(1:1)/ver}

definition of vertical spatial frequency requirement of resolution (MTF)

Note 1 to entry: It is denoted as MTF10_{MIN(1:1)/ver} and it is measured in line widths per picture height [LW/PH] of an assumed monitor defined size $W'_{monitor/hor} = H_{monitor/ver}$, resulting in a horizontal versus vertical output aspect ratio of 1:1; the requirement is given as observable number of lines along this assumed monitor defined size $W'_{monitor/hor} = H_{monitor/ver}$ and it is calculated as:

$$MTF10_{MIN(1:1)/ver} = \left(\frac{H_{monitor/ver}}{H_{monitor/ver/min}} \right) * M_{mirror/avg} * \alpha_{mirror/ver/min} * V_{eye/min} * 60 \frac{\text{arcmin}}{\circ} \quad (16)$$

Note 2 to entry: The spatial frequency requirement is derived from the number of observable lines in the required field of view of a traditional mirror which is given by $M_{mirror/avg} * \alpha_{mirror/ver/min} * V_{eye/min} * 60 \frac{\text{arcmin}}{\circ}$. The

factor $\left(\frac{H_{monitor/ver}}{H_{monitor/ver/min}} \right)$ in [Formula \(16\)](#) reflects the size correction, as the ratio of the monitor vertical defined size ($H_{monitor/ver}$) versus the monitor vertical size displaying the required field of view ($H_{monitor/hor/min}$), compensating for the different size in the monitor defined size measurement. In a distortion free CMS with a constant magnification throughout the entire monitor defined size, the following approximation applies $\left(\frac{H_{monitor/ver}}{H_{monitor/ver/min}} \right) \approx \left(\frac{\alpha_{monitor/ver}}{\alpha_{mirror/ver/min}} \right)$. For such a system, the calculation formula of the measurable value

MTF10_{MIN(1:1)/ver} can be simplified as $MTF10_{MIN(1:1)/ver} = M_{mirror/avg} * \alpha_{monitor/ver} * V_{eye/min} * 60 \frac{\text{arcmin}}{\circ}$.

3.18

MTF50_{MIN(1:1)}

spatial frequency of the *modulation transfer function* ([3.12](#)), where an average modulation value equal to 50 % of the modulation of its black and white reference level, where the monitor displayed field of view is shown in the monitor defined size, with horizontal versus vertical output aspect ratio of 1:1

Note 1 to entry: Adaptation of measurable value to specific CMS with different aspect ratio or to different measured field of view has to be done accordingly as it is done for MTF10_{MIN(1:1)}. For more details of unit conversion and measurement, see information given in [D.3](#), [D.4](#) or [D.5](#). Lower frequency of this value results in lower contrast of the scene observed through the CMS and the value is used to characterize the sharpness performance of the CMS.

3.19

luminance white level

luminance of the monitor when driven with an artificial 70 % grey-scale image measured from a specific viewing direction (θ, Φ)

Note 1 to entry: It is denoted as $L_{monitor/white}(\theta, \Phi)$ and measured in cd/m².

Note 2 to entry: This luminance is representing the white level output of the camera.

3.20

luminance of region white at contrast chart

luminance of a high reflective part of a contrast chart reproducing a contrast ratio CR of at least 20:1; the luminance value is measured with an area luminance photometer in cd/m^2 from the CMS cameras point of view

Note 1 to entry: It is denoted as $L_{\text{chart}/\text{white}}$.

3.21

luminance of region black at contrast chart

luminance of a low reflective part of a contrast chart reproducing a contrast ratio CR of at least 20:1; the luminance value is measured with an area luminance photometer in cd/m^2 from the CMS cameras point of view

Note 1 to entry: It is denoted as $L_{\text{chart}/\text{black}}$.

3.22

luminance of region white at contrast chart reproduced from the monitor

luminance of the high reflective part of a contrast chart (min CR = 20:1) displayed on the CMS monitor; the luminance value is measured at darkroom conditions with an area luminance photometer in cd/m^2 from the design viewing direction

Note 1 to entry: It is denoted as $L_{\text{monitor}/\text{chart}/\text{white}}$.

3.23

luminance of region black at contrast chart reproduced from the monitor

luminance of the low reflective part of a contrast chart (min CR = 20:1) displayed on the CMS monitor; the luminance value is measured with an area luminance photometer in cd/m^2 from the design viewing direction

Note 1 to entry: It is denoted as $L_{\text{monitor}/\text{chart}/\text{black}}$.

3.24

luminance of region white at contrast chart reproduced from the monitor under ambient light

luminance of the high reflective part of a contrast chart (min CR = 20:1) displayed on the CMS monitor; the luminance value is measured at test conditions with ambient light with an area luminance photometer in cd/m^2 from the design viewing direction

Note 1 to entry: It is denoted as $L_{\text{monitor}/\text{chart}/\text{white}/\text{ambient}}$.

3.25

luminance of region black at contrast chart reproduced from the monitor under ambient light

luminance of the low reflective part of a contrast chart (min CR = 20:1) displayed on the CMS monitor; the luminance value is measured at test conditions with ambient light with an area luminance photometer in cd/m^2 from the design viewing direction

Note 1 to entry: It is denoted as $L_{\text{monitor}/\text{chart}/\text{black}/\text{ambient}}$.

3.26

reflected luminance from ambient light at monitor displaying a bright scene

luminance of the reflected ambient light measured at an area of the monitor displaying a bright part of a contrast chart (min CR = 20:1)

Note 1 to entry: The luminance value is denoted as $L_{r/\text{white}}$ and is calculated from measured values with an area luminance photometer in cd/m^2 from the design viewing direction using the following formula:

$$L_{r/\text{white}} = L_{\text{monitor}/\text{chart}/\text{white}} (\text{ambient light on}) - L_{\text{monitor}/\text{chart}/\text{white}} (\text{ambient light off}) \quad (17)$$

3.27**reflected luminance from ambient light at monitor displaying a dark scene**

luminance of the reflected ambient light measured at an area of the monitor displaying a dark part of a contrast chart (min CR = 20:1)

Note 1 to entry: The luminance value is denoted as $L_{r/black}$ and is calculated from measured values with an area luminance photometer in cd/m² from the design viewing direction using the following formula:

$$L_{r/black} = L_{monitor/chart/black} (ambient\ light\ on) - L_{monitor/chart/black} (ambient\ light\ off) \quad (18)$$

3.28**background luminance**

luminance of the monitor displaying the image of a completely dark scene (e. g. the camera covered with opaque tissue), measured in a dark environment

4 Symbols and abbreviated terms

$\alpha_{mirror/hor}$	horizontal field of view of a mirror (see 3.2.17)
$\alpha_{mirror/ver}$	vertical field of view of a mirror (see 3.2.19)
$\alpha_{mirror/hor/min}$	minimum horizontal field of view of a mirror (see 3.2.18)
$\alpha_{mirror/ver/min}$	minimum vertical field of view of a mirror (see 3.2.20)
$\alpha_{camera/hor}$	horizontal field of view of a camera (see 3.3.15)
$\alpha_{camera/ver}$	vertical field of view of a camera (see 3.3.16)
$\alpha_{monitor/hor}$	horizontal displayed field of view on the monitor defined horizontal size (see 3.4.28)
$\alpha_{monitor/ver}$	vertical displayed field of view on the monitor defined vertical size (see 3.4.29)
$\alpha_{system/hor}$	horizontal field of view of the CMS (see 3.5.5)
$\alpha_{system/ver}$	vertical field of view of the CMS (see 3.5.6)
$\alpha'_{mirror/hor}$	horizontal angular size of a mirror (see 3.2.14)
$\alpha'_{mirror/ver}$	vertical angular size of a mirror (see 3.2.15)
$\alpha'_{monitor/hor}$	horizontal angular size of the monitor (see 3.4.20)
$\alpha'_{monitor/ver}$	vertical angular size of the monitor (see 3.4.21)
$\alpha'_{monitor/hor/D}$	horizontal angular size of the monitor defined horizontal size derived from the monitor design viewing direction (see 3.4.23)
$\alpha'_{monitor/ver/D}$	vertical angular size of the monitor defined vertical size derived from the monitor design viewing direction (see 3.4.24)
β_{mirror}	mirror viewing angle (see 3.2.5)
$\beta_{mirror/driver/min}$	minimum mirror viewing angle on the driver side (see 3.2.6)
$\beta_{mirror/driver/max}$	maximum mirror viewing angle on the driver side (see 3.2.7)

$\beta_{\text{mirror/passenger/min}}$	minimum mirror viewing angle on the passenger side (see 3.2.8)
$\beta_{\text{mirror/passenger/max}}$	maximum mirror viewing angle on the passenger side (see 3.2.9)
$\theta_{\text{monitor/hor}}$	horizontal viewing angle onto the monitor (see 3.4.7)
$\theta_{\text{monitor/ver}}$	vertical viewing angle onto the monitor (see 3.4.8)
$\theta_{\text{monitor/hor/D}}$	horizontal viewing angle onto the monitor derived from the monitor design viewing direction (see 3.4.13)
$\theta_{\text{monitor/ver/D}}$	vertical viewing angle onto the monitor derived from the monitor design viewing direction (see 3.4.14)
θ_{monitor}	inclination viewing angle onto the monitor in spherical coordinates (see 3.4.5)
Φ_{monitor}	azimuthal viewing angle onto the monitor in spherical coordinates (see 3.4.6)
$\theta_{\text{monitor/D}}$	inclination viewing angle onto the monitor derived from the monitor design viewing direction (see 3.4.11)
$\Phi_{\text{monitor/D}}$	azimuthal viewing angle onto the monitor derived from the monitor design viewing direction (see 3.4.12)
a_{mirror}	distance from the ocular reference point to the centre of the mirror (see 3.2.2)
$a_{\text{mirror/driver/max}}$	maximum distance from the ocular reference point to the centre of the mirror on the driver side (see 3.2.3)
$a_{\text{mirror/passenger/max}}$	maximum distance from the ocular reference point to the centre of the mirror on the passenger side (see 3.2.4)
a_{monitor}	distance of the mid-eye point of the viewer to the centre of the monitor coordinate system (see 3.4.4)
$a_{\text{monitor/D}}$	distance of the ORP to the centre of the monitor coordinate system (see 3.4.10)
d_{object}	distance from the mirror to an object being viewed by the driver (see 3.2.10)
EP_{camera}	entrance pupil of a camera (see 3.3.13)
$H_{\text{monitor/ver}}$	monitor defined vertical size (see 3.4.18)
$H_{\text{monitor/ver/min}}$	vertical height of the minimum (required) vertical field of view (see 3.2.19 and Figure D.7) as displayed on the monitor
$L_{\text{chart/white}}$	luminance of region white at contrast chart (see 3.20)
$L_{\text{chart/black}}$	luminance of region black at contrast chart (see 3.21)
$L_{\text{monitor/chart/white}}$	luminance of region white at contrast chart reproduced from the monitor (see 3.22)
$L_{\text{monitor/chart/black}}$	luminance of region black at contrast chart reproduced from the monitor (see 3.23)

$L_{\text{monitor/chart/white/ambient}}$	luminance of region white at contrast chart reproduced from the monitor under ambient light (see 3.24)
$L_{\text{monitor/chart/black/ambient}}$	luminance of region black at contrast chart reproduced from the monitor under ambient light (see 3.25)
$L_{\text{monitor/white}}(\theta, \Phi)$	luminance of the monitor when driven with an artificial 70 % grayscale image, measured from a specific viewing direction (θ, Φ) (see 3.19)
L_r/white	reflected luminance from ambient light at monitor displaying a bright scene (see 3.26)
L_r/black	reflected luminance from ambient light at monitor displaying a dark scene (see 3.27)
M_{mirror}	magnification factor of a mirror (see 3.2.21)
$M_{\text{mirror/avg}}$	average magnification factor of a mirror (see 3.2.22)
$M_{\text{mirror/driver/avg}}$	average magnification factor of a mirror on the driver side (see 3.2.23)
$M_{\text{mirror/passenger/avg}}$	average magnification factor of a mirror on the passenger side (see 3.2.24)
$M_{\text{mirror/min}}$	minimum magnification factor of a mirror (see 3.2.25)
$M_{\text{mirror/driver/min}}$	minimum magnification factor of a mirror on the driver side (see 3.2.26)
$M_{\text{mirror/passenger/min}}$	minimum magnification factor of a mirror on the passenger side (see 3.2.27)
$M_{\text{mirror/0}}$	ideal magnification when viewing an object at a large distance straight from front, i.e. at viewing angle $\beta_{\text{mirror}} = 0$ and d_{object} approaching infinity
M_{system}	magnification factor of the CMS (see 3.5.7)
$M_{\text{system/avg}}$	average magnification factor of the CMS (see 3.5.8)
$M_{\text{system/hor/avg}}$	horizontal average magnification factor of the CMS (see 3.5.9)
$M_{\text{system/ver/avg}}$	vertical average magnification factor of the CMS (see 3.5.10)
$M_{\text{system/hor/min}}$	horizontal minimum magnification factor of the CMS (see 3.5.11)
$M_{\text{system/ver/min}}$	vertical minimum magnification factor of the CMS (see 3.5.11)
MTF10	spatial frequency of the MTF, where the modulation has dropped to 10 % of the modulation of its reference black and white signal level (see 3.13)
MTF10 _{(1:1)/hor}	spatial frequency of the CMS as measured and converted to an assumed monitor aspect ratio of (1:1) using the test procedure given in 7.5.3 (see 3.14)
MTF10 _{(1:1)/ver}	spatial frequency of the CMS as measured and converted to an assumed monitor aspect ratio of (1:1) using the test procedure given in 7.5.3 (see 3.15)
MTF10 _{MIN(1:1)/hor}	$\overline{A_1}$ required minimum resolution MTF10 in the horizontal direction as defined in an assumed view size monitor with 1:1 aspect ratio (see 3.16) $\overline{A_1}$
MTF10 _{MIN(1:1)/ver}	$\overline{A_1}$ required minimum resolution MTF10 in the vertical direction as defined in an assumed view size monitor with 1:1 aspect ratio (see 3.17) $\overline{A_1}$
MTF50 _(1:1)	spatial frequency of the MTF, where the modulation has dropped to 50 % of the modulation of its reference black and white signal level (see 3.18)

$N_{camera/hor}$	horizontal resolution of a camera (see 3.3.10)
$N_{camera/ver}$	vertical resolution of a camera (see 3.3.11)
$p_{camera/hor}$	percentage of camera horizontal field of view displayed on the monitor defined horizontal size (see 3.4.26)
$p_{camera/ver}$	percentage of camera vertical field of view displayed on the monitor defined vertical size (see 3.4.27)
r_{mirror}	radius of curvature of a mirror (see 3.2.11)
$r_{mirror/min}$	minimum allowed radius of curvature (see 3.2.12)
V_{eye}	visual acuity of the human eye (see 3.2.29)
$V_{eye/min}$	minimum allowed visual acuity (see 3.2.30)
$W_{monitor/hor}$	monitor defined horizontal size (see 3.4.17)
$W_{monitor/hor/min}$	horizontal width of the minimum (required) horizontal field of view (see 3.2.18 and Figure D.7) as displayed on the monitor
x_{camera}	distance of the camera to the ocular reference point in x-direction (see 3.3.4)
y_{camera}	distance from the outermost point of the same side of the vehicle to the entrance pupil of a camera replacing side mirrors in y-direction (see 3.3.5)
y'_{camera}	distance from the longitudinal centre x-z-plane to the entrance pupil of a camera replacing the interior centre mirror in y-direction (see 3.3.5)
z_{camera}	distance from the road surface to the centre of the entrance pupil of the camera (see 3.3.6)
ADAS	Advanced Driver Assistance System
CMS	Camera Monitor System (see 3.5.1)
GVW	Gross Vehicle Weight
MTF	Modulation Transfer Function (see 3.12)
ORP	Driver Ocular Reference Point (see 3.1.4)
SFR	Spatial Frequency Response (see 3.12)

5 General information and use case definitions

The main content of the displayed image on the monitor is “reality information” (according to [ISO 9241-307](#)) that is the imaging of objects and scenes that do have existing originals in our world — e.g. faces, people, landscapes, etc. — in colour presentation.

The perception is summarized as follows:

- view of the field of vision of the intended mirror class;
- observation of traffic situations;
- observation of the near and far environment around the vehicle;
- perception of objects (e.g. vehicles, cyclists, pedestrian, traffic signs, signal lights, etc.);

— perception of location, distance and velocity of objects.

The use cases serve as an orientation for the derivation of system requirements. In addition, they may be used for practical evaluation of a CMS during road tests.

A use case identifies a single traffic situation in which a CMS is used together with its specific task to be performed by the driver as well as its associated potential critical situations and metrics.

[Table 2](#) is the list of possible use cases applicable for CMS.

Table 2 — List of possible use cases applicable for CMS

Title	Task description	Critical situation	Critical metric	Justification
Roundabout	Monitoring traffic when whole image content rapidly changes (e.g. roundabout with multiple lanes)	Night time	Frame rate and controlling the driver side field of view	Night time is critical because of higher exposure time for the camera
Merge lane	Vehicle is entering a freeway	Inability to merge into freeway traffic	Limited field of view	Inability to expand the field of view similar to head movement using conventional mirror
Lane change (1)	Object are next to vehicle when a lane change is intended	Object in blind spot	Limited field of view	According to UN Regulation No. 46, conventional mirrors can have aspheric extension for covering the blind spot
Lane change (2)	Objects approaching from behind at a high relative speed	Day time and night time	Distance and speed estimation	Different cues for estimating distance and speed during day and night time
Tunnel	Drive into/out of tunnel at high speed	Significant and fast ambient light change	Camera and monitor parameters	Change in overall lighting on bright days require a fast adjustment of camera and monitor parameters
Direct light in the display	Ambient light reflection on display surface	Direct sunlight	Legibility of information	Ambient light could affect contrast ratio
Direct light in the camera	High dynamic ambient light	Reflections, low sun, headlamps, etc.	Legibility of information	Ambient light could affect contrast ratio
Cold start	Start driving immediately after a cold start	Cold temperature	Start-up, boot time	System requires initialization
Reverse driving (1)	Detect relevant objects while backing up	N/A	Field of view	Fixed versus dynamic field of view
Reverse driving (2)	Estimate distance to relevant objects while backing up	N/A	Distance estimation	Lack of stereoscopic vision while using two-dimensional monitor and camera
Vehicle in garage situation	Detect relevant objects while backing up	Daylight versus dark environment	Legibility	Camera and monitor in different modes (day versus night)

Title	Task description	Critical situation	Critical metric	Justification
Engine stop	Detect relevant objects when engine is stopped	N/A	Availability of the system	Observation of traffic is necessary even engine is stopped
City drive	Concentrate on relevant critical objects	Day and night time	Distance estimation and spatial relation	Distraction, depth of field is usually static with CMS while a driver can adjust the focal plane using a conventional mirror
Long-time drive (1)	Monotonous drive of longer distances most likely on free-ways	Day time	Ergonomic factors	Possible fatigue of the driver due to frequent changes of accommodation
Long-time drive (2)	Monotonous drive of longer distances most likely on free-ways	Night time	Ergonomic factors	Possible annoyance due to nonblack display
Elderly driver	Presbyope wear special eye glasses (bifocal or progressive lens)	N/A	Position of the display	Focus on near objects limited to angular sizes beneath the Frankfort plane
Turning	Percept critical objects while turning	Persons, children, bicycles, etc.	Field of view	Inability to expand the field of view similar to head movement using conventional mirror
Signal lamps	Percept an emergency vehicle in action, percept turn signals, etc.	Night time	Colour rendering index; frame rate	Recognize colour of signal lamps
Static evaluation	Precise measurement of the field of view	N/A	Field of view	Check accordance with legal requirements
Display arrangements for natural driving behaviour	Monitoring a complex situation where the display position should come natural in relation to other vision means	Complex traffic situations or tricky manoeuvring where adjacent or approaching objects are to be detected	Safety and driver acceptance	Arrangements of displays and how field of views are presented in relation to other vision means could be dangerous and cause incidents or even accidents
Round-about with trailer	Monitoring vehicle, trailer and rear end of trailer, but also road side, lines, and other road users	Day time and night time when passing through a round-about	Field of view (increase from head movements not available as with a conventional mirror system)	Without considering the increased field of view from head movements, a CMS will provide too little and become unsafe/hard to implement
Monitor reflections into window surfaces	Viewing objects through lower side-windows or windscreen either with direct vision or via external indirect vision devices gets disturbed by monitor reflections onto the window surfaces	Night time	Geometrical relations between monitor and windows as well as monitor luminance level	Reflections that prevent direct or indirect vision of objects around the vehicle form a safety risk

Title	Task description	Critical situation	Critical metric	Justification
Light and shadow in the same view	Viewing and understanding the near surroundings around the vehicle gets difficult when different parts of the surroundings have very different light conditions (e.g. direct sunlight and complete shadow)	Objects in direct sun light versus complete shadow can be missed if not displayed in a discernible way	Legibility (brightness and contrast control by camera and display)	Camera and monitor need to process areas with different light conditions differently to secure that the driver can see critical objects properly
Light and shadow in different views	Viewing what happens around the vehicle when each camera view covers surroundings with very different light conditions	Camera views with better light conditions get more attention than camera views with poor conditions where something critical actually takes place	Legibility (brightness and contrast)	Camera views need to be processed so they can be presented for the driver in a balanced way securing that critical objects are brought to the driver's attention
Reversing with trailer	Monitoring vehicle, trailer and rear end of trailer. It is also important to see the object that you are reversing towards and any obstacles along the way.	Day time and night time when reversing	Field of view (increase from head movements not available as with a conventional mirror system)	Without considering the increased field of view from head movements, a CMS will provide too little and become unsafe/hard to implement.
Extreme driver sizes	An extreme driver size (e.g. very short, very tall or with unusual anthropometric proportions) gets an awkward relation between eye locations and the monitor arrangement.	Display gets hard to view due to distance, viewing angle and/or large required head rotation	Ergonomic factors	Potential safety risks compared to a conventional adjustable mirror designed to take most driver sizes into account
Turning with trailer	Monitoring vehicle and trailer as well as more of the road to understand how the vehicle combination is located in relation to surroundings	Day time and night time when turning left or right	Field of view (increase from head movements not available as with a conventional mirror system)	Without considering the increased field of view from head movements, a CMS will provide too little and become unsafe/hard to implement
Exiting after temporary standstill	Indirect vision is needed in order to see if it is safe to exit the vehicle	Another vehicle is coming close to the vehicle when the driver and/or passengers intend to exit	CMS availability; thanks to the wise use of conditions for keeping the system active	Dangerous situations need to be avoided compared to the functionality that conventional mirrors provide
Exiting after longer period of resting in the vehicle	Indirect vision is needed in order to see if it is safe to exit the vehicle	Another vehicle is coming close to the vehicle when the driver and/or passengers intend to exit	CMS availability despite fewer conditions that could trigger system initiation	Dangerous situations need to be avoided compared to the functionality that conventional mirrors provide