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Measuring autofocus repeatability of sharpness and latency

Mesure de la répétabilité de la netteté et de la latence de l'autofocus

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 42, *Photography*.

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

This document is focusing on measuring the repeatability of the AF latency and the sharpness of the captured images. ISO 15781 specifies how to measure and report the shooting time lag, shutter release time lag, shooting rate and start-up time lag for digital still cameras. This document focuses on combining the autofocus latency with measured sharpness of the captured photos, making it more comprehensive test procedure for evaluating autofocus systems.

This document widens the options for usable test charts from high contrast digitally created charts to natural images and to other test charts and even 3D scenes, challenging the autofocus systems. It also allows measurements to be carried out in variable lighting conditions, and in presence of handshake, challenging the AF system further.

ISO 15781 is mainly focusing on traditional single autofocus solutions actuated by half pressing physical shutter button, widely used with SLR cameras. However, this document can be applied to continuous AF systems, commonly used in mobile camera devices, as well as to single autofocus systems.

This document provides procedures and methods to measure and report the autofocus (AF) repeatability of sharpness and latency of a digital still camera. The data gathered is useful when comparing camera devices with sufficiently similar autofocus solutions and it helps with further investigations into a camera's autofocus repeatability performance.

The terminology is defined within this document along with describing the test charts, the setup, the methods, the performance metrics and analysis methodology to assess and report on the autofocus repeatability of a camera device. This document covers the test setups, the process, what pictures to capture and the metrics to calculate.

A great camera system should be capable to deliver repeatably sharp images within acceptable and repeatable latency, making the characterization of the AF system very important.

Measuring autofocus repeatability of sharpness and latency

1 Scope

This document is focused on measuring the autofocus (AF) repeatability of sharpness and latency, meaning camera system's capability to produce sharp images within certain time frame. The scope of document is limited to testing autofocus sharpness and latency repeatability with stationary charts only as testing with moving charts is not covered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15781, *Photography — Digital still cameras — Measuring shooting time lag, shutter release time lag, shooting rate, and start-up time lag*

3 Terms and definitions and abbreviated terms

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
autoexposure
AE
system to automatically adjust the exposure parameters such as gain, exposure time and aperture

3.2
autofocus
AF
focusing system which can automatically control the optical system in a camera to bring a subject into focus

3.3
continuous autofocus
AF-C
autofocus system continuously keeping subject in focus

3.4
field of view
FoV
extent of the observable world that is seen (solid angle through optics to sensor) at any given moment by an imaging system i.e. camera

3.5
depth of field
DoF
distance between the nearest and the furthest objects that are in acceptably sharp focus in an image captured with a camera

3.6
spatial frequency response
SFR
relative amplitude response of an imaging system as a function of input spatial frequency

3.7
single autofocus
AF-S
focusing system which focuses on the selected target once, often activated by pressing camera button halfway down, and keeps the selected focus until focused again

4 Test description

4.1 General

The measurement shall be carried out using output images from a digital still camera with which the test is conducted.

The following measurement conditions should be used as nominal conditions when measuring the autofocus repeatability of a digital still camera. If it is not possible to achieve these conditions, the actual capture conditions shall be listed along with the reported results.

Target of the study is to measure if the devices in question are capable to focus and produce sharp images within a certain timeframe which is based on measurements of human reaction time in photographic situation per Annex C.

4.2 Test device settings

Cameras are to be tested in default out of the box settings. If testing is done with something else than out of the box settings, those settings should be mentioned in the report.

4.3 Environmental conditions

The measurements shall be carried out in the following environment unless otherwise stated:

— temperature: 23 °C ± 3 °C.

4.4 Apparatus and hardware

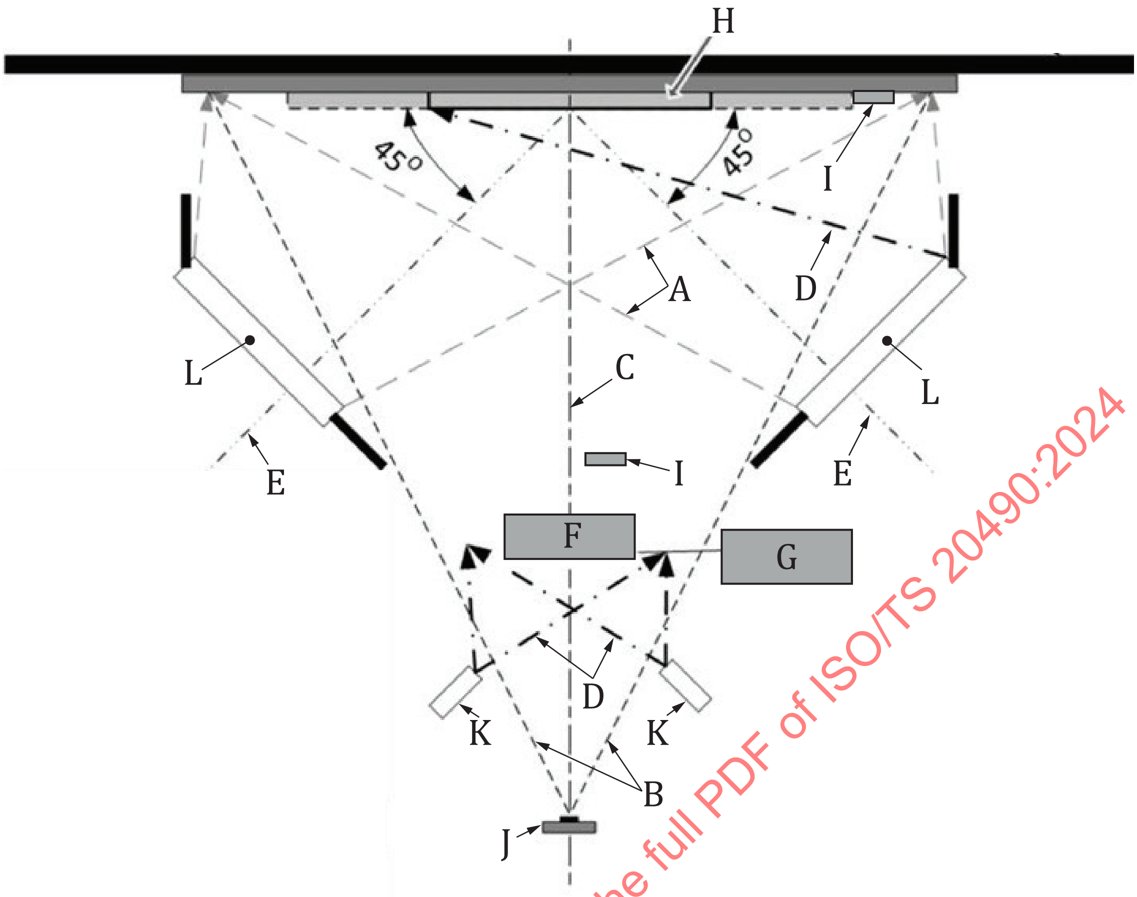
The test setup consists of several components: close distance and far distance test charts, illumination setup for both charts, actuated holder to move the close distance chart, timing LED panel, and computer system to control the timing of the image capture and peripheral devices like the close distance chart actuation and LED timing panel or timer.

In this document the test setups and recommendations are assuming usage of reflective test charts. In special situations also transmissive test chart can be used, but particular care needs to be applied when using transmissive charts. For example, the recommended lux conditions should be in-line with the used panel brightness. The light flux from the chart shall be diffused and shall not include any specular component.

The camera holder should allow the centre of the camera optical axis to be aligned along a line perpendicular to the chart in such a way that the optical axis is perpendicular for both close distance and far distance charts.

The close distance chart actuation stage shall allow the chart to be removed or inserted into the field of view of the camera within 0,1 s or less, as required in ISO 15781.

Figure 1 shows the top view of the example test setup. The close distance and far distance charts are aligned orthogonally to the camera. Baffles can be used to block light traveling directly from the light source to the camera lens and minimize light being cast outside the 18 % grey area.



Key

A line A: Light rays from the edges of the lamps are shown intersection of which the 18 % gray background edges. — — — —

B line B: Camera HFoV ----

C line C: Camera optical axes — - — - — - —

D line D: Light rays from close distance chart illuminators — · — · — · —

E line E: Light intensity pattern from the lamp is pointing parallel to the direction of this line. The line intersects the target at 45 degrees - ·· - ·· - ·· -

F close distance chart

G close distance chart actuator stage

H far distance chart

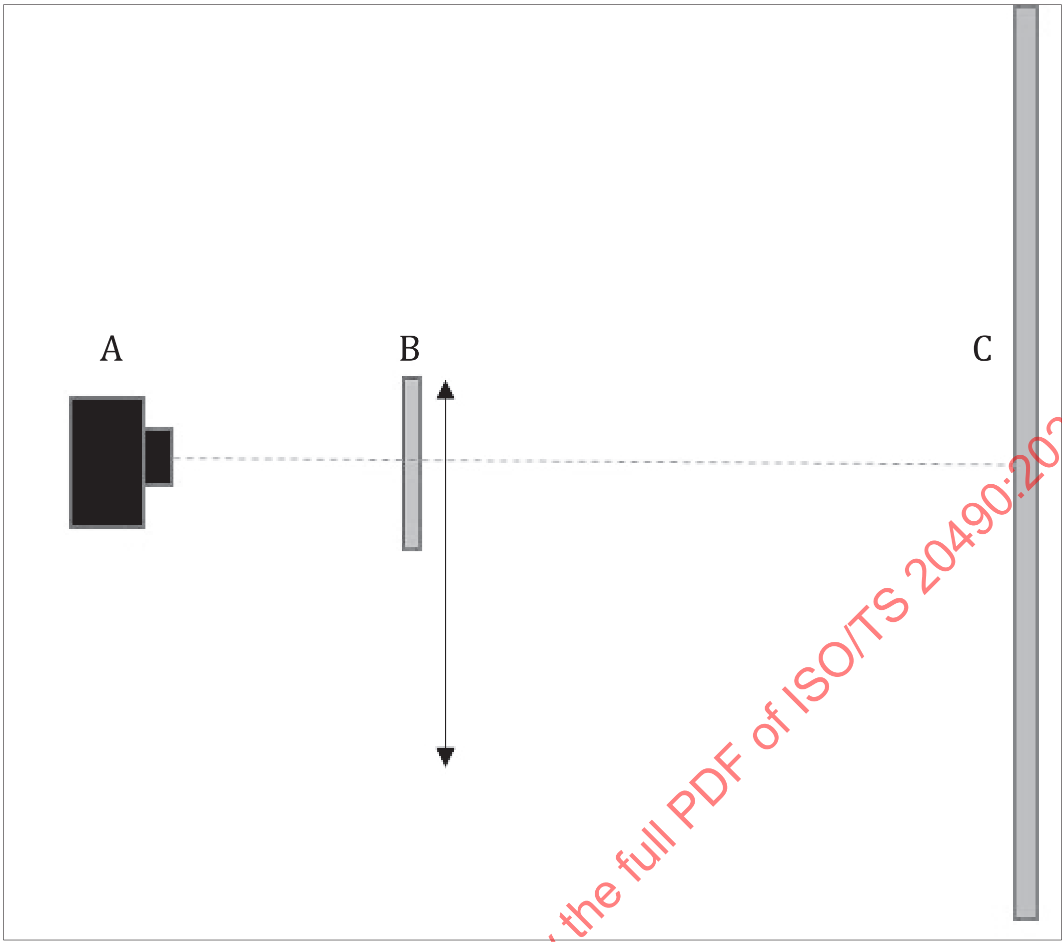
I LED timer

J camera under test

K close distance chart illuminants

L far distance chart illuminants

Figure 1 — Top view of example test setup



Key

A camera under test

B close distance chart

C far distance chart

Figure 2 — Side View of Test Setup. The close distance chart is moved in and out of the field of view

4.5 Test distance

For test distances, the following chart distances are recommended.

The close distance chart distance is set to 10 times the lens 35 mm equivalent focal length. The far distance chart distance is set to 7 times the close distance chart distance. If the 10 times focal length close distance cannot be achieved, then the closest possible focusing distance should be used.

For example, if the closest focusing distance for camera with 24 mm lens is 24 cm, the far distance chart distance is 168 cm.

If recommended distances cannot be achieved, the actual used distances shall be clearly stated in the results.

4.6 Test charts

4.6.1 General

Test chart content can have a significant impact for autofocus repeatability and latency. Because of this, it can be very useful to test the autofocus with different kinds of test charts. Using the algorithm provided in Annex B, tests can be conducted with multiple types of test chart contents including natural or artificial images, low or high contrast content, or even 3D scenes, assuming reasonable image information content (entropy).

This test procedure is also applicable by using other proven sharpness charts with accompanying metrics, for example spatial frequency response (SFR) or texture charts described in ISO 12233 and ISO/TS 19567-2 using the specified algorithms.

4.6.2 Recommended test charts

This test procedure can be conducted with several different test charts, including natural or artificial images, low or high contrast content or 3D scenes. Including a photo realistic mannequin into the test scene can reveal interesting properties of autofocus (AF) systems using face information in supporting the AF decision making. However, when using 3D targets, it is important to consider the depth of field of the camera system in question and ensure that the camera is correctly focused to the same depth plane on each repetition and in case of camera comparison, each device is focused on the same depth plane. Due to the image content impact on autofocus performance, devices shall be compared using similar test charts or 3D scenes. There are examples of recommended test charts in the Annex A.

4.7 Test conditions

Illumination intensity and spectrum should remain the same for close distance and far distance charts to minimize the autoexposure (AE) and AWB convergence time, and their overall impact to the measured latency. Close distance and far distance charts should be illuminated at an illumination level within ±0,3 exposure values, aligned with the ISO 15781.

It's recommended to carry out measurements in both bright and low light conditions using the testing process described. Recommended test illuminations are 10 lx and 1 000 lx, but more conditions can be included to gain further insight into the autofocus system under test.

Handshake can have an effect on autofocus behaviour. Therefore, it is allowed to incorporate handshake into the test procedure where it serves the specific test needs. Handshake can be added for example by attaching the capture device to a handshake simulator and using a handshake profile as described in the 2019 IS&T International symposium on Electronic Imaging Science and Technology publication “Issues reproducing handshake on mobile phone cameras”[1]. However, note that this document is designed for autofocus repeatability and latency measurement, not for evaluating the stabilization capability of the test device.

Table 1 provides the lighting and illumination requirements. No direct light should reach the lens from light source within or outside the field of view of the camera. Target is to avoid having flare and/or ghost images impacting the results.

Testing should take place in both high and low illumination conditions as outlined in Table 1. Ideally, the illumination level for bright image should be high enough to reach the base ISO speed of the camera in question. Colour temperature should reflect the real-life lighting conditions, meaning that bright light testing should take place in higher colour temperature, and low light testing at low colour temperature.

Table 1 — Lighting and illumination requirements

Colour temperature	Bright: 5 500 K ± 1 000 K. Low: 3 000 K ± 1 000 K.
Flicker	The light sources are to not cause flicker.
Incident lux light level	It's recommended to do measurements with at least two different light levels (10 lx and 1 000 lx) to ascertain focus repeatability performance under low light and bright light conditions.
Light uniformity	Incident lux measurements are to be made at the corner locations on the chart or background grey areas that are visible in the image captured at that distance. These corner incident lux levels shall be within ±10 % as compared to the centre of the chart.

4.8 Sharpness measurement

Test image sharpness is analysed by using a suitable sharpness measurement algorithm. A recommended algorithm is described in the Annex B. There is also a subjective study results in the Annex D that shows the correlation between the sharpness algorithm (see Annex B) and the subjective sharpness results (see Annex D).

5 Autofocus measurement

5.1 General

Idea of the test is to measure the autofocus repeatability of sharpness and latency using specified capture delay which is defined in Annex C. Test can also be pushed until failure to define the minimum device latency with which the device can still produce correctly focused images. With this method the set capture delay is shortened on each repetition, and the standard test sequence, as described in this chapter is repeated.

5.2 Camera test position and distances

The camera AF performance shall be tested between two test distances, close distance and far distance as shown in Figure 1 and Figure 2. The principle is to alternate an AF event at close and far distances, the far distance being a fixed chart. The close distance chart is attached to a motorized linear stage allowing it to be moved in and out of the camera FoV quickly. The removal or appearance of the close distance chart triggers a focus event causing the camera to focus to close or far distance respectively.

5.3 Capture test sequence

5.3.1 Test sequence for continuous autofocus (AF-C)

The image capture process for continuous autofocus (AF-C) cameras, such as mobile phone cameras, goes as follows:

a) Set the test system with close distance and far distance charts and camera in the test according to Figure 1.

b) Ensure the camera is focused on the close distance chart.

c) Simultaneously remove the close distance chart from the FoV of the camera and start the led timer (or record the state of continuously running LED timer).

d) Initiate the capture delay according to Annex C.

e) After the capture delay, capture and save the far distance chart photo.

f) Ensure device is focused on the far distance chart.

g) Simultaneously move the close distance chart in to the FoV of the camera and start the LED timer (or record the state of continuously running LED timer).

h) Initiate the capture delay according to Annex C.

i) After the capture delay, capture and save the close distance chart photo.

j) Repeat the process 10 times.

The image analysis process goes as follows:

— Download the 20 images: 10 far and 10 close distance chart images.

— Measure the sharpness of the photos with the provided algorithm (see Annex B).

— Measure the actual image device latency from the LED panel information in the captured photo.

— Plot the results according to Figure 5.

The capture procedure for the image capture process using continuous autofocus (AF-C) is shown in Figure 3.

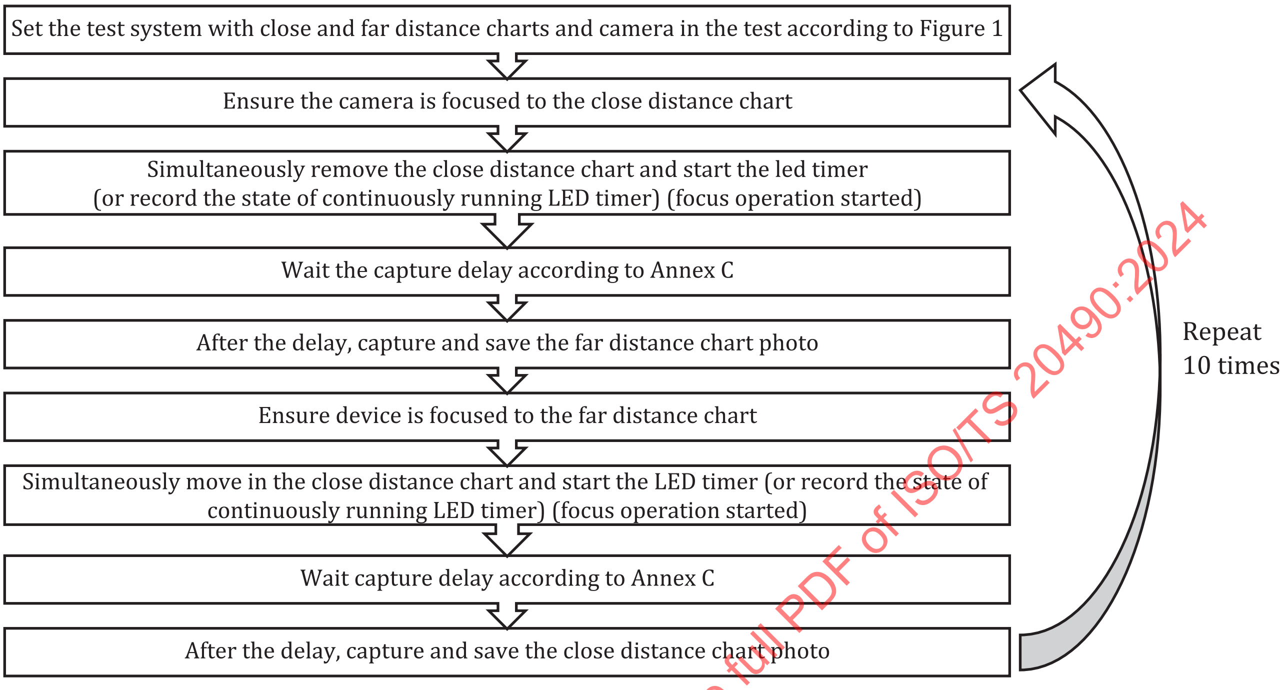


Figure 3 — Image capture test sequence for continuous autofocus (AF-C) cameras

5.3.2 Test sequence for single autofocus (AF-S)

Test process described in this document can also be used to measure autofocus repeatability and latency for single autofocus (AF-S) system, actuated by fully pressing or half pressing physical shutter button or using external accessory to initiate the focusing. In this case the test procedure goes as follows:

a) Set the test system with close and far distance charts and camera in the test according to Figure 1.

b) Ensure the camera in focused on the close distance chart.

c) Remove the close distance chart.

d) When the close distance chart has been removed from the FoV of the camera, start the LED timer (or record the state of continuously running LED timer), and initiate the AF sequence and image capture by fully pressing the shutter button.

e) Capture and save the far distance chart (Picture A).

f) Stop and reset the LED timer.

g) Half press the shutter button, and ensure the camera in focused the far distance chart, and keep half pressing the shutter button.

h) Start the LED timer and initiate image capture by fully pressing the shutter button.

i) Capture and save the far distance chart (Picture B).

j) Stop and reset the LED timer.

k) Bring the close distance chart into the FoV of the camera.

l) When the close distance chart is fully in the FoV of the camera, start the LED timer (or record the state of continuously running LED timer), and initiate the AF sequence and image capture by fully pressing the shutter button.

m) Capture and save the close distance chart (Picture C).

n) Stop and reset the LED timer.

o) Half press the shutter button and ensure the camera is focused to the close distance chart, and keep half pressing the shutter button.

p) Start the LED timer and initiate image capture by fully pressing the shutter button.

q) Capture and save the close distance chart (Picture D).

r) Repeat the process 10 times.

The image analysis process goes as follows:

a) Download and analyse the 40 images: 20 far and 20 close distance chart images.

b) Measure the far distance chart sharpness from Picture A with the provided algorithm (see Annex B).

c) Measure the close distance chart sharpness from Picture C with the provided algorithm (see Annex B).

d) Measure the autofocus component of the device latency for the far distance chart by subtracting the LED timer time for Image B from the LED timer time for Image A for each iteration.

e) Measure the autofocus component of the device latency for the close distance chart by subtracting the LED timer time for Image D from the LED timer time for Image C for each iteration.

f) Plot the autofocus component of the device latency results according to Figure 6.

When testing with this procedure, the AF mode shall be focus priority, not shutter priority.

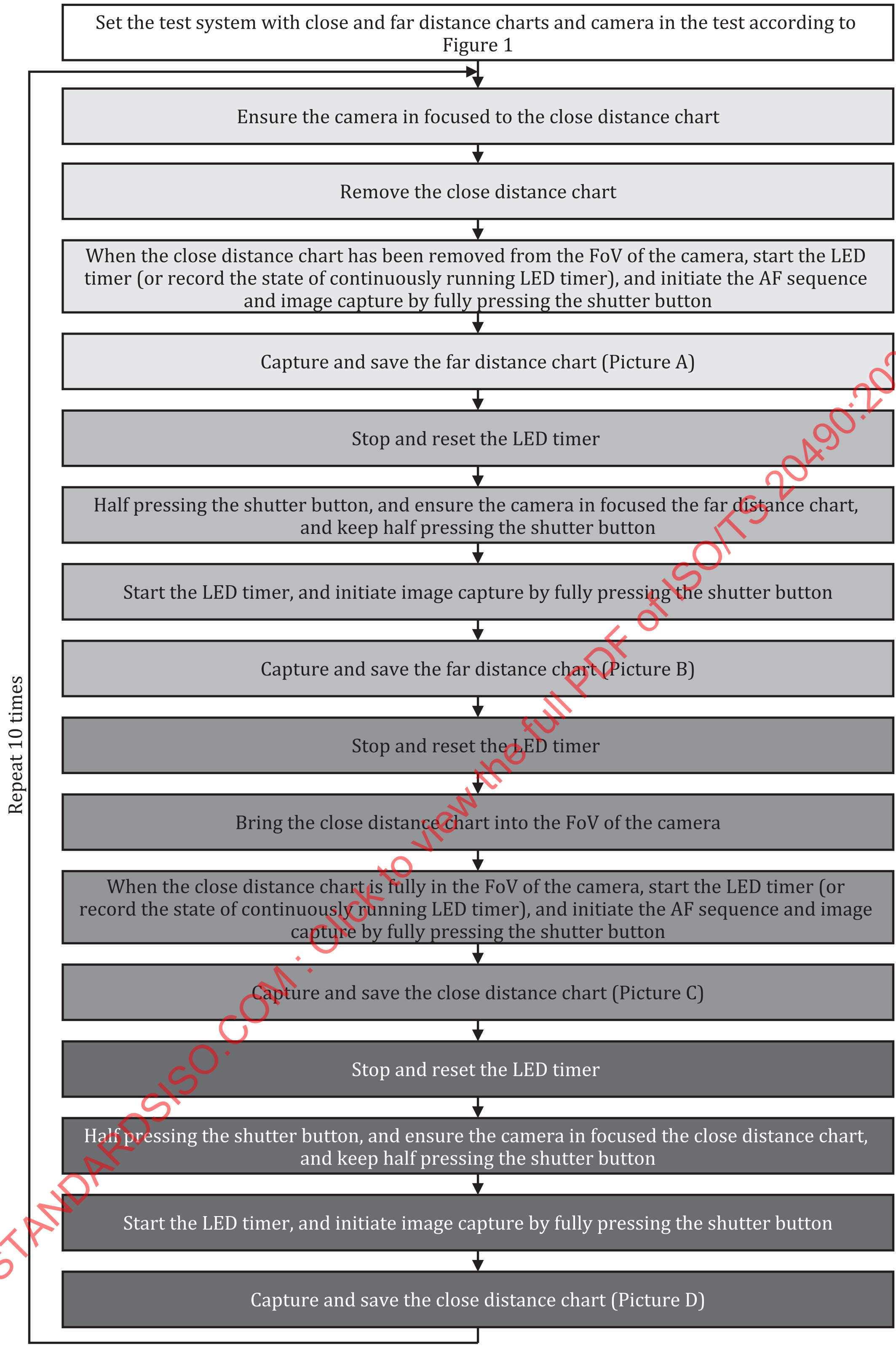
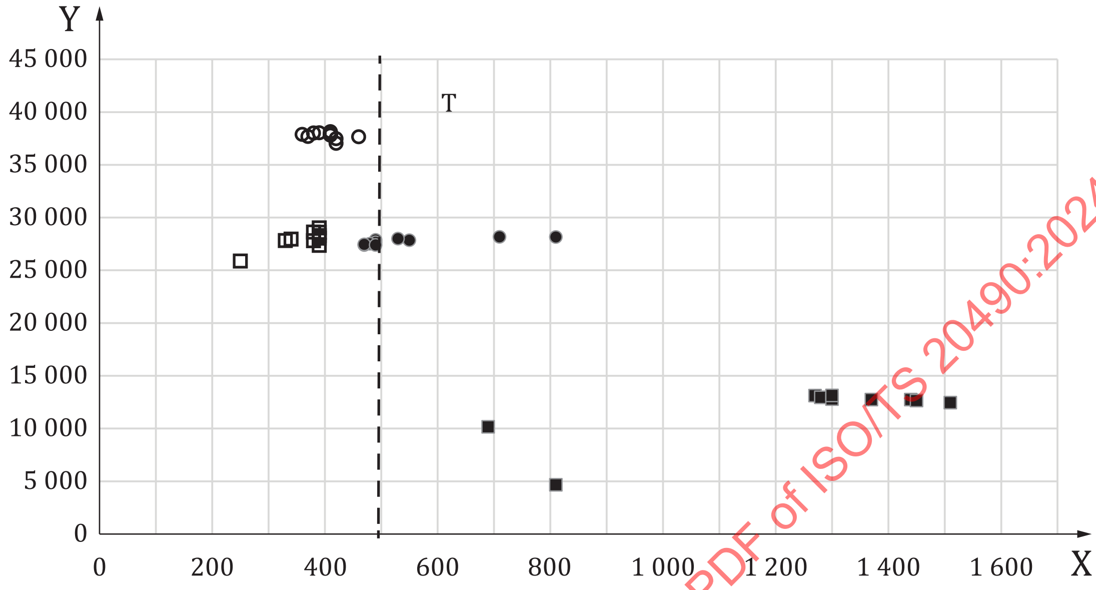


Figure 4 — Image capture test sequence for single autofocus (AF-S) actuated by half-pressing a physical shutter button

6 Presentation of results

6.1 Result figure

The sharpness metric and the actual device latency are measured from the images and plotted as in Figure 5 and Figure 6.



Key

X device latency, in ms

Y sharpness

T trigger

● device 1, 1 000 lx

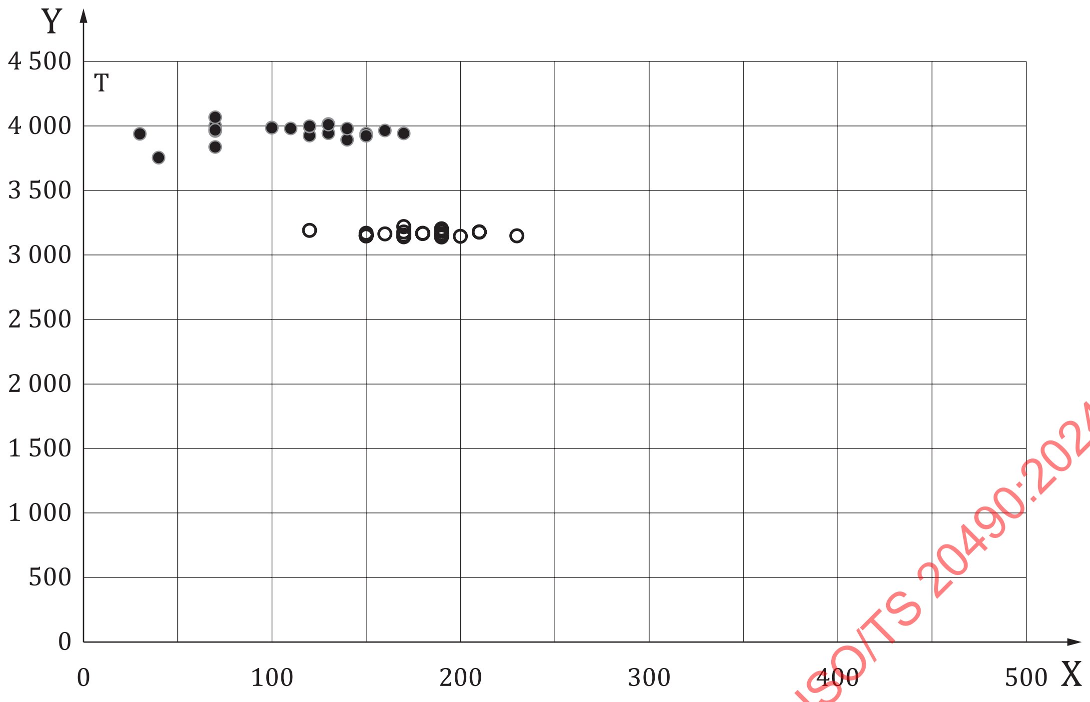
■ device 1, 10 lx

○ device 2, 1 000 lx

□ device 2, 10 lx

NOTE Capture delay of 500 ms marked with dotted line.

Figure 5 — Plot of the sharpness metric versus device latency comparing the continuous autofocus (AF-C) repeatability of two different mobile devices in two light levels



Key

X device latency, in ms

Y sharpness

T trigger

● lens A

○ lens B

Figure 6 — Plot of the sharpness metric versus device latency comparing the single autofocus (AF-S) repeatability of two different SLR lenses

6.2 Reporting the results

Reporting the results shall include the graphs showing the measurements. Example graphs are shown in Figure 5 and Figure 6, for continuous and single autofocus respectively.

An ideal camera system should produce images that are captured close to requested time (or slightly before in the case of negative latency), and are consistently sharp. This means that variation of sharpness and the actual measured device latency should be minimized, and actual device latency should be close to requested capture delay (for example 500 ms, per Annex C). This means that in good results the points are closely clustered together.

Variation of the sharpness metric gives a good idea of the repeatability of the AF system. The absolute value of the metric is not important considering the scope of this document.

There is a risk of misjudgement when comparing the results of cameras with significantly different camera specifications, different shooting settings, different test conditions and different test sequences between continuous autofocus (AF-C) and single autofocus (AF-S). Good practice is to include detailed description of the capture conditions: camera model, focal length, AF mode, AF area, used test chart, description of a handshake simulator and handshake profile (if used) and other relevant details, like chart distances if different from the specified ones. The measurement result without handshake shall be reported and the measurement result with handshake may be reported additionally. Test parameter information is important to be reported because several things can impact the autofocus repeatability, for example focusing with larger aperture system can be more challenging than with smaller aperture camera system, and this may impact the test results.

Annex A
(informative)

Test setup and chart details

A.1 Overview

Required test setup can be established in various ways as two examples in Figure A.1 demonstrate.

Figure A.1 — Examples of two different test setups

A.2 Chart recommendations

Several different chart types may be used for autofocus (AF) testing, including artificially created charts and photorealistic charts as described in Figure A.2.

The coloured dead leaves test chart shown in Figure A.2 is almost perfectly scale invariant, making it easy to be used in different sizes, and provides features to enable a wide range of camera types and categories to focus on the chart. We recommend the coloured dead leaves chart since its statistics resemble those of natural scenes. Details of the dead leaves test chart are described in ISO/TS 19567-2.

The highly structured natural scene contains contrast edges and a mix of low frequency as well as high frequency detail.

The algorithm can handle a large variety of different chart types as illustrated in Figure A.2. Our recommendation is that the chart be planar with the camera, having medium and high frequency content. Figure A.3 contains examples of charts that do not work well with the algorithm, as the images only contain low spatial frequency content or no details at all.

Figure A.2 — Examples of acceptable charts for sharpness measurement

Figure A.3 — Examples of unacceptable test charts for sharpness measurement

Annex B
(informative)

Test software and algorithm details: sharpness estimation algorithm

B.1 Algorithm overview

The algorithm estimates the sharpness of the image. Sharpness estimate is based on the contrast of small and medium-sized details in the image. This algorithm has the benefit over traditional contrast algorithms of being insensitive to illuminance changes and small camera motion between images.

A detailed description of the algorithm is as follows:

a) Read the image/images from the folder.

b) Convert the RGB colour image to a gray-scale image.

c) Crop the image from the centre:

   1) The sharpness is usually higher in the middle of the image.

   2) Remove noise by low-pass filtering the image.

   3) Normalize the image: Setting the mean to zero and variance to one.

   4) Calculating the 2D derivative on the cropped image.

   5) This is a high-pass filter.

d) Window the 2D derivative:

   — This is needed to avoid the high frequency errors in Fourier transform

e) Calculate the 2D Fourier transform:

   — Transforms the image from the spatial domain to the spatial frequency domain (x,y) → (f_x,f_y)

f) Calculate the magnitude of each frequency:

   — Magnitude is calculated by taking the absolute value of the complex numbers

g) Transform from 2D Cartesian coordinates to 2D polar coordinates to compute a frequency vector:

   — Now there exist frequency vector for each direction (f_x,f_y) → (angle, f)

h) Convert 2D frequency data (angle, f) to 1D frequency vector (f) by choosing the 25 % percentile frequency value from all possible directions. Output is a 1D frequency vector.

i) Sum up the vector values for the desired frequency band to compute the sharpness metric.

The final magnitude of the sharpness depends on the content of the chart. Thus, the magnitudes are comparable if the same chart is used between the images. However, if the chart is different between the images (e.g. dot chart vs. dead leaves pattern) no conclusions based on the magnitude of the sharpness can be made.

B.2 Example use of sharpness algorithm

B.2.1 General

This section contains two examples of how to use the sharpness algorithm in a MATLAB[1)] environment.

B.2.2 Inputs

There are five inputs:

a) p: Folder path where the images are located.

b) bestImgInd: The best image index specifies the reference (= good sharpness) image from the image set. This image should be visually selected from the captured photos. If this is set empty, the algorithm chooses the best sharpness image automatically. It is good practice to go through the images before the analysis and ensure that the overall sharpness is good enough. Otherwise, it is possible that folder contain only blurry images and the algorithm chooses the best from that image set.

c) freqLims: Default value is the [0.03, 0.15] frequency band. Number 0.5 means Nyquist frequency. Default value works in most of the imaging charts and in normal camera resolutions. It is possible that this needs to be adjusted if camera resolution is extremely high e.g. 100 MPix.

d) cropPercXy: Default value is [0.5, 0.5], which means that cropped area is covering 50 % from the image width and 50 % from the image height. The smaller area is always cropped from the middle of the image. Value [1, 1] means that the whole image area is used for analysis.

e) noiseFilterSizePix: Default value is 1, which means that the image is not noise filtered. The value describes the size of the noise filter in pixels. If low lux levels are used then the filter size can be increased.

B.2.3 Outputs

There are four possible outputs from the algorithm:

a) sharpnessVal: This is the sharpness value estimated from each image in the folder. Higher magnitude means better sharpness.

b) sharpnessDiff: This is the sharpness difference compared best sharpness image. The best sharpness image index can be given as an input or it can be chosen automatically (see bestImgInd -input).

c) bestImgInd: This is the image index of best sharpness image. If the function chooses the best image index automatically, it outputs the value here.

d) imgNames: These are the names of the analyzed images. The order of the names corresponds to the order of sharpness values in the sharpnessVal and sharpnessDiff – output vectors.

B.3 Examples

B.3.1 Case 1

This example is useful for most cases. When the input parameters are left empty, the function uses the algorithm default parameters, which are suitable ones in most of the cases.

```
% input parameters
p = …\focusImages\far3\';
bestImgInd = []; % automatic choose
freqLims = [];  % default: [0.03, 0.15]
cropPercXy = []; % default: [0.5, 0.5]
noiseFilterSizePix = []; %default: 1
```

1) MATLAB is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

```
[sharpnessVal, sharpnessDiff, bestImgInd, imgNames] = estimateSharpness(p, freqLims,
cropPercXy, noiseFilterSizePix, bestImgInd);
```

B.3.2 Case 2

This example is valid in some cases in which the image content contains low-frequency noise that needs to be filtered out prior to running the sharpness analysis (noise filter size = 5). In this example, the planar target is located in a small spatial region in the center of the image. This results in the cropping region to be set to “small”. Because of these conditions, the best image index has to be chosen manually.

```
% input parameters
p = …\focusImages\aas_images\';
bestImgInd = [5]; % Manually set
freqLims = [0.03, 0.15]; % the percentage limits included to the sharpness estimation
cropPercXy = [0.35, 0.35]; % The size of the cropped area. Target covers only small area from
the middle
noiseFilterSizePix = 5; % this image set includes noise, thus large noise filter size

[sharpnessVal, sharpnessDiff, bestImgInd, imgNames] = estimateSharpness(p, freqLims,
cropPercXy, noiseFilterSizePix, bestImgInd);
```