# What is wrong with Depth of Field and Hyperfocal Distance?



While both concepts are based on sound mathematical principals, they are fundamentally flawed by an assumption and a misunderstanding:

1. That Depth of Field (DoF) is a range of distances from the camera over which the image is equally sharp.
2. That everyone understands and agrees on the definition of the Circle of Confusion (CoC).

The first assumption is close but there is a difference between being equally sharp or acceptably sharp.

There will be only one distance at which an image is perfectly sharp. Consider a point source of light such as a star. If you set the focus at infinity, the star should project a point of light on your sensor that is smaller than a single pixel. The same would apply if the point source of light were much closer to the camera, for example 20 feet from the camera or much closer. When in focus, the point on your sensor could still be smaller than a pixel. If it were slightly out of focus it might be as large as a whole pixel and your camera would not know the difference.

How big is a pixel? A full frame 24x36 mm sensor that produces an image of 4000x6000 pixels or 24 MP – 24 mm divided by 4000 (or 36 mm divided by 6000) is 0.006 mm. Disregard for the moment that this may be either a red, blue or green pixel and that your lens might not be capable of projecting a point source that precisely. A CoC of 0.006 mm is much smaller than you normally need. If you were to aim at a star with a 50 mm lens at f/11, you might get the point of light to stay within a single pixel if your focus was anywhere from about 125 feet to infinity.

A common assumption for the size of the CoC is about 0.03 mm for a full frame sensor or film with the same format. That would mean that a point source of light could actually spread out to cover a diameter of 5 pixels and still be acceptably sharp. The star that is in focus at infinity will cover less than 5 pixels with a 50 mm lens at f/11 if you focus at any distance longer than about 25 feet, the hyperfocal distance for a 0.03 mm CoC.

Why 0.03 mm? Someone with normal eyesight can resolve a detail that is about 2 minutes of arc or 30 cycles of black/white stripes per degree. That works out to about 0.0291 mm for a 24x36 mm film or digital format.

The common assumption is that you will be making a print that is about 8x12 inches using the entire image and viewing it from about 10 inches with normal eyesight – or 8x12 feet and viewing it from 10 feet or any other ratio that keeps the print dimension proportional to the viewing distance. But if you crop the original image, view it from a distance that is different, with eyesight that is different from normal, use a loupe or magnifying glass, then 0.03 mm may no longer be appropriate.

So you need to know something about how your image will be viewed before deciding on the size of the CoC. If you are going to display it within the parameters described in the previous paragraph the 0.03 mm will work. If you will be displaying the whole image on a smart phone, tablet or printing it smaller than 8x12 inches then 0.03 mm will be more than adequate. But if you plan to enlarge it, crop it, pixel peep, print it large and look at it closer than normal viewing distance, you will need to use a smaller CoC.

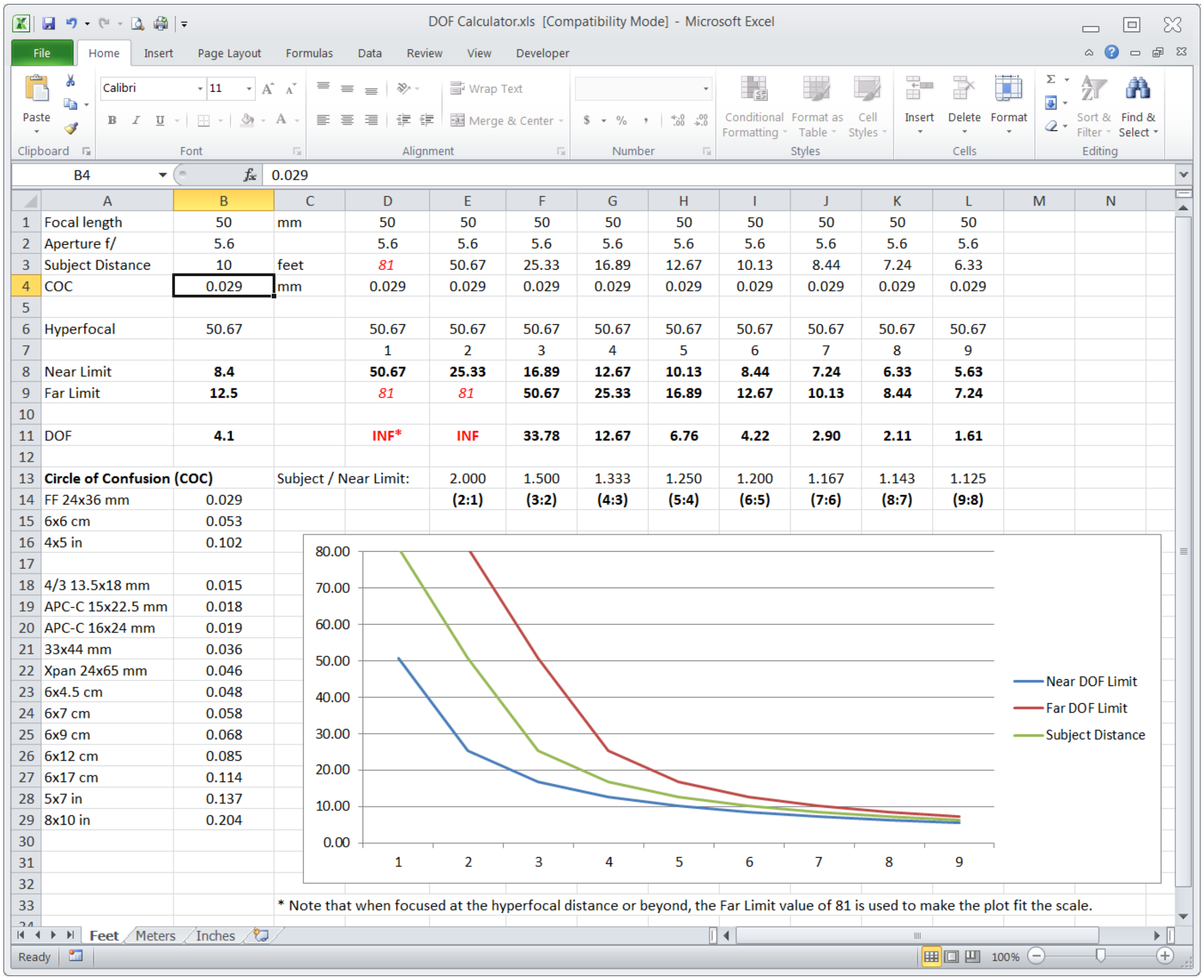
**DoF Calculators**

There are dozens of DoF calculators on line or as apps you can install on your smart phone or tablet. All of them are based on the same assumptions for CoC (sensor or film format divided by a constant like 1500). All of them calculate the hyperfocal distance first, then the near and far DoF limits.

There are two reasons you might want to use something other than the default CoC value:

1. If you are going to crop the image, you need to use a smaller CoC in proportion to the amount of crop. For example, a 1.5 crop would need to use a CoC of about 0.02 mm, just as if you were using a crop sensor.
2. If you plan to print and view at a not-standard size you also need to adjust the CoC. For example, "standard" means making an 8x12 inch print to be viewed from about 10 inches, or an 8x10 foot image to be viewed from 10 feet or similar print size and viewing distance proportions. If you plan to view from closer than normal distance, you need to use a smaller CoC. If you plan to make only a smaller print to view from further than normal you can get away with a larger CoC.

Here is an excel version that shows you a little more information:




| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Focal length | 50 | mm | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 2 | Aperture f/ | 5.6 | | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 |
| 3 | Subject Distance | 10 | feet | *81* | 50.67 | 25.33 | 16.89 | 12.67 | 10.13 | 8.44 | 7.24 | 6.33 |
| 4 | COC | 0.029 | mm | 0.029 | 0.029 | 0.029 | 0.029 | 0.029 | 0.029 | 0.029 | 0.029 | 0.029 |
| 5 | | | | | | | | | | | | |
| 6 | Hyperfocal | 50.67 | | 50.67 | 50.67 | 50.67 | 50.67 | 50.67 | 50.67 | 50.67 | 50.67 | 50.67 |
| 7 | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 8 | Near Limit | **8.4** | | **50.67** | **25.33** | **16.89** | **12.67** | **10.13** | **8.44** | **7.24** | **6.33** | **5.63** |
| 9 | Far Limit | **12.5** | | *81* | *81* | **50.67** | **25.33** | **16.89** | **12.67** | **10.13** | **8.44** | **7.24** |
| 10 | | | | | | | | | | | | |
| 11 | DOF | **4.1** | | **INF*** | **INF** | **33.78** | **12.67** | **6.76** | **4.22** | **2.90** | **2.11** | **1.61** |
| 12 | | | | | | | | | | | | |
| 13 | **Circle of Confusion (COC)** | | Subject / Near Limit: | | 2.000 | 1.500 | 1.333 | 1.250 | 1.200 | 1.167 | 1.143 | 1.125 |
| 14 | FF 24x36 mm | 0.029 | | | **(2:1)** | **(3:2)** | **(4:3)** | **(5:4)** | **(6:5)** | **(7:6)** | **(8:7)** | **(9:8)** |
| 15 | 6x6 cm | 0.053 | | | | | | | | | | |
| 16 | 4x5 in | 0.102 | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | 4/3 13.5x18 mm | 0.015 | | | | | | | | | | |
| 19 | APC-C 15x22.5 mm | 0.018 | | | | | | | | | | |
| 20 | APC-C 16x24 mm | 0.019 | | | | | | | | | | |
| 21 | 33x44 mm | 0.036 | | | | | | | | | | |
| 22 | Xpan 24x65 mm | 0.046 | | | | | | | | | | |
| 23 | 6x4.5 cm | 0.048 | | | | | | | | | | |
| 24 | 6x7 cm | 0.058 | | | | | | | | | | |
| 25 | 6x9 cm | 0.068 | | | | | | | | | | |
| 26 | 6x12 cm | 0.085 | | | | | | | | | | |
| 27 | 6x17 cm | 0.114 | | | | | | | | | | |
| 28 | 5x7 in | 0.137 | | | | | | | | | | |
| 29 | 8x10 in | 0.204 | | | | | | | | | | |



* Note that when focused at the hyperfocal distance or beyond, the Far Limit value of 81 is used to make the plot fit the scale.



You can input the focal length, aperture, subject distance and use one of the CoC values from the table or any other appropriate value. The remaining fields are calculated.

The table in columns D through L are a series of calculations starting with the subject distance set to infinity (not “81” which is used to make the plot work) and then stepping through a series of subject distances where each new subject distance is copied from the Near limit for the previous column.