AN016: Field of view

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1. Field of view

Field of view is a function of lens focal length and lens distortion. And in the case of field of view in millimeters or other engineering units, a function of object distance as well. As an input value, the field of view can be converted to focus and zoom motor step positions using the calibrated data of the lens.

There is lens to lens variation. So for the most accurate results, use the calibration data provided with the lens. Even so the distortion calibration data can have some variation depending on the rotation angle of the lens which will lead to a small variation in the final field of view for the image.

2. Read the data file

The calibration data is at the top level of the JSON formatted data file. It can be found under keys “FL”, “dist”, and “tracking”. This abridged sample of the calibration data file shows focus-zoom tracking curve. This case shows that there are 4 curves to choose from (“count”: 4) based on the object distance control point (“cp1Type”: “1000/obj dist”). It may be required to read the coefficients for a couple curves and interpolate to match the actual setup. The parameters for the first 2 curves are shown.

```
"tracking": {
    "type": "cal",
    "idx": 1,
    "count": 4,
    "xAxis": "zoom step",
    "xMin": 0,
    "xMax": 3147,
    "yAxis": "focal step",
    "cp1Type": "1000/obj dist",
    "cp2Type": "",
    "cp1": [
        1,
```

```
            100,
            200,
            400
        ],
        "cp2": [
            0,
            0,
            0,
            0
        ],
        "coef": [
            [
                6759.133767954516,
                -13.266890381130867,
                0.012903478977987942,
                -7.821620295284879e-06,
                3.1040961493589914e-09,
                -6.794893760069593e-13,
                6.079222365350608e-17,
                0,
                0,
                0,
                0
            ],
            [
                6340.913193162877,
                -12.807459523420478,
                0.01366060335123544,
                -9.581190218374742e-06,
                4.314254359301763e-09,
                -1.030045758461539e-12,
                9.764951444254434e-17,
                0,
                0,
                0,
                0
            ],
           [ …
```


2.1. Focal length curves

Focal length parameters create a focal length vs. zoom motor step curve. This data is measured for each lens individually. The inverse polynomial curve coefficients are also provided (zoom motor step vs. focal length) and they are used in this calculation.

2.2. Distortion curves

Distortion curves are a function of focal length (and in the future possibly a function of object distance as well). When accessing the distortion curve parameters, refer to the control point 1 (focal length) to make sure the distortion matches the set focal length of the lens. It may be necessary to read parameters for a couple curves and interpolate between them to get the correct distortion.

See application note *AN010 Distortion correction* for more information about distortion calibration data.

2.3. Tracking curves

Because the lens is a varifocal lens, the focus motor must change whenever the zoom motor changes to remain in focus. This relationship between focus and zoom motors is referred to as the tracking curves.

See application note *AN012 Focus zoom tracking* for more information about the tracking curve calibration data.

Focus zoom tracking data can be very different from lens to lens so it is calibrated for each lens at several object distances. As with distortion, parameters for a couple curves should be read from the calibration data file so the focus zoom tracking position at the actual object distance can be interpolated. This final interpolation is not discussed in this application note.

3. Motor position calculation

The goal is to calculate the zoom and focus motor positions to create the desired field of view for the image. Object angle (*OA*) is related to the desired field of view and image height (*IH*) is related to the image sensor width.

$$OA = \frac{-FOV}{2}$$

Where field of view (*FOV*) is in degrees. The negative sign is for the image inversion that occurs in a typical lens.

$$IH = \frac{wd}{2}$$

Where *wd* is the sensor image width in millimeters.

The distortion calibration data relates object angle (OA) to image height (IH) at different focal lengths using a polynomial equation.

$$OA|_{cp1} = \sum_{k=0}^{6} P_{k,cp1} * IH^k$$

The equation is dependent on the focal length of the lens so each calibration curve has a related control point (*cp1*) for the focal length. Most likely the object angle will require interpolation between 2 or more distortion curves.

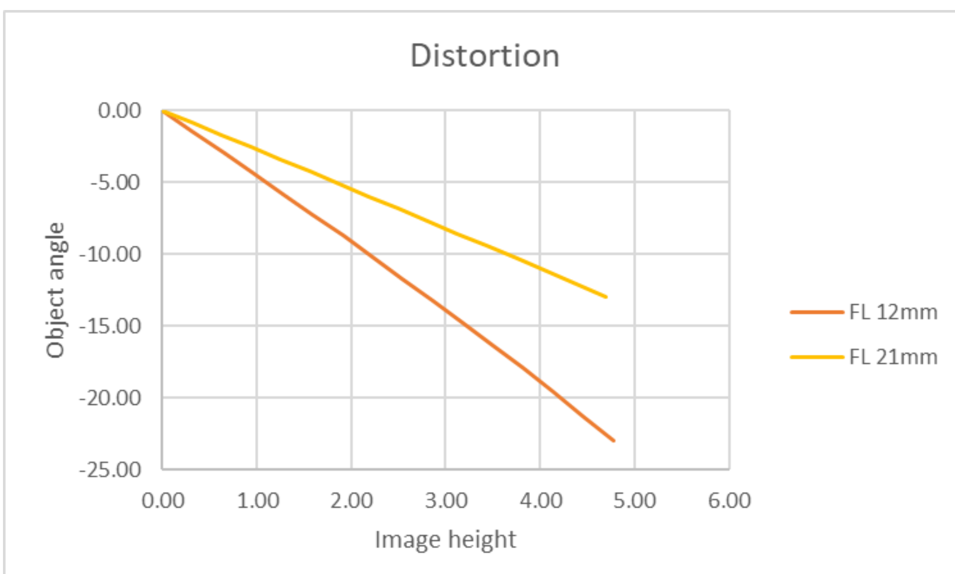

Fig 3.1 example calibrated distortion curves for Theia's TL1250 calibrated lens at 2 focal lengths

The focal length can be interpolated between two or more calibration curves to calculate the focal length for the desired field of view. From this focal length, the inverse focal length calibration curve can be used to convert to zoom motor step position. This is also a polynomial equation.

$$zs = \sum_{k=0}^{3} Q_k * FL^k$$

Where *zs* is the zoom motor step position.

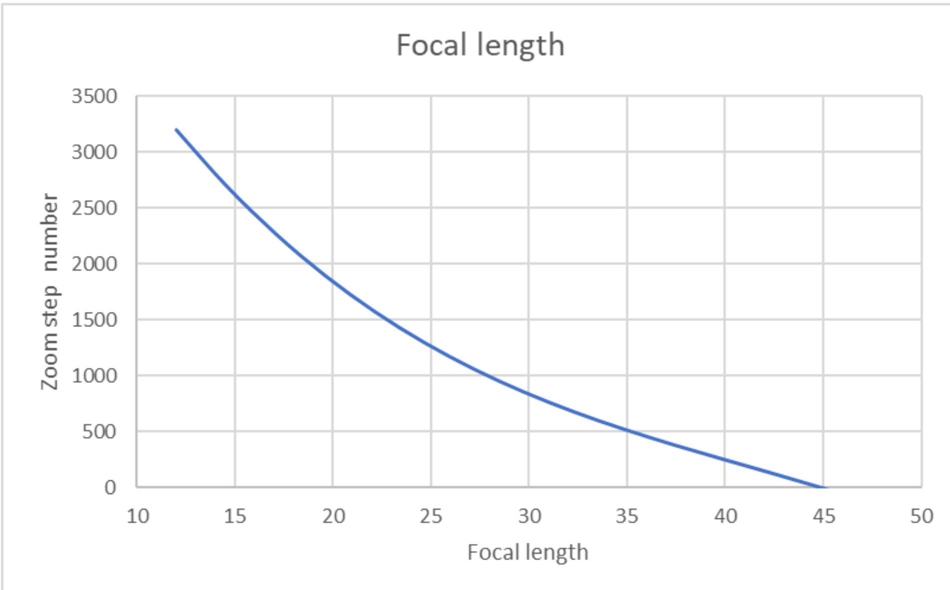

Fig. 3.2 inverse focal length calibration curve for Theia's TL1250 calibrated lens.

The final step is to calculate the focus motor step position. Because the lens is a varifocal lens, any change in focal length will require a change in the focus motor position to keep the object in focus. The focus/zoom tracking curve is applied as a final polynomial equation.

$$fs = \sum_{k=0}^{6} P_k * zs^k$$

Where *fs* is the focus motor step number.

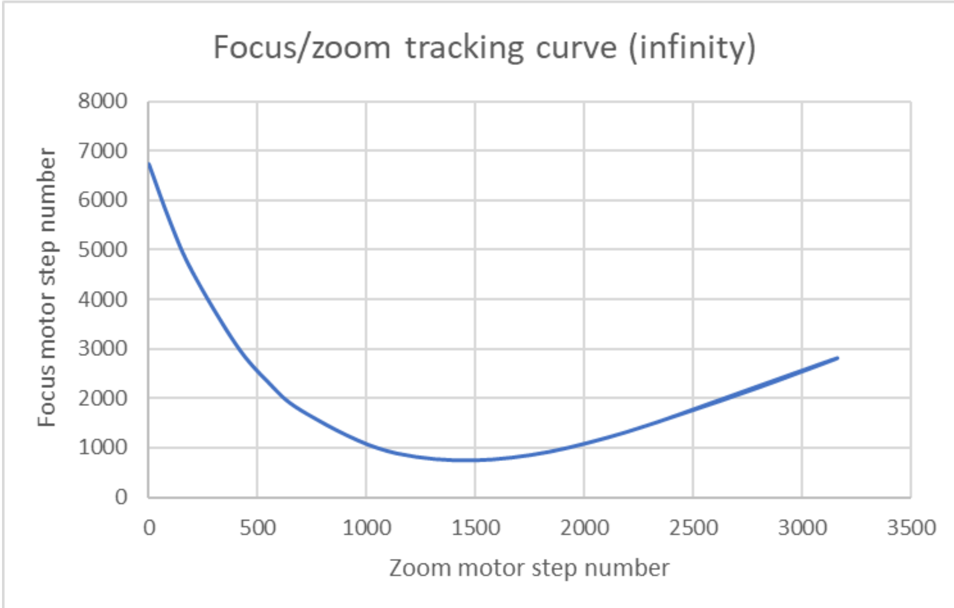

Fig 3.3 Focus/zoom tracking curve at infinite object distance and ideal BFL compensation.

In addition, there will be a back focal length calibration that should be added to the focus motor step position (see application note *AN004 BFL compensation* for more information about BFL calibration) and the object focus distance may be less than infinite which will affect the polynomial parameters for the focus/zoom tracking curve (see application note *AN012 Focus/zoom tracking* for more information about close objects). Neither of these adjustments are included in this example.

3.1. Example: focal length

For example, a 30° field of view is required on a 1/1.7" sensor. The sensor width is 7.6mm. In this example: OA = -15°, and IH = 3.8mm are the two input parameters.

Object angle will probably fall between two calibration curves such as the 12mm and 21mm provided calibration curves. The object angles for the calibration curves can be calculated from the polynomial coefficients. For example:

Coefficient	12.352mm	20.672mm
P0	-8.56195E-05	5.48325E-04
P1	-4.54771E+00	-2.73379E+00
P2	-3.71877E-05	1.72813E-03
P3	-6.83801E-03	-5.25740E-04
P4	3.54010E-05	-1.28473E-04
P5	-2.39491E-04	-6.41639E-05
P6	1.58785E-06	4.55171E-06

At IH = 3.8, the two object angles are calculated as

$$OA|_{FL=12} = -17.83 \quad and \quad OA|_{FL=21} = -10.46$$

A simple linear interpolation can be used but other interpolation methods may provide more accurate results. By linear interpolation,

$$FL = 15.5483mm$$

3.2. Example: zoom motor position

Using the calculated focal length and the parameters for the focal length calibration curve shown below, the final zoom motor step can be calculated.

Coefficient	
Q0	6.60454E+03
Q1	-3.67578E+02
Q2	7.71943E+00
Q3	-6.25441E-02

Result: zoom step zs = 2520.

3.3. Example: focus motor position

For an infinitely distant object on a camera with ideal back focal length calibration, the focus step can be calculated from the focus/zoom tracking curve polynomial coefficients.

Coefficient	
P0	6.75913E+03
P1	-1.32669E+01
P2	1.29035E-02
P3	-7.82162E-06
P4	3.10410E-09
P5	-6.79489E-13
P6	6.07922E-17

Result: focus step fs = 1795.

Setting the lens focus motor and zoom motor based on the calculation above will give a focused field of view of 30° on the chosen sensor size. There may be some variation in focus due to lens tolerances so a final focus adjustment should be made for best focus.

4. Revisions

Version	Change	Reason
230301		Preliminary release