The Camera's Eye

An exploration of the lenses that we use

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Cameras & Lenses

Today we are going to have a look at the lenses used by TV cameras and their limitations.

Cameras come in different sizes and have different sensor sizes. This vintage camera from the 1970s has 25mm tubes with an image size similar to the 16mm. film format.





As progress was made sensors became ever smaller through tubes to CCDs. Thus the cost and size of lenses diminished almost to vanishing point.

Cannon XA10 HD camera with 1/3 inch CCDs

Different types of lens

The most obvious difference is between a Zoom & a fixed focal length lens, there are also lenses for special purposes.

We will have a look at fixed lenses first. TV Lenses, like their photographic counterparts come as built in or removable.

Removable lenses give better control and choice over the image process.

The first parameter to consider is the “Focal Length” put simply this determines the field or angle of view.

A wide angle lens will have a short focal length and vice-versa.

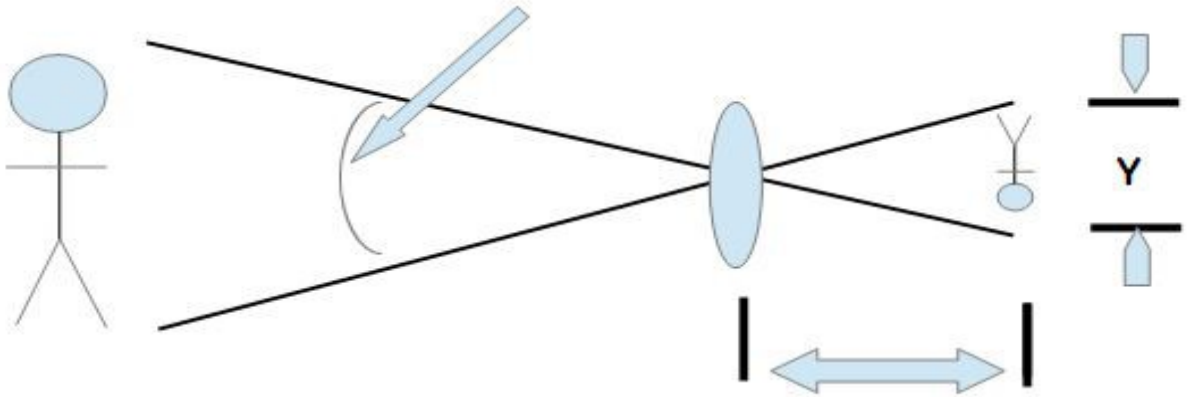


This is a 3 inch “C” mount lens a modest close up view.

Focal Length

This formulae describes the relationship between Focal length and the angle of view.

W, the angle of view $W = 2 \tan^{-1} \frac{Y}{2F}$



You can see as “F” becomes smaller the angle of view increases. “Y” also plays a part and is why very small sensors have small lenses for comparable fields of view.

The Aperture & the Iris

The aperture of a lens is a measure of it's light gathering power. The bigger the glass the more light can be admitted and the smaller the Iris number.

The Iris controls the effective diameter of the lens and hence the amount of light admitted.

To reduce the light admitted the Iris is closed, or "stopped Down", the Iris setting is measured in *f* numbers typically *f*1.4 to F22 in the ratio of $\sqrt{2}$ each stop increase, halving the light. eg. The bigger the *f* number the less light.

Confusingly F is the focal length and *f* is the aperture.

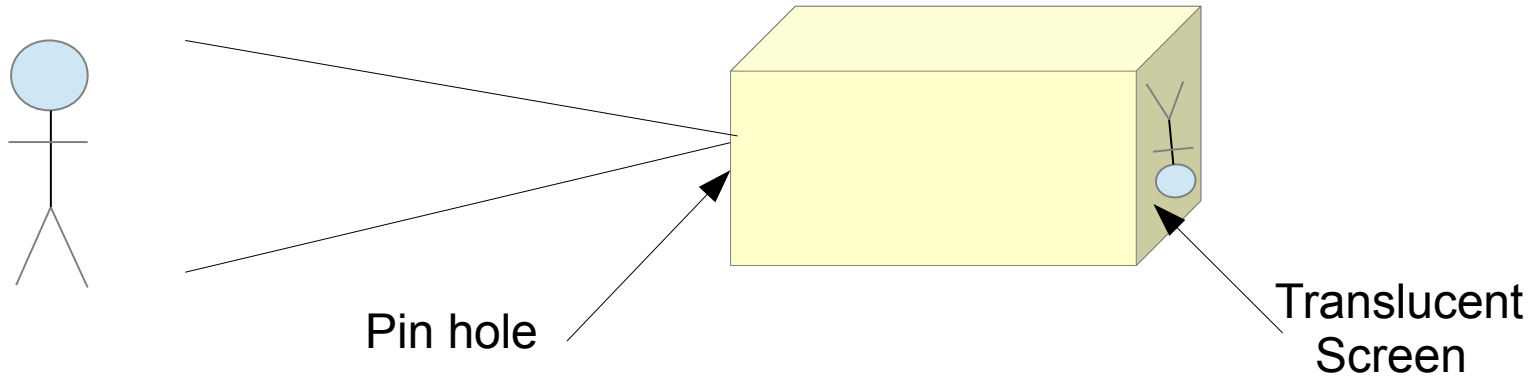
They are related by this formulae:-

$$f = \frac{F}{D}$$

were F is the focal length and
D is the effective diameter

Iris & depth of field

This is best explained by considering first a Pin Hole Camera.



Here we have a very small aperture, literally a pinhole.

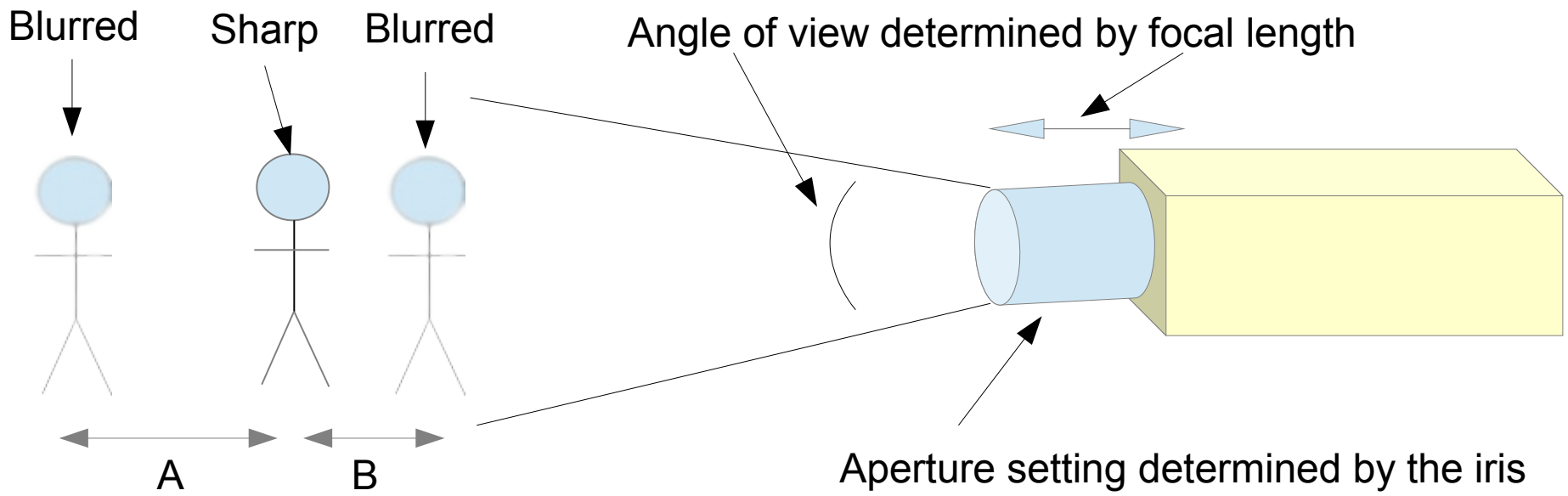
The effect is the subject is in focus on the screen at whatever distance from the camera.

The depth of field is near infinite.

It is also used for some small cameras without focus adjustment

Iris & depth of field

With a real Lens of the type we use, the depth of field depends on both the Iris aperture and the Focal length.



The key things here are:- as the aperture gets larger and the angle of view smaller, zooming in, the depth of field reduces.

Of note is the distance "B" is shorter than "A" which can be infinite, this is called the hyperfocal distance.

Depth of field demo





Apart for artistic effects, most of us would want a large depth of field and this can be obtained by having sufficient light available so the the iris can be closed to perhaps *f* 11 or *f* 16

Iris & auto Iris





Very often cameras are left in auto iris and for the most part acceptable exposure results.

However it is not perfect, we have all seen the result when the camera pans and a bright object is then in the background and the auto closes the iris and the subject, now looks very dark.



Shutter

Cameras, if left on their default settings will also use “Shutter” on it's own or in conjunction with the iris to control exposure.

The old tube cameras collected the light over the whole field period and a CCD sensor can do the same.

Or it can discard some of the collected photo-electrons and use some shorter collection period, thus reducing the CCDs output.

For a stationary picture this has no visual effect, but for moving pictures it can appear jittery, like a series of still pictures, which is what it actually is. This is because of the integration of the light over the field period causes movement blur, sometimes good sometimes not!

Art really.

Lens adjustments

As a user there are not many, indeed for some cameras none at all!

1. Zoom, the field of view.
2. Focus, subject in sharp view
3. Iris, subject at correct exposure
4. Back Focus, focus correct over zoom range.

Now the first three are obvious but perhaps not the fourth one.

In a zoom lens the angle of view or the focal length is variable and the focal length is not the actual distance from the lens to the sensor.

But this distance must be set correctly, according to the lens design, so that the image remains in focus over the whole of the zoom range.

If your camera has a built in lens it will likely be fixed at manufacture but for cameras with interchangeable lens it may need to be set.

Adjusting “Back Focus”

To set the back focus to the correct position:-

First set the iris to fully open, use filters or shutter.

Zoom in to a convenient distant object or at the distance recommended by the lens manufacturer and focus the image.

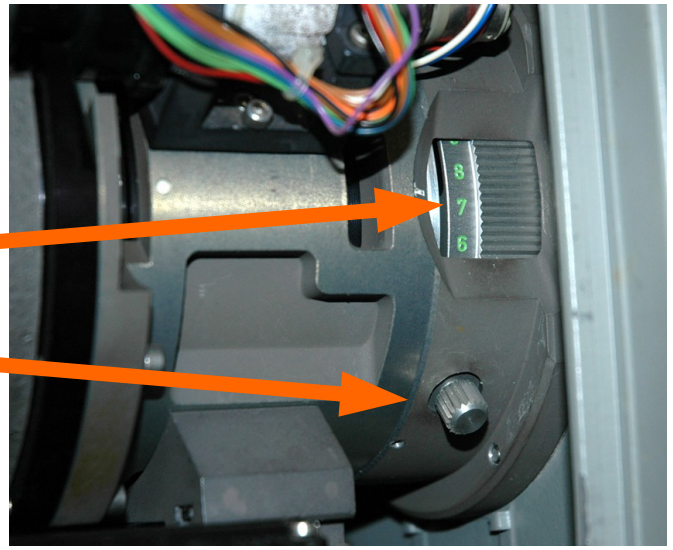
Next zoom out and without touching the focus control, adjust the Back Focus for best image focus.

It may be that you have to repeat the process for best results.

When correct, the image should stay in focus over the whole zoom range.

Adjusting the Back Focus

A close up of the back of a zoom lens



The Back Focus adjuster

Locking screw



A Sony "C" format zoom lens

There is no provided adjustment, just the threaded C mount.

It is often possible to move the sensor (tube) to achieve the correct position, very fiddly!

Format or image size

TV lens were closely related to film lens, indeed in the early days they were film lenses. Lens sizes post 1945:-

- Image Orthicon tubes, 35mm Format with. 21.4mm diagonal
- 1” vidicons tubes, 16mm Format with ..... 16mm diagonal
- 17mm ENG broadcast plumbicons, with..... 11mm diagonal
- 12.5mm ENG broadcast tubes & CCDs, with..... 8mm diagonal
- 1/3” modern CCD size for High end applications.. 5mm? dia.

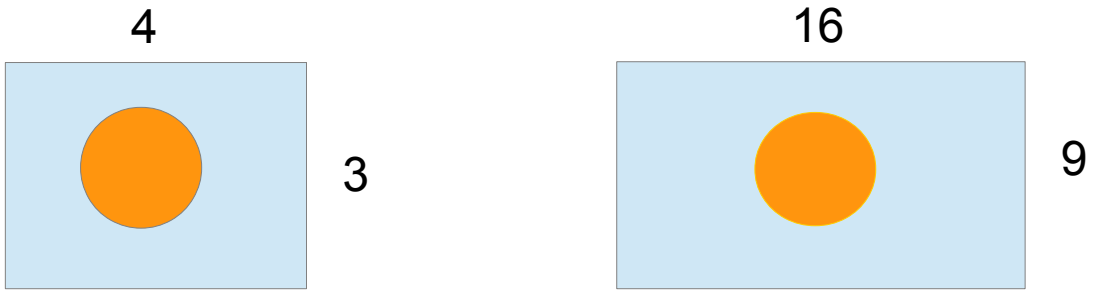
Beyond this point there is little sensor standardisation, with 1/4” or less almost to a vanishing point!

One great advantage in reducing the sensor size is the reduction in lens size for any particular field of view and aperture setting.



Aspect Ratio

For years there was no problem or confusion here. It was 4:3 that is the picture was 4 units wide and 3 units tall. Easy!



The key to success the circle in the scene is a circle on the screen

Problems arise when the size of the sensor patch is not the same as the viewing screen. Short & fat or tall & thin!!

The lens does not care which format is in use provided the diagonal is much the same. Often instead of the image being wider, is is of less hight to achieve the same result.

Aspect Ratio Problems

There are no easy solutions to this one, it is unusual to be able to change the aspect ratio of your camera so:-

4:3 to 16:9 reduce the width of your display monitor to suit.

16:9 to 4:3 reduce the hight of your display monitor to suit.

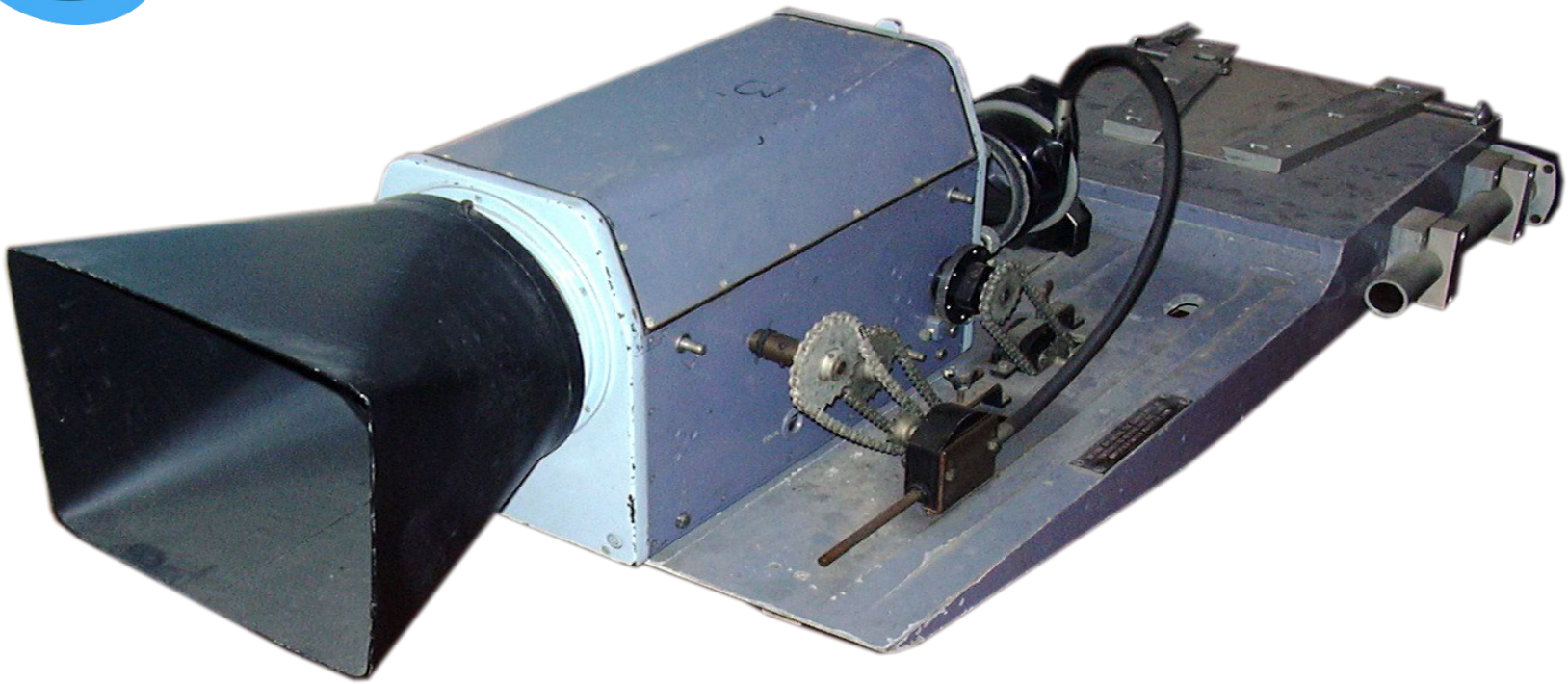
In these two we change the display area of the monitor even though the screen remains the same size.

There are electronic solutions that “letter box” or “Pillar box” the image, giving black bars top & bottom or to the sides.

Another method is to crop the image so that it is the right shape to fit the target display monitor.

All of these are unsatisfactory often leading to loss of resolution.

The History of the Zoom Lens



This is the Watson Zoom Lens

Developed in 1951 by H.H. Hopkins and manufactured by Watson & Sons Ltd. of Barnet.

It had the new 5:1 zoom range appreciably greater than any previous lenses.

The History of the Zoom Lens



The Varotal III

by Taylor-Hobson Cooke, part of the Rank Organisation

It still had the basic 5:1 range but it had a built in range extender giving focal lengths of:-

4 to 20 inches and 8 to 40 inches, it was well suited to outside broadcasts

The History of the Zoom Lens



Early 1960's

Taylor-Hobson Varotal V

10:1 range with cable driven control

This lens was available to fit many cameras with lots of optional variants

The History of the Zoom Lens



This is an Angenieux lens with servo controls by Evershed Power Optics

It has 3 motors for Focus, Iris and Zoom circa 1965.

Offered as a studio lens, it still had a 10:1 range 18 to 180mm at *f* 3.8

The History of the Zoom Lens



This Angenieux Lens has been cut away to reveal the multitude of lenses and sliding parts.

It was done as a teaching aid at BBC TVC.

The History of the Zoom Lens

A Schneider Variogon

15:1 range 12.5-190mm

at *f* 1.7

circa mid 1970s.

The servo motors and amplifiers are now built in to the quick change black boxes at the bottom of the lens.



This lens has one of the limitations of longer zoom ranges. Although it is *f* 1.7 at wide angles, as you zoom in there comes a point were the aperture is limited by the size of the front glass and the effective *f* number increases. This is called Ramping.

The History of the Zoom Lens



An early ENG style lens by Schneider with a 10:1 range.

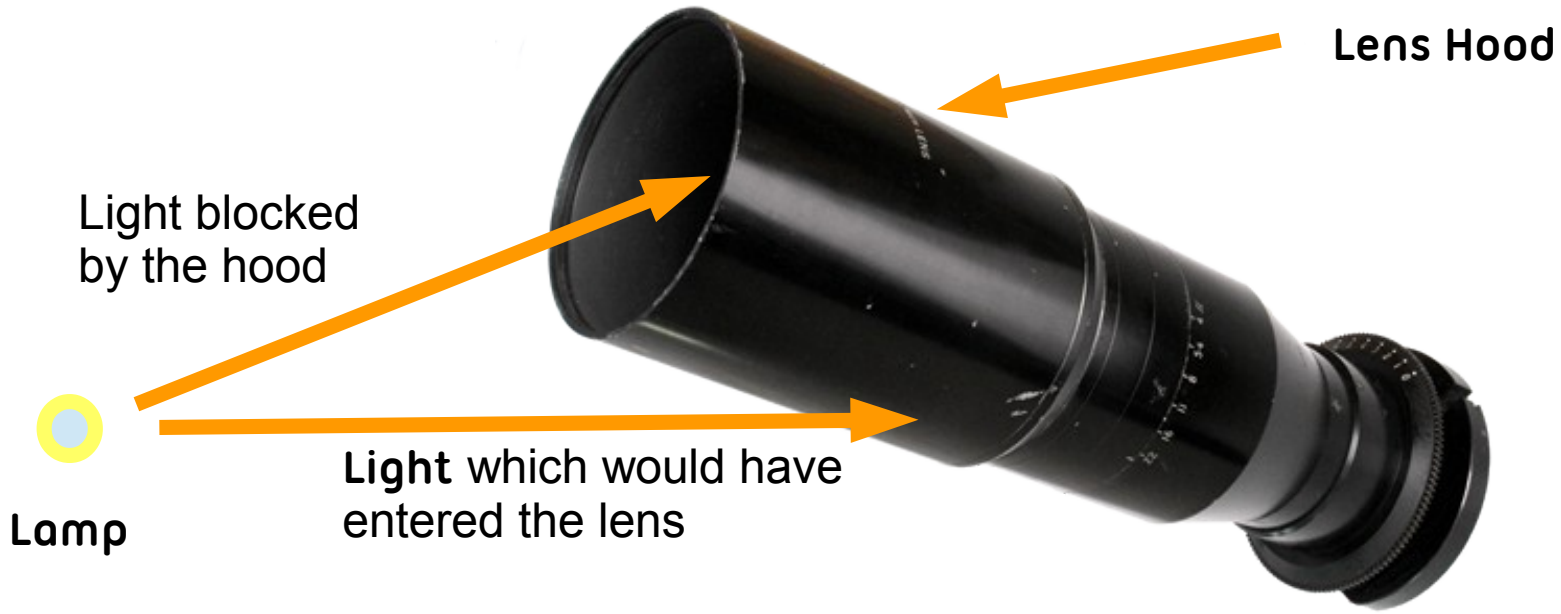
The History of the Zoom Lens



A modern ENG lens
Fitted to a BBC
Sony HD camera.

Lens Hoods, a good thing!

Lenses are not perfect and a lens hood will always improve the pictures, WHY?



Stray light from bright "out of shot" lamps or windows causes Flare, Internal reflections and ghost images

The Cannon Digi Super 100 Lens



This picture taken at the London Olympics is one of Cannons mega zoom lenses.

100 to 1 range plus a 2X extender gives a enormous 9.3mm to 1860mm range. f 1.7 ramping to f 4.7 @ 930mm. It weighs in at 51.8lbs



Lens Deficiencies

Lenses are far from perfect and can suffer from:-

- Poor resolving power, MTF
- Port-holing & Shading
- Chromatic Aberration
- Barrel distortion
- Pincushion distortion
- Flare
- Unwanted UV or infra red transmission
- Coma, astigmatism, spherical aberrations



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Any Questions?