Video Fundamentals 2 Colour Bars

Brian Summers G8GQS

Everybody knows what colour bars look like, but what are they for?

In an analogue transmission system you can use them to measure the gain and distortions that might be present. The most demanding version are the 100% bars, but there are a wide range of different bar options for different uses:- 75%, EBU, BBC, NTSC, red patch, the list goes on…

The gains, luminance and chrominance, can be quickly set using a waveform monitor or oscilloscope. If a vectorscope is available the burst to chroma phase can be measured and some estimate of the differential gain & phase errors made.

Quickly said, but lets have a better look at what these terms mean.

Luminance Gain is simply the gain of the system, perhaps a DA[1] on the end of a long cable run, the white bar is adjusted to 0.7 volts amplitude and the sync pulse would be checked to see that it was correct at 0.3volts.

Chrominance gain is the HF gain of the system, for PAL[2], centred on 4.43Mhz. In a simple DA there would be some interaction between these two controls.

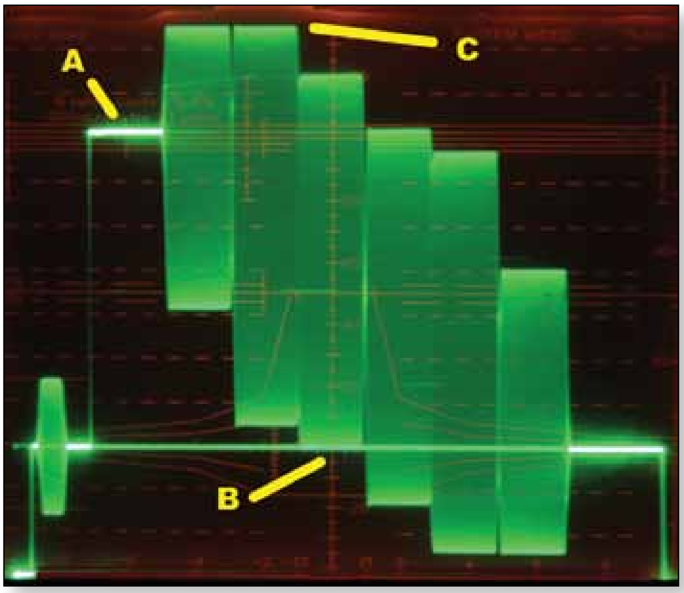
The burst to chrominance phase(s) for the 6 colours can be checked on a vectorscope as in Fig.4

Differential Gain & Phase is a more complex problem and is due to the non-linearity of amplifiers. Put simply the HF (chrominance) gain changes as the luminance signal level changes, i.e. if the chrominance gain is correct at a certain luminance level the gain might increase or decrease as the signal amplitude changes. The effect of this is to change the saturation[3] of the coloured areas of the picture.

Differential Phase is were the phase of the subcarrier changes according to the luminance amplitude, this time the hue of the colour changes according to the luminance amplitude. As the eye is quite sensitive to hue this can be a particular problem.

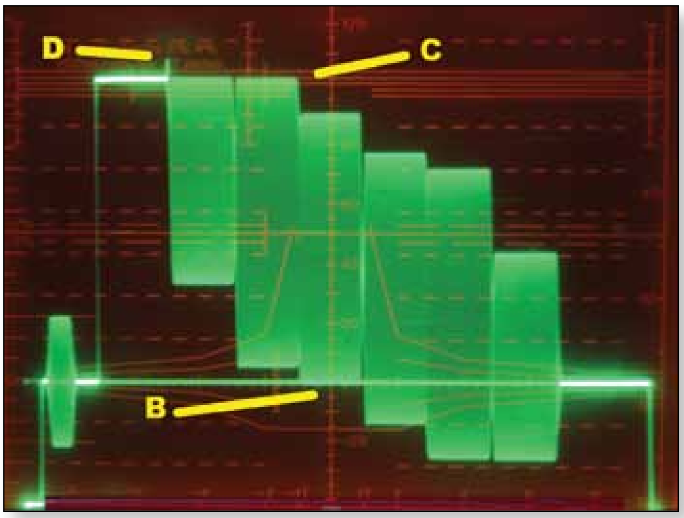
Whilst an incorrect signal level is easy to fix with a simple gain adjustment, Diff. Gain and Phase are very much harder to repair, so it is important that they don't occur in the first place.

1. DA = Distribution Amplifier
2. PAL Phase Alternate Line, an acronym referring to the colour system in use.
3. Saturation, the amount of colour in a picture area, 0 to 100%

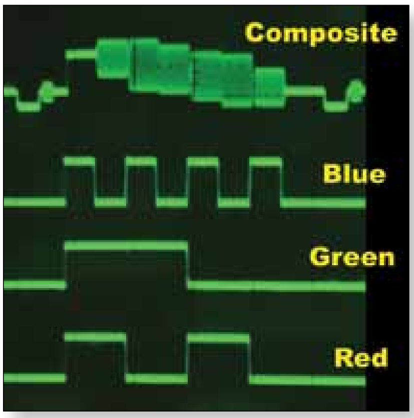


▶ *Fig. 1 100% Bars*
A = The white bar, 0.7volt no subcarrier present
B = Correct chroma amplitude when green bar just touches blacklevel
C = Flat top when U & V amplitudes correct

Now we have all seen colour bars on the monitor screen, Fig.1 is what the waveform monitor shows for a correct 100% bars signal and Fig.2 shows 75% bars. 100% bars is a demanding signal and will expose any deficiencies it the system. 75% bars are less demanding of the amplitude range of a video system and transmitters (AM broadcast) were the yellow and cyan bars of the 100% version would cause over modulation of the carrier. Less of a problem with FM and digital transmitters.



▶ *Fig. 2 75% or EBU Bars*
D = The top of these bars are flat, the little "pip" is not an error! These Bars were made by a Tek TSG271 digital generator and are as near perfect as possible, hence the pip.



▶ *Fig. 3 Here is the RGB component signals the show the relationship between them and 100% coded signal.*

Colour bars are of course the coded version of the R G B components[4] which are simple square waves, with correctly shaped rise times. Fig.3 shows the RGB signals that are coded to produce the composite PAL signal. Added together in the ratio of R=30% G=59% B=11% to make the luminance signal to which is added the 4.43Mhz subcarrier modulated with the U and V axis signals. Depending on the abilities of the measuring vectorscope, the decoded RGB or YUV[5] waveforms can be observed.

Fig.4 is a vectorscope with 100% bars displayed. I would like to go through some of the common vertorscope features.

▶ *Fig. 4 100% bars displayed on a venerable Systems Video 1205 vectorscope.*

The graticule is marked with boxes that the dots representing the colours should be in, 12 for PAL, 6 for NTSC[6]. The small boxes are ± 3° and the larger boxes ± 10°.

Around the outside of the display is a circle, sometimes marked with degrees of rotation. This circle is used as part of the quadrature/gain calibration check that most vectorscopes have.

In the centre are the burst graticules, two lines at 90° for PAL, there is a amplitude mark for 100% and 75%, a switch adjusts the vectorscope gain so that the vector dots fall in the boxes and the burst to the appropriate mark.

A PAL vectorscope usually has a PAL/NTSC switch which overlays the PAL 180° V axis switch to show an apparent NTSC display, useful for checking that the length of the vectors are the same in both of the PAL axis. It is not a standards change switch and does not enable the display of true NTSC which has a different subcarrier frequency of 3.58Mhz.

Before you can measure the performance of a video system you have to start with a good test signal, PAL, or NTSC for that matter, colour bars are quite hard to make with any precision using analogue equipment, many "TV test" units can be quite poor. A number of manufacturers have got over this by generating the colour bars digitally via a D to A[7]. Fortunately for us amateurs these good quality digital PAL units are now redundant with the broadcasters and are cheaply available on the auction sites along with a range of waveform and vector monitors. An example would be a Tek 271 which makes a useful range of "perfect" test signals.

In closing it is worth mentioning that in a fully digital video transmission system, colour bars are not a lot of use as digital systems have a different set of errors, not much shown up by colour bars. A subject for a future topic.

This necessarily brief article only scratches the surface of the subject, for a full study please see the following for further reading:-

- Pal Specification IBA Technical Review 2 Technical Reference Book. [8]
- Principles of PAL Colour Television, H.V. Sims, ILIFFE books 1969. A full description, 154 pages.
- Television Measurement Techniques, L.E. Weaver, IEE monograph series 9. Very detailed, 518 pages.
- Television Engineering Handbook, K. Blair Benson, McGraw-Hill, 1986, covers all systems, 1478 pages.
- There is a Wikipedia entry:- https://en.wikipedia.org/wiki/PAL which should be read with the usual caveats.
- BBC DD. Technical Memorandum No. 8 242(67) Colour Bars.

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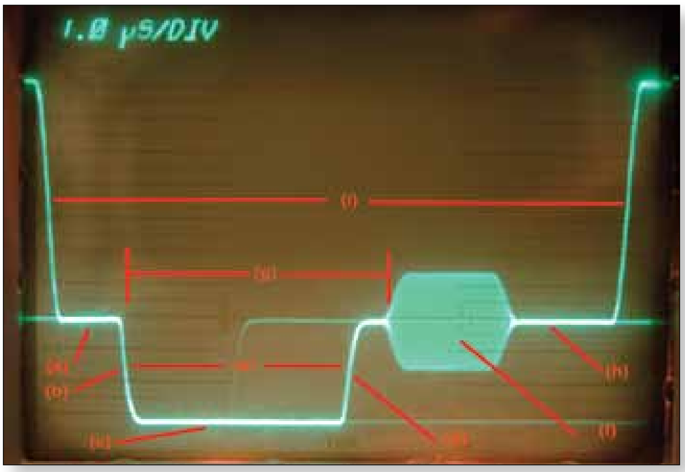
4. Component, a colour signal is made of 3 signals RGB or the colour difference signals, Y, R-Y & B-Y.
5. YUV, Luminance and the coded colour difference signals, see also R-Y & B-Y.
6. NTSC National Television Standards Committee, color television standard, defined as RS-170a
7. D to A Digital to Analogue converter
8. Download from the NTL pensions association http://www.ntlpa.org.uk/memorabilia

Video Fundamentals 1
The Line Sync Pulse

Brian Summers G8GQS

In these days of digital video it is all to easy to loose sight of the underlying principles, in this series of (notes) (monographs?) I hope to cover the basics of analogue signals from which the digital signals are often derived. A good place to start is the PAL waveform, this in it's turn is based on the older monochrome work.



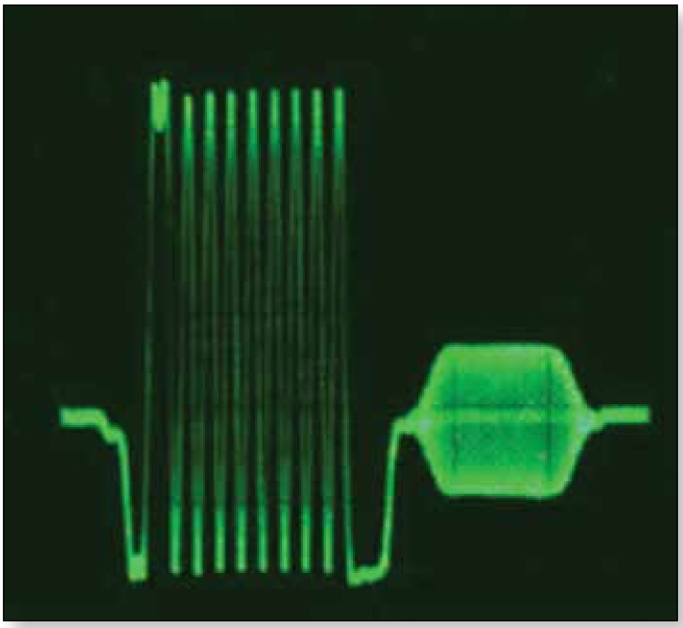
It is useful to be able to name the parts of the waveform, here is the Line sync pulse and the Burst.

a. Front Porch 1.55µs ±250ns.
b. Leading edge of the line sync pulse, normally taken as the "time reference" point.
c. Sync bottom.
d. Trailing edge of line sync pulse.
e. Line Sync pulse duration 4.7µ/s ± 100ns., amplitude 300mv ±9mv.
f. The PAL Colour Burst 300mv ±9mV amplitude symmetrical about black level 10 ±1 cycles 2.25µs ±230ns duration. Frequency 4.43361875Mhz ±1Hz.
g. Burst start 5.6µs ±100ns from leading edge of the sync pulse.
h. Back Porch 5.8µs ±600ns from trailing edge of line syncs.
i. Blanking 12.05µs ±250ns, measured with a white level signal.

Notes:-

The Gaussian slopes to all the waveform edges, this ensures that there are no high frequency "out of band" components to the signals. The measurements are taken from the half amplitude points on these waveforms.

The back porch period (h) is normally taken as the black level reference for the signal. It is also important that the Burst (f) is of the correct amplitude, or related to the amplitude of the chrominance information in the picture, as much domestic equipment, TV's and the like will auto-correct the saturation of the picture using the burst as a reference and if the burst is wrong the picture saturation will be affected.



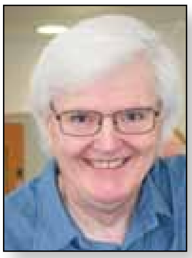
Sound-in-Syncs

The Sync bottom period (c) was used by broadcasters to carry a sound signal "Sound-in-Syncs". The idea was first described, as an analogue PWM signal, by Lawson, Kharbanda and Lord in 1946. The idea was developed by the BBC research department and Pye TVT into a digital system and it was much used on outside broadcasts, first as mono and then stereo circuit. This reduced the number of circuits needed and was a great cost saving device, it also kept the sound and vision together! It made sync separation difficult and the normal sync pulse had to be re-inserted with a SIS Blanker before any monitoring. It was only used on internal circuits and was never broadcast.

This is the first of an ongoing series of Video Fundamentals;- Next month colour bars and what they mean.

Further reading:-

SIS:- BBC Engineering Monograph Number 86
http://www.bbc.co.uk/rd/publications/bbc_engineering_86



Video Fundamentals - Part 3

Picture Monitors

Brian Summers – G8GQS

The final destination of a television picture is the retina of the viewers eye, and the last item we have control of is the picture monitor. Today we are going to look at how to achieve the best result. For television purposes monitors & TV's can be put into four groups:-

Grade 1 monitors are devices for high-grade monitoring of the technical quality and evaluation of pictures. They should not conceal any picture defects or artefacts.

Grade 2 monitors are used when the precision, and cost, of a grade 1 monitor is not justified, they have wider tolerances on the accuracy of reproduction.

Grade 3 monitors, are equivalent to domestic or consumer displays. They often have improvements to the mechanical construction. Grade 3 monitors can have a high brightness, suitable for use in areas of high illumination.

Ungraded, Domestic TV's and computer displays all into this group.

All monitors & TV's have adjustments to obtain the best results. If you are going to make judgements about your picture quality and offer reports to others your monitor must be correct or errors could be made.

Setting up your colour monitor

There are 3 simple controls on the monitor to tweak:-

▶ Brightness ▶ Contrast ▶ Saturation

It is easy to just make the picture look good and while this is OK for a domestic TV, it is hardly suitable for a monitor that will be used to make engineering judgements!

A couple of test signals are need to ensure correctness. Pluge[1] is used first to set the picture levels.

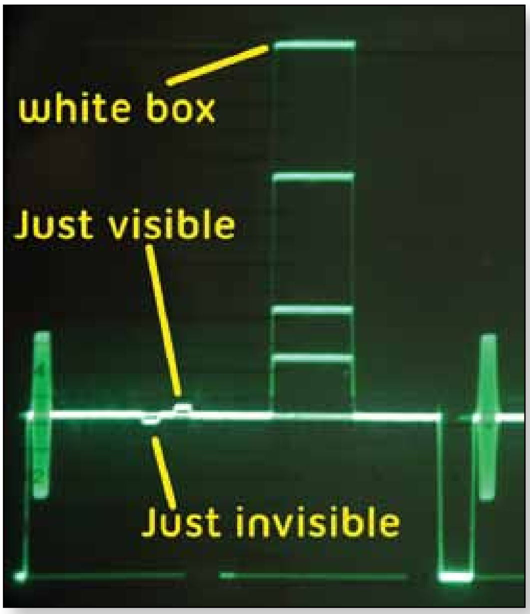
Black Level (brightness)[2]

On the left side of the Pluge signal are two vertical bars ± 14mV amplitude, with the contrast at a reasonable setting adjust the brightness control so that the left most bar is invisible, but the right bar can just be seen.

▶ *Fig. 1 The Pluge signal on a Plasma TV, it proved hard to photograph, so I enhanced the rectangular area to show the two bars.*

Peak White (contrast)

On the right of the pluge signal are a number of grey to white rectangles, the contrast control is adjusted so that the white square has the correct light output. What this value is depends on the job that monitor is used for, a light meter is offered up to the white square and the contrast adjusted to give the desired reading. The important thing here is consistency, all monitors in an area should have the same output.



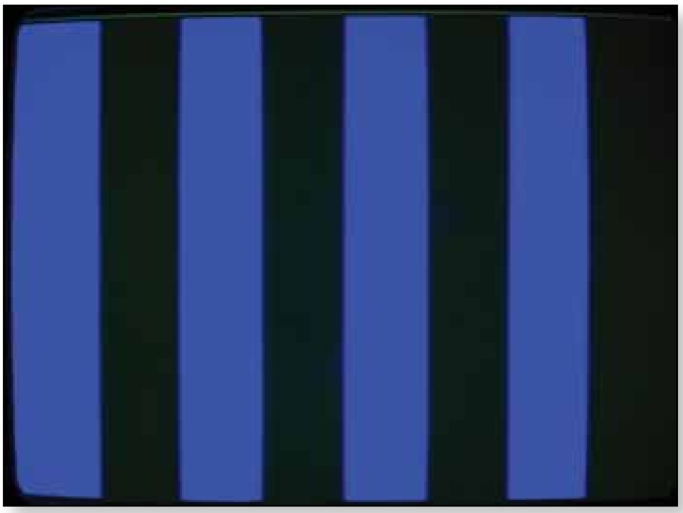
▶ *Fig. 2 The Pluge waveform*

1 Pluge a BBC acronym for Picture Line-Up Generator.

2 The terms "sit" or "lift" are sometimes used to describe the black level state.

Saturation (colour intensity)

Colour bars are used for this, 100% bars are simplest to use, now a bit depends on what controls your monitor has, ideally it has a blue only switch, when this is operated a row of 4 blue bars will be seen, Fig.3 (sometimes the monitor produces white bars, depends on the make). Adjust the saturation control so that all 4 bars are of equal brightness. In the absence of a blue only switch, the best option is to use a known good picture source and adjust so that the face flesh tones look natural. It is worth mentioning that the instructions for BBC test card F recommends setting the saturation for a natural appearance of the child in the centre circle. It also has a Pluge like dot in the black step of the greyscale wedge and a white dot in the white square, both should be just discernible.



▶ *Fig. 3 Colour bars showing 'blue only'. The waveform can be seen in CQ-TV 247 fig.3*

Other adjustments to consider are:

Colour temperature (an internal adjustment or a menu set-up option).

In broadcast PAL environments the white is CIE illuminant D, a colour temperature of 6500°K, is used. This approximates to average daylight illumination. It is a warmer white than the usual TV set white of 9300°K . If this is not a preset option, the white on the screen will have to be measured by a meter. These have three sensors that attach to the screen and a readout of some sort. Or just by eye, visually comparing with a lamp of known colour emission.

Black & white balance (& grey scale)

When displaying a grey scale, each step on the grey scale should be without any colour cast, e.g. the tracking of each of the three colours should be in the correct proportion to give a true grey.

Choice of monitor

Today, most users go for an LCD or Plasma display. A certain amount of care has to be taken when choosing one. They do tend to be big and quite bright but careful observation may well show defects. With the profusion of line standards, coding and interlace standards it has become a bit of a minefield. The EBU document called Tech 3320, User Requirements for Video Monitors in TV[3], may help and is very revealing about the problems of flat panel displays. Many video engineers still insist on a CRT[4] Grade 1 for final evaluation of pictures.

A trend in using large flat screen monitors is the use of "multi-viewers" to display up to 16 small pictures on the one big monitor. These often have UMDs (under monitor displays) showing the name of each picture and the cues, red or green.

▶ *Fig. 4 A 42 inch display with 12 small pictures and UMDs showing the source*

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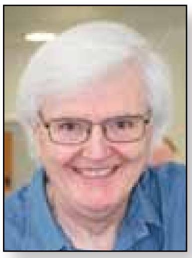
3 The EBU monitor evaluation guide. ***https://tech.ebu.ch/docs/tech/tech3320.pdf***

4 BBC Engineering G.P.TV colour picture monitors. Specification TV1282. Dated 1984



Video Fundamentals - Part4

The Camera's Eye

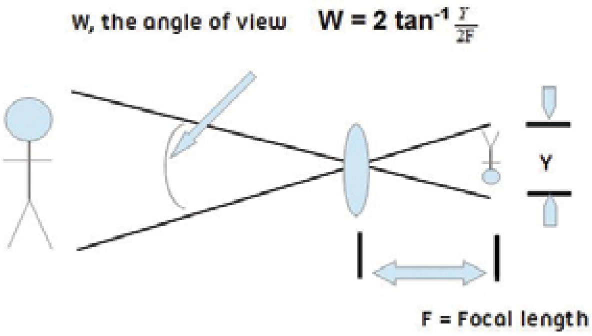
Brian Summers – G8GQS

Lenses and optics are a big subject and often neglected - after all we want our pictures to look good. In previous issues we looked at how to measure and view our pictures, today we look at the start of it all with the lens.

This is the first step in the process of television and here are a few terms used about lenses with short explanations. There can be a lot of formula describing optics, but only a few here!

Focal length

This is the distance from the principle point of the lens to the focal point and it is expressed as length in inches or mm. From this comes the angle of view offered up to the camera's CCD. Larger format sensors require a longer focal length for the same angle of view.



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

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.

Aperture

This is a measure of the light gathering power of the lens - the larger the aperture the more light is focused on to the sensor. It is calibrated in "f" numbers typically f1.4 to f22 in the ratio of $\sqrt{2}$ each stop increase, halves the light. e.g. 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 aperture, F is the focal length and D is the effective diameter.

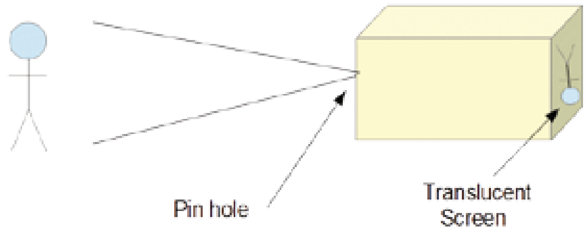
The Iris control adjusts the lens aperture, by means of a ring around the lens body.

Focus:

adjusted to bring the subject in the picture into sharp display. In a fixed focal length lens by altering the distance of the lens from the sensor. In a zoom lens the front, and other, elements move independently to focus the image.

Depth of field:

the distance in front and behind an optimally focused subject that is still in sharp focus. Many parameters affect this distance, the Iris setting has the most effect. The wider open the iris is the shorter the depth of field and conversely a "pin hole" lens is completely sharp.



If we consider a pinhole 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.

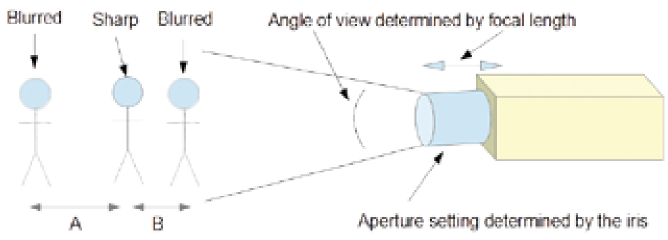
With a real Lens of the type we use, the depth of field depends on both the Iris aperture and the Focal length.

▶ *This picture with the lens at f 4 shows a short depth of field, note that Felix is more defocussed than Fido*

▶ *With the lens set at f 22 all are within the depth of field and appear sharp*

Example of depth of field differences

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

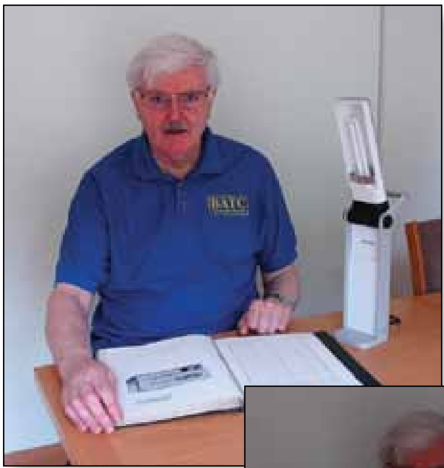


Of note is the distance "B" is shorter than "A" which can be infinite, this is called the hyperfocal distance.

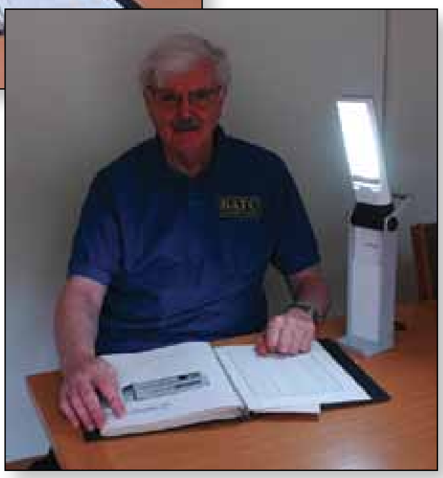
Apart from artistic effects, most of us would want a large depth of field and this can be obtained by having sufficient light available so the the iris can be closed to perhaps f11 or f16

Iris and auto iris

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



▶ *Although the light source is off, the subject is better exposed as the auto iris is not compensating for the bright light source.*

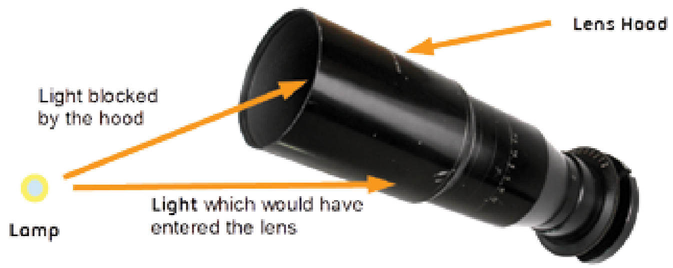


▶ *With the light source on, our subject is actually under exposed as the iris is compensating for the bright light.*

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.

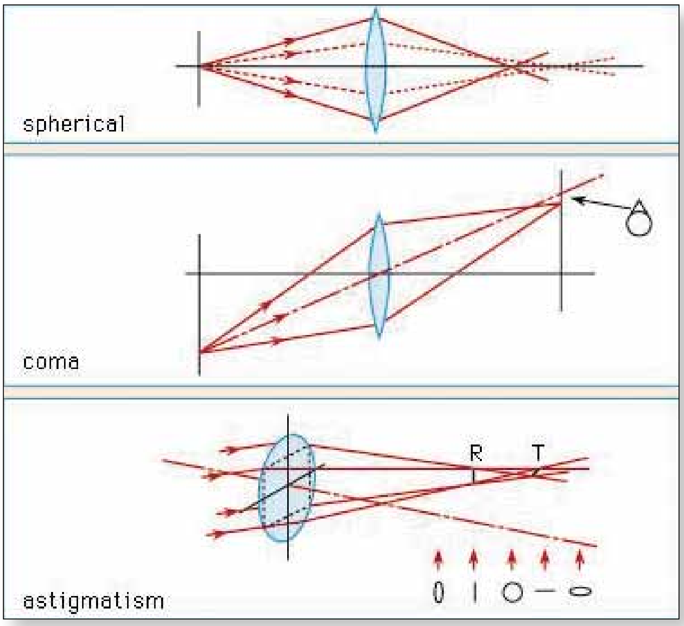
A good cameras auto iris setup may allow the choice the part of the picture used, exclude the sky or just use the centre part. Setting the exposure is a bit of an art, aim for the faces looking correct!

Lens Hoods, a good thing!

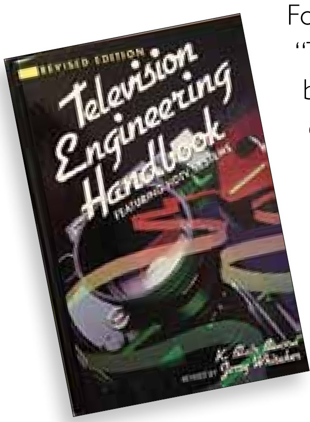


Lenses are not perfect and bright light from an "out of shot" lamp or window can cause, Flare, internal reflections, and ghost images. Hoods are easy to do for fixed or prime lenses and hoods for zooms often need to be adapted on the fly to shield the offending light source. These are sometimes called "french flags."

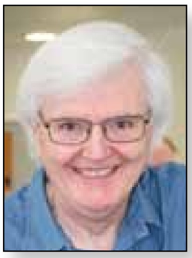
Lens Aberrations



There are many lens aberrations, to name a few:- Poor resolving power or MTF, Port-holing & Shading, Chromatic Aberration, Barrel distortion, Pincushion distortion, Flare, Unwanted UV or infra red transmission, Coma, astigmatism, spherical aberrations.



For further reading, I can recommend "Television Engineering Handbook" by K.Blair Benson, it's 1000+ pages cover almost everything including lenses, and there's always Google!



Video Fundamentals - Part5

After the Lens

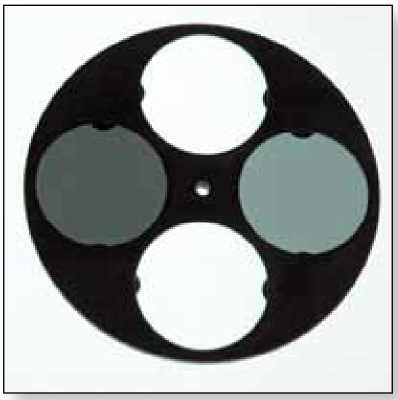
Brian Summers – G8GQS

Last time we looked at the camera lens, this month we will look at the next stage in the process.

Lens mounts: Perhaps a word about how the lens attaches to the camera, a common one is the 'C' mount[1] derived from the film industry and used on many CCTV cameras. It is a screw thread nominally 1 inch in diameter, with 32 threads per inch. There is also the less common 'D' mount of 0.625 inch diameter. In broadcast there have been many different mounts but recently many manufacturers have used the 'B4' mount, but even within this mount there are different image sizes and servo unit connectors.

Filters: Immediately after the lens and in front of the sensor there may be one or more filters.

- Neutral density filters, these are often mounted in a disc which can be rotated to place one in the light path to reduce the light level. A typical choice is, clear, 10%, 1% and a cap position. These are often quoted as the equivalent number of lens 'stops', see last issue of CQ-TV.
- A colour correction filter, if the cameras normal white balance is for indoor lighting a minus blue helps a lot with outdoor lighting which has more 'blue' in it than indoors artificial light. Sometimes both Colour and ND filters are mounted in the same disc.
- Especially with older cameras there may be an optical low pass filter.



▶ *Fig: 1 Filter Wheel*

▶ *Fig: 2 Top row = -Blue, Clear, ND and a dark ND filters*
Bottom = a different -Blue and a Star filter

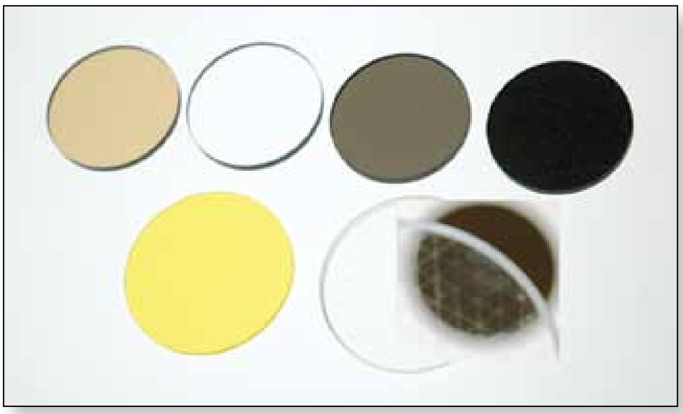


Fig: 1 shows a typical filter wheel with 2 clear filters and $^{1}/_{16}$ ND and $^{1}/_{4}$ ND.

Fig: 2 shows a selection of filters, the different minus blue filters give correction for different camera colour temperatures. ND and colour filters can be mounted on the front of a lens for cameras without a filter wheel.

Special effect filters are often used, this one is a star filter and it is made by lines scribed onto the filter surface. The number of star points being related to the line pattern.

The optical low pass filters or Birefringent Filters, to give them their proper name, are made from several layers of thin sheets of glass Fig: 3. Without going into the details of their construction[2], the need for them is easier to understand if you first consider the electrical low pass filter placed before an A to D converter and the Birefringent filter serves a similar purpose and eliminates the alias effects in the CCDs output. The pixel structure of a CCD x by y pixels forms the equivalent of the sampling frequency of a A to D converter.

▶ *Fig. 3 Birefringent Filter*

The older analogue tube cameras did not need a Birefringent filter as the tube target itself acted as a low pass filter, but with the pixel structure of CCDs a filter was needed. Newer CCDs & C-Mos sensors have a higher pixel density (equivalent to a higher sampling frequency) so in some instances the birefringent filter is not needed as the lens itself becomes the low pass filter, see MTF[3].

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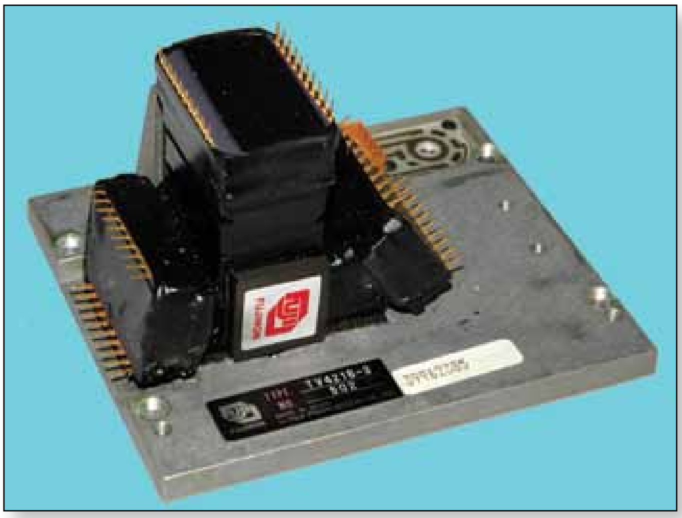
1 Wikipedia.org/wiki/C_mount

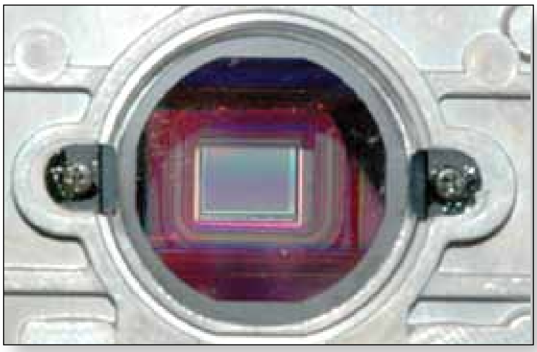
2 Wikipedia.org/wiki/Birefringence
pmoptics.com/files/Birefringent_filter_plates.pdf

3 MTF or modulation transfer function, the optical equivalent of frequency response.



▶ *Fig: 4 A three chip light splitter block*

There is a choice for the next item. The traditional tube colour camera had either a light splitter that separated the light into red, green and blue light and on to the tubes or the other, and cheaper, choice was to use a tube with coloured stripes on the target. Sometimes a two tube combination was used.

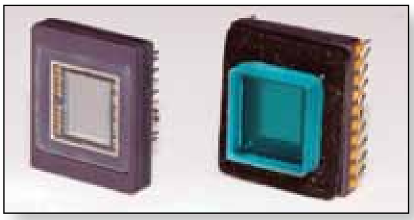


▶ *Fig: 5 the view into the light splitter block showing the image of the 3 CCD's together.*

When CCDs were first used both methods were used, the choice with a light splitter and 3 CCDs giving much superior results. These 3 CCDs were precision glued to the light splitter and a lot of the old tube adjustments disappeared. In Fig: 4, the light splitter block is face down, the lens would be below.

As in the tube case it was possible to 'Stripe' the CCD and this is what was used in domestic and economy cameras.

Of course the march of technology has improved the performance of sold state sensors to give large pixel densities and the descendants of the stripe CCDs are very good. Broadcast cameras still tend to 3 CCDs but there are new single sensor designs (the Red cameras, for instance) that produce excellent results.



▶ *Fig: 6 Two CCD chips, one with the Birefringent filter.*

At this point it is worth stating that CCDs are essentially analogue devices. The spacial resolution is digital in the sense that there are x by y pixels, giving the resolution, but the output signal depends on the number of photons arriving and generating a proportional number of electrons that are accumulated in each pixel site before being clocked out. These electrons are applied to the input of a A to D converter at the earliest point possible, in recent devices on the CCD chip itself.

The CCD[4] was described in CQ-TV 141 to 143 downloadable from The BATC website

4 Wikipedia.org/wiki/Charge-coupled_device

Video Fundamentals 6

What shape and how many Lines?

Brian Summers – G8GQS

What shape?

In 1936 the UK's high definition all electronic television service started with 405 lines. In 1936 this was at the cutting edge of technology and the aspect ratio was 5:4, that is the picture was 5 units wide by 4 units high. Today we would call this standard 405/50i. The March 1950 edition of *Wireless World* announced the first change to the wider aspect ratio of 4:3. In practice as everybody had the similar round tubes it was effectively a reduction in the picture height.

Things have moved on a bit since then and now we have a plethora of line and aspect ratio standards. First I would like to talk about the aspect ratio. Looking at the film world – which has it's own set of different formats, cinemascope, etc – there are problems showing films on television as to how they are presented. The simple choice is to show all of the film with black areas top & bottom (letterbox)[1]. This looks bad on a 4:3 TV screen and it wastes the vertical resolution as many lines have no picture information. The next option is to just show the middle of the film, but here the action in the picture wings is lost. A more costly option, is to do "pan & scan" and pre-record it before transmission, perhaps the least worst option.

In the late 1990s we started to see the arrival of TV widescreen with camera and display devices of 16:9 aspect ratio, this was artistically an improvement, but many compromises had to be taken during the period when the viewers had both aspect ratios in use.

The principle to keep in mind is a circle viewed by the camera should still be a circle when seen by the viewer.

There are many variants on the above; for a while the BBC shot and recorded programs in 16:9 and transmitted them domestically in 14:9, a halfway house, and sent them to Europe in 4:3. This all made framing the shot and the positioning of graphics interesting with shoot and protect safe areas. The electronic changing of the aspect ratio mentioned above was done, predictably, in an Aspect Ratio Converter (ARCing). The same result could be achieved in a conventional DVE (Digital Effects Unit), now often combined with the vision mixer. What was once hard and needed lots of silicon has now become commonplace. There is a very good website[2] by Alan Pemberton that goes into this in much greater detail.

* An "Active Format Descriptor" or AFD is transmitted so the TV can auto switch to the correct display shape. The analogue version of this was called WSS, (Wide Screen Signalling) transmitted on the first half of line 23.

How many Lines?

So having looked at the shape of the picture, how many lines should there be? And what of interlace?

Originally in the 1930s interlacing solved two problems. They are related to each other and the problems still apply today.

The first was flicker, the film industry solved this by showing each image twice from a base image rate of 24 pictures per second. Film pull-down, flash image, flash same image again, pull-down next image and so on. This fooled the eye into thinking the display rate was 48 pictures per-second.

The second problem was bandwidth, still with us today. Not much of a problem for film, just use 35mm instead of 8mm. Looking here at the resolution of film as spatial bandwidth.

Television copied this basic idea of showing the picture twice, field 1, then field 2 that is half of the then 405 lines in each frame. So 25 complete pictures per second at

Camera format	4:3 screen option 1	4:3 screen option 2	4:3 screen option 3
16:9 Widescreen aspect ratio	Reduce monitor/TV scan height to match 16:9 with un-scanned area top & bottom	Electronically reduce the height of the picture with black top & bottom (letterbox)	Electronically crop the sides to provide 4:3 ratio (pillarbox)

Camera format	16:9 screen (CRT)	16:9 screen	16:9 active screen
4:3 Aspect ratio	Reduce scan width,	Electronically reduce the width of the picture with black at the sides (pillarbox)	Modern display screens can switch aspect ratios* if this function can be accessed.

a rate of 50 half pictures[3] per-second solves the flicker problem and reduces the bandwidth by half. It does also reduce the temporal resolution by half, as movement in the picture causes each frame to be different.

The same idea applies to most current line standards 525/60, 625/50, 1080/50i notice here that the HD 1080 has an i to indicate interlace. Even today bandwidth is a problem, but a different problem from 1936 when it was technically hard to achieve the required analogue bandwidth. Today you can in principle have as much digital bandwidth as you like, it just costs money.

The intermediate HD standard of 720 lines could be transmitted as i or p. You could have 1080p but it doubled the bandwidth and therefore the transmission costs. Once you are in the digital domain there are any number of options, 1080p at 25 pictures was one that springs to mind. (film effect).

TV's can now have the ability to up-convert the frame rate, 100 or 200Hz rates are promoted as a way of reducing flicker. Some TVs make a better job of this than others. Often an attempt is made at interpolating the movement between the transmitted frames with varying degrees of success. It is worth mentioning that the human eye when viewing larger, brighter screens is more likely to perceive flicker and increasing the display rate reduces this problem[4]. We in the 50Hz countries are used to our field repetition rate, but visitors from the 60Hz areas can often see flicker on 50Hz displays until they become used to it.

Bandwidth

Perhaps we ought to look at some numbers – they can be staggeringly large. For an SD (Standard Definition) picture, that is for 625 lines, the broadcast studio uses the REC601 SDI[5] = 270Mb/s. 1080/50i HD is much more at 1.485Gb/s and 1080/50p at 2.97Gb/s. It is patently obvious that there is a huge amount of compression applied to these signals for distribution and transmission. Bits or Bytes? Note the small b, so it's bits.

Where bandwidth is not limited, as for instance, in your computer/monitor cable, the line rate (vertical pixels) can be high as can the refresh rate (frames per-second no interlace). This can be 60 - 80Hz. to eradicate flicker.

When you enter the computer world of video editing there are still bandwidth limitations. Storage, processing, distribution are still problems even with the high compression rates with the resultant artefacts. It's worth mentioning here that video with MPEG compression can be tricky to edit as you get I & P frames which means you can't always cut where you wish.

As explained Progressive is a higher bandwidth solution with a refresh rate high enough to avoid flicker, at least 50hz. Stepping down from this is full Interlaced with 2 half pictures, this reduces the bandwidth by half. Next is a fudge of progressive at 25hz and show it twice, the artistic film effect. If you are viewing on a LCD or projector this may not be too much of a problem as the pixels are turned on for longer, but you do get movement judder. Next is 'either field' – this is effectively a picture with half the vertical resolution as you have thrown away a field of information and this leads to jagged edges on diagonal lines.

The whole area of resolution, display rates, compression, recording formats, LCDs & projectors, video cable formats, SDI, HDMI, Firewire… have become increasing complex. For example 1080-line standards are defined for 23.98p, 24p, 25p, 29.97p, 30p, 50i, 50p, 59.96i, 59.96p and 60i and 60p according to what mains power frequency and country you are in.

With todays technology, and if you were starting with a clean sheet of paper to write your design on, it is unlikely that you would choose to employ interlace, but then there is already a lot written on our sheet of paper…

It's worth mentioning that with the proposed new 4K system, 3840 pixels by 2160 lines, there is a strong argument for increasing the picture rate to 100 or 120hz to give improved temporal resolution to match the spacial resolution of the picture.

My personal view is that there are enough pixels in HD for viewing a normal, say 45 inch screen at a normal distance, something to do with the resolution of the human eye versus the pixel size. As a BBC vision engineer trained to spot defects in the picture I do find I am annoyed by the artefacts introduced by the high compression used. It would be better to improve the fidelity of the picture, up the frame rate and have a few less shopping channels. There… rant over!

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1 Letterbox and Pillarbox are the slang terms used.

2 ***http://www.pembers.freeserve.co.uk/Test-Cards/Test-Card-Technical.html#Aspect-Ratio***

3 The lines are interleaved to give what we call interlace.

4 ***https://en.wikipedia.org/wiki/Flicker_fusion_threshold***

5 ***http://www.itu.int/dms_pubrec/itu-r/rec/bt/R-REC-BT.656-5-200712-I!!PDF-E.pdf***

6 The Quantel digital fact book is a mine of information a free download. ***http://quantel.info/resource.nsf/Files/DigitalFactBook_20th/$FILE/DigitalFactBook_20th.pdf***

Video Fundamentals 7

Camera Signal Processing

Brian Summers – G8GQS

Last time we had a look at how many lines were desirable and what shape the picture should be. This month we will look into the camera. There is quite a lot going on, unnoticed, there. The same processes that were used in the old analog days, still happen but this time with numbers. In some ways this is easier, a lot less adjustments and setting up for a start!

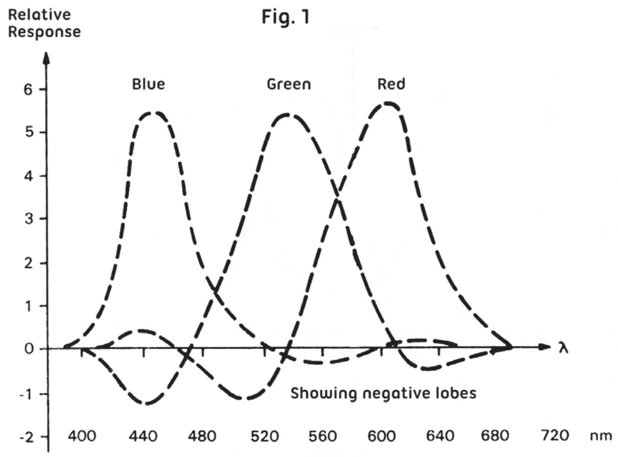
Amplification and Digitisation

The first point to appreciate is that ALL camera sensors are analog. A certain number of photons arrive at a pixel and a corresponding number of electrons are clocked out. This small signal is then amplified to a reasonable level and passed to the A to D converter. The signals at this point are RGB for 3 chip cameras or a single interleaved RGB stream for single chip cameras. The older cameras used 8 bit words for each colour and newer cameras 10,12 or even 16 bit words. The need for more bits will become clear later.

It's worth pointing out that the normal proportions of R, G & B apply and for a white signal, R = 30%, G = 59% and B = 11% . For convenience in processing these are amplified to be the same level, and then to however many bits the camera uses.

Matrixing

We need first to consider the response of human eye to colour stimuli. If we are to have good pictures that correctly convey the colours to the eye we need to do some processing. This is a complex field and whole text books have been written on just this. Considering fig. 1 you can see the red, green & blue responses. The tricky bit is that these response curves have negative lobes!. It is also quite tricky to make CCD's or LCD's that have negative output! The way to do it is to have a Matrix where the RGB signals and their inverse signals are added together in a way that improves the colour fidelity. This attempts to take account of the characteristics of the optical system, light splitter, CCD response and so on. See fig. 2 for a block outline of a matrix.



Gamma correction

In a perfect system, light in = light out, but due to the non linear signal response of the display cathode Ray tube, CRT, with a typical gamma of 2.2 – 2.8 cameras have the complimentary gamma of 0.45 applied to the signal.

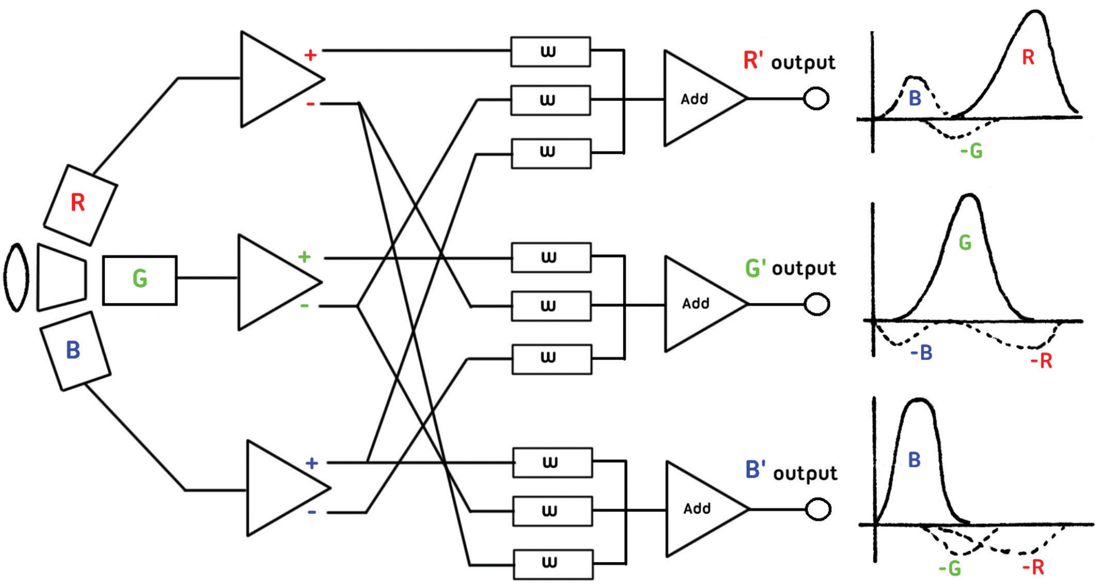


Fig. 2 Simplified Matrix diagram showing the creation of negative lobes and the weighting factor w

There is usually some choice in the exact gamma value applied (3.5-4.5). Some artistic licence and company policy comes into play. See fig. 3. It is worth noting that modern LCD displays, which are linear, have CRT type gamma built into them to maintain compatibility.

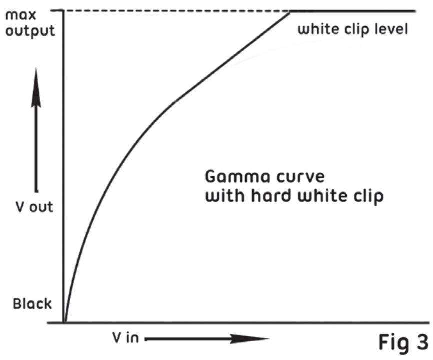


Fig 3

Black

It should be a statement of the obvious that there should be no "blacker than black" part of the picture, so it's clipped off! The setting of the Black Level control has a big effect on the picture and it can be lifted (blacks look grey) or crushed (grey parts are black). Sometimes done for "aesthetic effect"??

White clipping and the white "knee"

Again you can't have "whiter than white". Whatever the digital range of your camera, max output is max output. However there is a way of soft clipping that allows some detail through, referred to as the Knee or white Knee. See fig 4. With powerful digital processing this can be very effective in extending the dynamic range and showing detail in the clouds say, that would otherwise be lost. Different manufacturer's have their own approaches in this area.

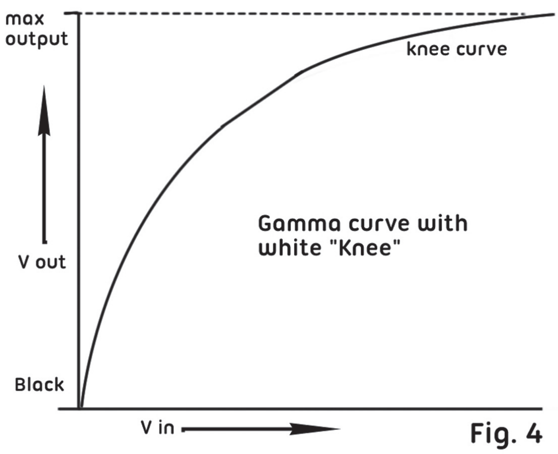


Fig. 4

Shading

Not used in the old sense of fixing tube errors, CCD's and CMOS sensors have essentially flat outputs, but it can be employed to fix lens errors like port-holeing.

Aperture correction

Originally used to correct for the loss of fine detail in camera tubes. There were two types:- horizontal correction and vertical (VAK). In analog processing horizontal along the line was easy to do, but vertical much harder as 2 one line stores were needed. Now easy to do in digits, but there is less need for it as the resolution of sensors is determined by how many pixels are used. However some sharpening of the edges in pictures can be beneficial as it helps with the loss in the optics.

Flare correction

Again correction of a lens defect. Flare is caused by internal reflections in the optical system causing black level changes. An algorithm for this will look at the lens zoom, focus and iris positions and attempt to correct.

Colour Balance

Is achieved by adjusting the gain and black level of the Red and Blue signals relative to Green. It can be done manually, automatically on demand, or continuously. Again the algorithms are very clever, but can be caught out. Use with care.

Digital arithmetic

Once the signals are digitised the old linear way of processing no longer applies and several processes can be carried out at the same point in the processing. Specially developed processing chips are used containing proprietary software and little can be changed by the user. Modern cameras claim up to 600% dynamic range and up to 38 bit internal processing. The reason for such big digital numbers is that if you multiply two 10 bit numbers you get a 20 bit answer. Do it again and you have 40 bits! The answers have to be truncated in some way and the lower order bits discarded. This can be a problem with small 8 or 10 bit numbers and If this is not done well it can lead to visible artifacts in the picture.

Output arrangements

The broadcast SDI (serial digital interface) is a good choice. Normally 10 bit and uncompressed. I shall be looking at outputs and cable formats in the next issue.

Postscript

This consideration is a general one. It applies to no camera in particular, but all cameras to a greater or lesser extent. Different manufacturers have there own ways of achieving the same ends.

The spec for a high end camera with 16 bit processing can be viewed here:- http://www.ikegami.co.jp/hchd300/feature/index.html