Appendix I: aspect ratios

History
The aspect ratio of a two-dimensional image is the ratio of the width to the height. In the film world, the width is expressed as a multiple of the height, so Cinemascope might be 2.35:1. It is different for television. The two principle standards in use since the introduction of the cathode ray tube have been 4:3 and 16:9. In filmic terms, these would be 1.33:1 and 1.67:1.

Widescreen television needs more bandwidth than 4:3 because there is more picture information. This is why it is generally available only through digital delivery systems.

The Golden Mean, widescreen and the human eye
How were these formats chosen? Why was 4:3 chosen for the original TV service? What about the Golden Mean?

The fovea centralis
The most sensitive part of the human eye for colour and detail is the centre – it’s called the fovea centralis. In a healthy system, the brain combines the signals from each eye into a single image. The most detailed area within the wide angle covered by both eyes together is in an aspect ratio of roughly 16:9 – certainly widescreen and not 4:3.

The Golden Mean
The Golden Mean is a concept going back to Euclid, a mathematician in Ancient Greece. If you take any line, you can split it, as in Figure A1.1, so that the proportion AB:AC = AC:CB.
A1.1 The Golden Mean.

This ratio works out to approximately 1.62:1 (or 14.6:9 – not so very far off 16:9). Many people believed that a rectangle with this proportion (that is, with AC as the width and CB as the height) was in some sense ‘ideal’, more aesthetically pleasing than other rectangles. This, then, would have been a logical choice for television’s aspect ratio in the 1930s when the first television services were being developed. However, whilst the Golden Mean does have a lot of interesting mathematical baggage, it is not clear that such a rectangle really is any more psychologically appealing than any other.

Television screens

Towards the end of the nineteenth century, a film width of 35mm was chosen as a standard, probably as the greatest practical width for cellulose nitrate movie film. The frame, it was decided, should be four sprocket holes high. The ratio of the useable space between the sprocket holes and this height was 1.33:1. This did change slightly to 1.37:1 with the introduction of optical soundtracks (standardized around 1930), which took part of the film width – the frame height had to be reduced to compensate. When the first ‘high-definition’, 405-line systems were introduced, the screen size was chosen not for classical reasons, but because many commercial films were then available in a 1.33:1 format.

Television became so popular using its own material that cinema audiences began to dwindle. To bring people back to the cinema, audiences, it was felt, needed something new. Cinemascope and the other widescreen formats provided this – a more enveloping experience.

Overall, more than a dozen aspect ratios have been tried, so this section is merely raising the issues! Cinemascope was the first widescreen film format to be introduced commercially. In this system, the camera lens produced a distorted image, which was recorded onto standard 35mm film as what is called an anamorphic image. The true proportions were restored when the image was projected through a lens that corresponded to the one on the camera. The image was distorted in much the same way as figure A1.7, but the aspect ratio of the full image, originally, was 2.66:1 (though there were other versions at 2.55:1 and 2.35:1) Many films are issued on DVDs at 1.85:1 for showing on widescreen TVs. This gives a slight border top and bottom or a little cut off the vertical edges. The reasons for the discrepancy are technical.

There have been many variations on film aspect ratios. Some systems used 55 mm film, some used 70 mm. Some required three or more projectors running film absolutely matched and in sync. This is not the place to go further into film history, though.
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Mixing formats

Domestic cut-off

As soon as you try to show something shot in one format on a different one, you run into trouble. This is true whether you are making a TV programme about films needing film clips or showing old TV clips in a 16:9 programme (this will remain a challenge as long as titles like The Fifty Best/Worst/Greatest/Funniest... etc. survive). To keep this brief, let’s look at what happens to a simple circle on different screens.

![Diagram of domestic cut-off](image)

A1.2 Domestic cut-off. Cathode ray tubes were not true rectangles. The picture would usually be overscanned so the viewer’s screen was filled. The part of the picture generated in the studio (shown here in grey) was lost. Production teams had to bear this in mind when framing and ensure all necessary information was inside the usual domestic cut-off limits – camera viewfinders showed the limits and many still do.

16:9 and 4:3

The problems really begin when you show a TV picture shot in one format picture on the other type of screen. The widescreen diagrams are sixteen squares wide by nine high. The 4:3 screens are shown as twelve squares by nine squares – exactly equivalent to 4:3.
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Most widescreen TV sets will allow a choice for reframing. Sometimes, the content distributor does this for you through an ARC, or Aspect Ratio Converter.

Programme-makers take care to frame shots for good effect, so this kind of thing is not liked (at least by me). What is worse, though, is stretching the picture to fit, as in Figure A1.5.

Figure A1.7 shows what happens when a widescreen picture like Figure A1.6 is fitted into a 4:3 screen. The circle remains nine units high.

I would prefer to see the full picture undistorted, but ‘letterboxed’, even though this does leave 25% of the screen blank (Figure A1.8).

14:9 and protection

In the early days of widescreen, some programmes were shown on terrestrial channels in a 14:9 format, a halfway house between 4:3 and 16:9. There was a small letterbox effect, but viewers could see almost all the picture.
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A1.5  The circle and the 12 squares from Figure A1.3 are stretched horizontally so that the whole picture is shown without margins.

A1.6  True circle in a 16:9 frame.

A1.7  Figure 6's circle is 9 units high. It still is here, but has been squashed to 12/16 (3/4) its original width as it would be in a 4:3 frame. The image is said to be 'anamorphic.'
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A1.8  Letterbox’ framing of 16:9 picture in a 4:3 frame.

The practice (in the UK) was to shoot in 16:9 ‘protected’ either for 14:9 or for 4:3. This meant we had to ensure that all vital information was contained within the narrower frame. I used to ask for tape-marks on the monitor to indicate the edge of the appropriate frame to ensure 4:3 viewers missed nothing important.

A1.9  Appearance of 16:9 picture converted for showing as 14:9 on a 4:3 frame.

Other formats

One way of producing widescreen pictures in the early days was Super-16 film. All 16mm film is capable of storing an image in the aspect ratio 1.37:1 (equivalent to 12.33:9 – only a little wider than 4:3 – and the same ratio as 35mm film after the introduction of sound).
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A1.10 The relationship between 16:9 aspect ratio and Super-16 mm film. The whole frame would be exposed with a little top and bottom being regarded as in cut-off – safe to ignore.

There is also space to one side for an optical soundtrack, which would be transferred onto the master negative after editing and dubbing. By the 1960s, this facility was not used in the British television industry.¹ Instead, sound was stored on separate rolls of 16mm magnetic tape (‘Sep. Mag.’) – it needed a complicated mechanical system to keep everything in sync.

It was realised that by modifying the cameras, this spare film width could be used for filming with a wider aspect ratio – more picture information could be stored. The aspect ratio this generated was 1.66:1 (equivalent to 14.9:9). By losing a little of the image at the top and bottom of frame, a good 16:9 image could be produced and Super-16 was born.

The full grid in figure A1.10 approximates to the Super-16 frame (15:9). The shaded area shows the approximate 16:9 aspect ratio within this. You can see there is relatively little of the original picture that needs to be lost.

Now that so much material is commissioned in some variety of HD, Super-16 has fallen out of favour, as it is not able to deliver the same picture quality as full HD cameras.

A word about memory and storage

Whether it is recorded with analogue or digital technology, a 625-line 16:9 PAL picture takes more space in tape, memory or transmission bandwidth than a 4:3 picture. HD recordings at over 1,000 lines need even more memory, and so on. This is despite the use of ‘compression’, which allows picture information common to several frames to be stored once for that sequence of frames rather than to be

¹That is to say, I never came across it.
stored afresh for each frame (as it is on film). This can reduce significantly the amount of memory needed for each sequence.

The higher the compression ratio, the less is the memory needed – but the greater the likelihood of artefacts being introduced into the pictures. (Also, because parts of the picture information might be shared across four or more frames, the editing software has to be even more sophisticated to cope with even a straight cut from one clip to another.)

**Summary**

In short, where a picture is shown in an aspect ratio for which it was not designed, picture information is lost: the quality of the picture for the viewer is therefore reduced. The larger the screen on which such a picture is shown, the more obvious will be this quality loss.

The situation is made yet more complicated if PAL pictures are converted for use (perhaps as archive material) for use in programmes recorded in HD. The picture seen by the viewer may then suffer a further quality loss, but the explanations are very technical and outside the scope of this book. It is also probable that conversion systems will improve from their position in 2010.

It is useful to be aware of all these differences if there is any chance you might want to use or view archive footage from any source.