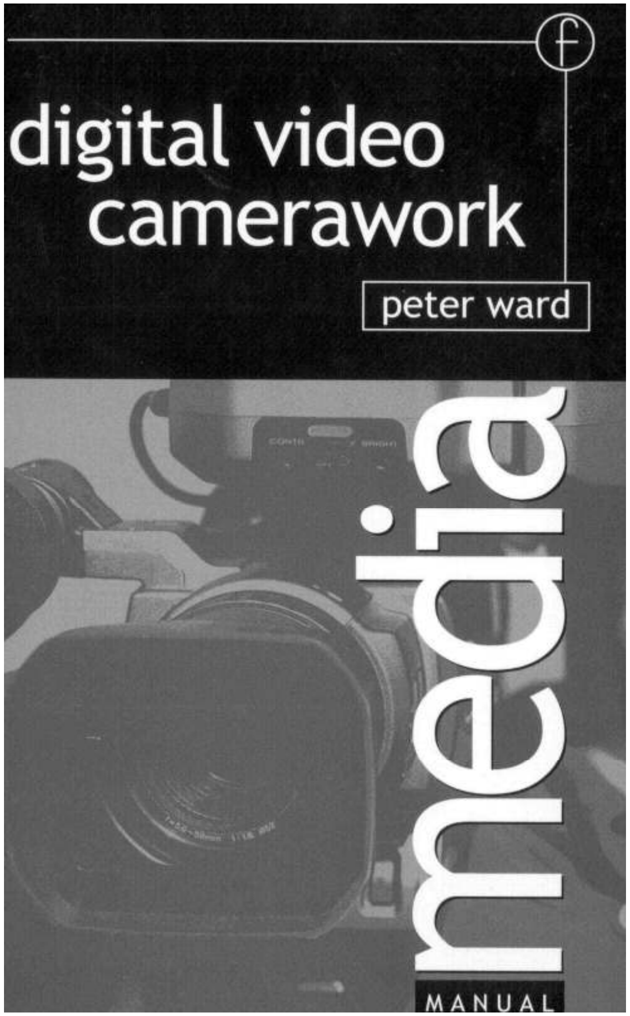


Ward, Peter. **Digital Video Camerawork. Media Manual.** Focal Press 2000

Technique and technology

There is an urban myth of an American tourist hiring a car in a foreign land and driving 200 miles in first gear. When the engine eventually overheated and seized up he was asked if did he not suspect somewhere along the journey that something was wrong. He said he thought it was noisy and slow compared to his own car with automatic transmission back home, but having never driven a car with a manual gear change he had no way of comparing the car's performance.

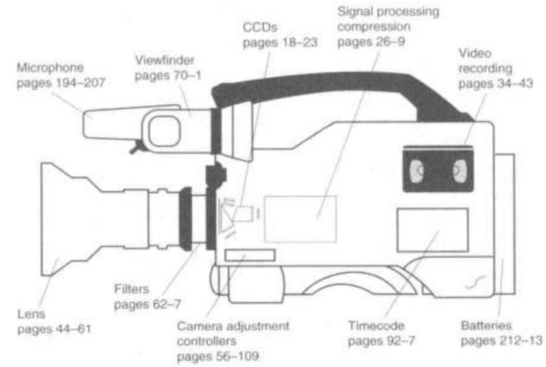
A basic knowledge of television technology is required to avoid a similar foul-up when new to programme making. Technology is simply a means to an end; the end being a programme that communicates with its audience. Without an understanding of the camera equipment employed or an over-reliance on automatic features, the end result may be less than satisfactory.

In 1888 the Kodak camera was launched as an easy, simple method of taking photographs. 'You press the button, we do the rest', was a sales slogan to demystify the arcane process of photography. In the early days of the craft, would-be photographers had to prepare their own glass plates, and then develop them in a combined camera/darkroom. After 1888, anybody could press a button and the camera and the chemist would do the rest. Training in photographic competence was condensed to the few minutes required to be instructed on which button to press.

Over 100 years later, in response to the needs of the TV industry, the craft of camerawork is promoted as a simple matter of knowing the position of a couple of buttons on the camera. After a very short training period, anybody can become a competent television cameraman. If this was true about photography and broadcast camerawork, there should be no visual difference between a holiday snapshot and an advertising brochure of a resort, or a holiday video and a feature film shot at that resort.

Technology and technique intertwine. How you do something in broadcasting depends on what equipment you are using. It is not simply a question of being told which button to press in order to get a professional result. In television camerawork, an understanding of camera technology plus the ability to exploit and take into consideration the attributes of the camera and the lens characteristics is the basis of practical programme production. Most camera equipment is now wrapped up with auto features in the hope of being user-friendly to technophobic customers, but camera operators should aim to understand what is happening when they are using a camera rather than trust the old slogan of 'you press the button, the equipment will do the rest'.

Simplified figure of a DV camera/recorder



Lens system: The design of the lens affects resolution, image quality, focal length, zoom ratio, exposure and control of zooming. Also important is the lens fitting to allow interchangeability with other lenses.

Charge coupled device: The choice of pick-up sensors (e.g. FIT, HAD, etc.) will determine how light is converted into electricity and will control the quality of image, definition, highlight handling, contrast range and sensitivity.

Television system: How the signal is read from the CCDs will depend on the video system chosen and how it will be seen by its potential audience. Choice of systems range from decisions on colour system (PAL, NTSC, SECAM), line structure (625, 525, 1088, etc.), aspect ratio (4:3 or 16:9), interlace or progressively scanned.

Digital conversion: Choice of sampling rate and how the colour information is sampled will affect how the material is displayed and edited.

Signal processing: How the signal is processed and modified such as knee, linear matrix, gamma will affect the appearance of the final displayed image.

Compression: Digital signals require compression before recording and the compression ratio chosen for the camera and the design and method of compression all affect the signal output.

Video recording format: There are many methods of recording video onto tape or disk (e.g. Betacam SX, DVCPro, DV, Digital-S, etc.). The method and format used in the camera will control the quality of recording and editing format.

Sound: An effective method of recording and monitoring audio levels is needed and the facilities for microphone inputs will affect the final edited audio presentation.

Camera controls: A range of controls are required to achieve a good technical quality image (e.g. white balance, shutter, gain, exposure, menus, set-up cards, built in filters, method of genlocking and monitoring outputs, etc.).

Viewfinder: A quality viewfinder to monitor all aspects of the image output.

Timecode: A method of setting up and recording timecode information on the tape is essential for editing.

Power supplies: Batteries and monitoring the state of charge of batteries is required. Also an input to use an AC adaptor if required.

Pan/tilt head and support system: Adaptor plate on the base of the camera to enable it to be mounted on pan/tilt head and tripod.

Robust mechanical design: A camcorder used for everyday programme production is subjected to much harder wear and tear than a camera used for holidays and family events.

Light into electricity

Light reflected from the subject in view will pass through the lens and be focused on the charge-coupled devices fitted in the camera. The effect of the lens and lens characteristics are discussed later. This page details how light is turned into an electrical signal.

How the eye sees colour

There are many nerve endings in the retina which respond to visible light including red, green and blue receptors which respond to a range of wavelengths. Colours are seen as a mixture of signals from these three types of receptors. Colour television adopts the same principle by using a prism behind the lens to split the light from a scene into three separate channels (see figure opposite).

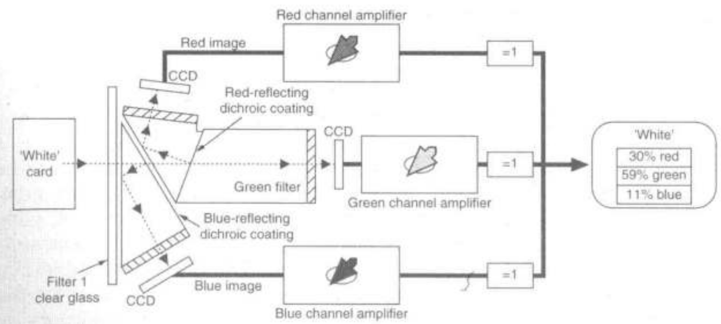
White balance

In colorimetry it is convenient to think of white being obtained from equal amounts of red, green and blue light. This concept is continued in colour cameras. When exposed to a white surface (neutral scene), the three signals are matched to the green signal to give equal amounts of red, green and blue. This is known as white balance. The actual amounts of red, green and blue light when white is displayed on a colour tube are in the proportion of 30 per cent red lumens, 59 per cent green lumens and 11 per cent blue lumens. Although the eye adapts if the colour temperature illuminating a white subject alters (see Colour temperature, page 64), there is no adaptation by the camera and the three video amplifiers have to be adjusted to ensure they have unity output.

Colour difference signals

To avoid transmitting three separate red, green and blue signals and therefore trebling the bandwidth required for each TV channel, a method was devised to combine (encode) the colour signals with the luminance signal.

The ability of the eye to see fine detail depends for the most part on differences in luminance in the image and only, to a much smaller extent, on colour detail. This allows the luminance (Y) information to be transmitted at high definition and the colour information at a lower definition resulting in another saving on bandwidth. Two colour difference signals are obtained, Er (red) – Ey (luminance) and Eb (blue) – Ey, by electronically subtracting the luminance signal from the output of the red and blue amplifiers. These two colour signals are coded into the luminance signal (Ey) and transmitted as a single, bandwidth-saving signal. Different solutions on how to modulate the colour information has resulted in each country choosing between one of three systems – NTSC, PAL and SECAM. At the receiver, the signal can be decoded to produce separate red, green, blue and luminance signals necessary for a colour picture. A receiver is a television set that derives its signal from an RF (radio frequency) source (e.g. a transmitter). A monitor is a visual display that is fed with a video signal via a coaxial cable (see Monitor termination, page 17).



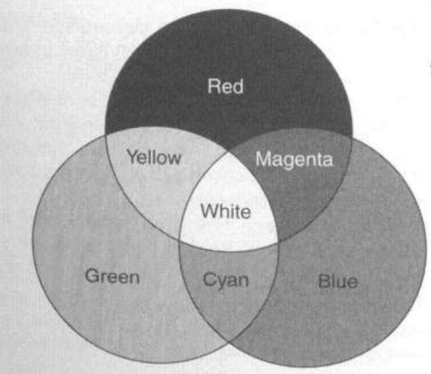
Light into electricity

The amplitude of the three individual colour signals depends on the actual colour in the televised scene. Colours are broadband and the light splitting block divides this 'broad' spectrum into red, green and blue light to produce three optical images on the respective red, green and blue CCDs. The CCD converts the optical image into an electrical charge pattern. A fourth signal, called the luminance signal, is obtained by combining proportions of the red, green and blue signals. It is this signal which allows compatibility with a monochrome display. The amplitude of the signal at any moment is proportional to the brightness of the particular picture element being scanned.

Additive colour

A composite video signal is an encoded combined colour signal using one of the coding standards – NTSC, PAL or SECAM. This can be achieved using the luminance (Y) signal and the colour difference signals of red minus luminance (Er – Ey) and blue minus luminance (Eb – Ey). The signals are derived from the original red, green and blue sources and this is a form of analogue bandwidth compression.

A component video signal is one in which the luminance and the chrominance remain as separate components, i.e. separate Y, R – Y and B – Y signals.



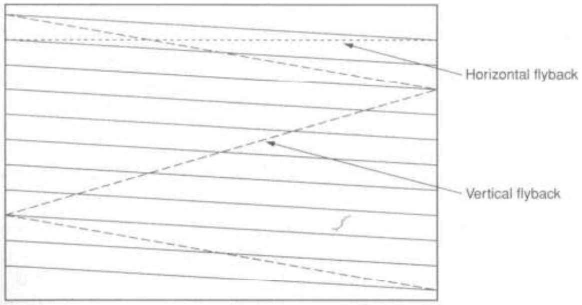
The video signal

Television translates light into an electrical signal and then back into light. In its journey from initial acquisition to the viewer's TV set, the television signal is subjected to adjustments and alterations before it is converted back into a visible image. Like all translations, something is lost along the way and a two-dimensional viewed image can never be an exact visual equivalent of the original. The amount of signal adjustment that occurs in broadcast television is a result of the historical need to ration and allocate transmission bandwidths. These technical restraints set limits to image definition and tonal range. The deliberate subjective creative choices made in creating the programme image also affect the picture viewed by the audience. There are continuing attempts to upgrade the existing various standard TV signals to a higher definition origination and transmission system, but the cost of re-equipping all production and receiving equipment and the lack of agreement on standardization inhibits rapid change.

The technical accuracy of the transmitted image depends on:

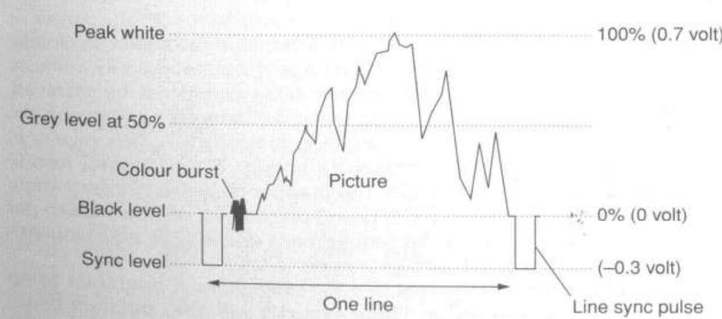
- **Time:** Human vision cannot instantaneously perceive a complex image and intuitively scans a field of view in order to visually understand what is presented. A video camera requires a mechanism to scan a field of view in a precise, repeated line structure.
- **Detail:** The choice of the number of lines and method of scanning is critical to the definition of the captured image and ultimately is dependent on the method chosen to relay the picture to its intended audience. The shape of the screen, the ratio of picture width to picture height, will determine line structure and resolution.
- **Movement:** Human perception requires that the repetition rate of each image must exceed approximately 40 pictures per second to avoid flicker and to provide a convincing simulation of smooth movement of any object that changes its position within the frame.
- **Synchronization:** The displayed image watched by the viewer must have a mechanism to stay in step with the original scanning of the televised image.
- **Accuracy of the tonal range:** Human perception is able to accommodate a wide range of brightness. The television system is only able to replicate a limited range of tonal gradations.
- **Colour:** A television electrical signal requires a method of accurately conveying the colour range of the reproduced image. As colour superseded black and white television, the colour system chosen was required to continue to provide compatible pictures for those viewers watching on black and white receivers.
- **Subjective creative choices:** The final production images can be customized in an almost limitless way to suit the creative requirements of the programme originator. The line structure and synchronization however remain unaltered.

The television scanning principle



The television picture is made up of a series of lines which are transmitted with synchronizing pulses to ensure that the display monitor scans the same area of the image as the camera. In the PAL 625 line system, each of the 25 frames per second is made up two sets of lines (fields) that interlace and cover different parts of the display. The electrical 'picture' is scanned a line at a time and at the end of each line a new line is started at the left-hand side until the bottom of the picture is reached. In the first field the odd lines are scanned after which the beam returns to scan the even lines. The first field (odd lines) begins with a full line and ends on a half line. The second field (even lines) begins with a half line and ends on a full line.

The television waveform



The waveform of the 1 V television signal divides into two parts at black level. Above black, the signal varies depending on the tones in the picture from black (0 V) to peak white (0.7 V). Below black, the signal (which is never seen) is used for synchronizing the start of each line and frame. A reference colour burst provides the receiver with information to allow colour signal processing.

Image quality

Video images are eventually displayed on a television screen. The quality of the screen, how it has been aligned and adjusted, any reflections or ambient light on the surface of the screen, the size of the screen and the distance at which it is viewed will all affect the quality of the image as seen by the viewer. Some compensation can be built into the video signal to mitigate receiver limitations (see Gamma and linear matrix, page 102), but other factors affecting viewing conditions are outside the control of the programme maker.

Unlike film, where the projected image consists of light reflected from a screen, a television tube emits light. The maximum white it can emit depends on its design and how the display has been adjusted. Black is displayed when there is an absence of any signal, but even when the set is switched off, there is never a true black. The glass front surface of the tube, acting like a mirror, will reflect any images or light falling on the screen degrading 'black'. These two aspects of the display, its maximum high intensity white and how much ambient light is reflected from its screen set the contrast range that the display will reproduce independent of its received signal.

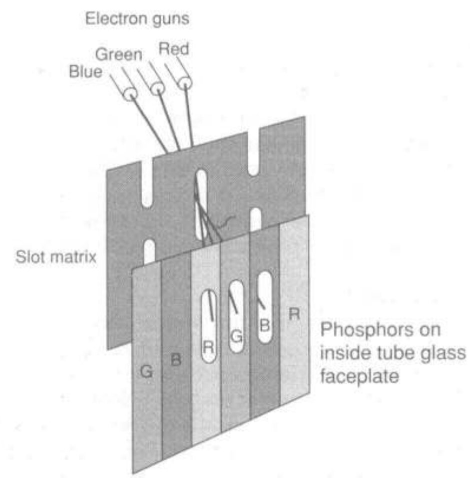
Resolution

The size of the display screen and its viewing distance will be one factor in how much detail is discernible in a televised image. Due to the regulation of television transmissions, the design of the system (e.g. number of lines, interlace, etc.) and the permitted bandwidth will affect the detail (sharpness) of the broadcast picture. Bandwidth will determine how much fine detail can be transmitted.

The active number of lines (visible on screen) in a 4:3 PAL picture is 575. However, a subject televised that alternated between black and white, 575 times in the vertical direction would not necessarily coincide with the line structure and therefore this detail would not be resolved. The limit of resolution that can be achieved is deduced by applying the Kell factor which for the above example is typically 0.7. This results in a practical resolution of 400 lines/picture height. The horizontal resolution will be 4/3 of 400 equalling 533. The number of cycles of information/line equals 533/2, resulting in 266.5 taking place in 52 μS (time taken per line). This results in a bandwidth requirement of 266.5/52 μS – approximately 5.2 MHz for 625 4:3 picture transmission.

5.2 MHz bandwidth will be required for each channel broadcast using PAL 625, 4:3 picture origination. Other systems will have different bandwidth requirements such as 1250 HDTV PAL which has twice the resolution and needs 30 MHz. Digital transmission allows some bandwidth reduction using compression (see Compression, page 26).

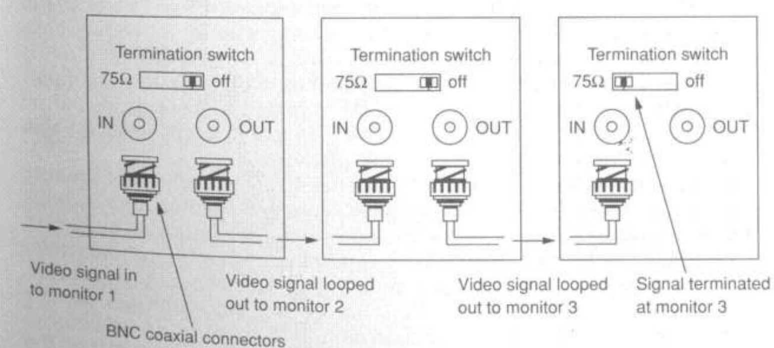
Slot-mask colour tube



Colour is created on a TV screen by bombarding three different phosphors (red, green and blue) that glow when energized by an electronic beam. The screen may be one of three designs, shadow mask, aperture grill or slot-mask (illustrated above), depending on how the pattern of phosphor dots are arranged on the inside face of the tube. The slot-matrix vertical slots are arranged so that each beam only strikes its corresponding phosphor line on the screen.

NB: a video monitor refers to a visual display fed with a video signal. A receiver refers to a display fed with a radio frequency signal.

Monitor termination



A video signal fed to a monitor must always be terminated (usual value is 75 Ω) unless it is looped through to another monitor. The last monitor in the chain (monitor 3 above) must be terminated to avoid signal distortion.

Charge-coupled devices

MOS capacitors

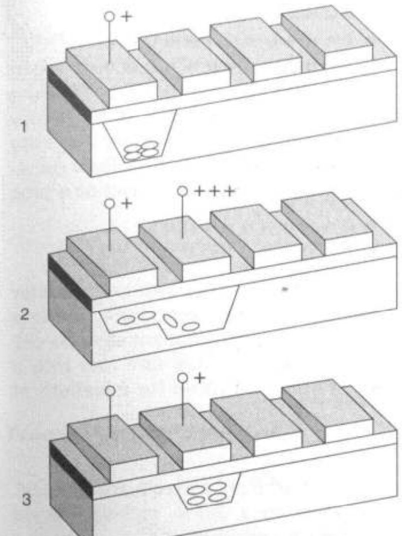
A MOS capacitor (see figure opposite) is a sandwich of a metal electrode insulated by a film of silicon dioxide from a layer of P-type silicon. If a positive voltage is applied to the metal electrode, a low energy well is created close to the interface between the silicon dioxide and the silicon. Any free electrons will be attracted to this well and stored. They can then be moved on to an adjacent cell if a deeper depletion region is created there. The ability to store a charge is fundamental to the operation of the charge-coupled device plus a method of transferring the charge.

Charge-coupled device

If a photosensor replaces the top metal electrode, and each picture element (abbreviated to pixel) is grouped to form a large array as the imaging device behind a prism block and lens, we have the basic structure of a CCD camera. Each pixel (between 500 and 800 per picture line) will develop a charge in proportion to the brightness of that part of the image focused onto it. A method is then required to read out the different charges of each of the half a million or so pixels in a scanning order matching the line and frame structure of the originating TV picture. Currently there are three types of sensors in use differing in the position of their storage area and the method of transfer; they are frame transfer, interline transfer and frame interline transfer (see page 20).

- **Frame transfer:** The first method of transfer developed was the frame transfer (FT) structure. The silicon chip containing the imaging area of pixels is split into two parts (see figure opposite). One half is the array of photosensors exposed to the image produced by the lens and a duplicate set of sensors (for charge storage) is masked so that no light (and therefore no build up of charge) can affect it. A charge pattern is created in each picture field which is then rapidly passed vertically to the storage area during vertical blanking. Because the individual pixel charges are passed through other pixels a mechanical shutter is required to cut the light off from the lens during the transfer. An important requirement for all types of CCDs is that the noise produced by each sensor must be equivalent, otherwise patterns of noise may be discernible in the darker areas of the picture.
- **Interline transfer:** To eliminate the need for a mechanical shutter, interline transfer (IT) was developed. With this method, the storage cell was placed adjacent to the pick-up pixel (see figure on page 21), so that during field blanking the charge generated in the photosensor is shifted sideways into the corresponding storage element. The performance of the two types of cell (photosensor and storage) can be optimized for their specific function although there is a reduction in sensitivity because a proportion of the pick-up area forms part of the storage area.

MOS capacitors



1: After a positive voltage (e.g. 5 V) is applied to the electrode, a low-energy well is created below the oxide/semiconductor surface, attracting free electrons.

2: If 10 V is applied to the adjacent electrode, a deeper low-energy well is created, attracting free electrons which now flow into this deeper bucket.

3: If the voltage on the first electrode is removed and the second electrode voltage is reduced to 5 V, the process can be repeated with the third cell. The charge can be moved along a line of capacitors by a chain of pulses (called a transfer clock) applied to the electrodes.

By replacing the electrode with a light-sensitive substance called a 'photosensor', a charge proportional to the incident light is transferred using the above technique.

Schematic of frame transfer CCD

The imaging area of a frame transfer CCD is exposed to the subject (X) and each photosensor is charged in proportion to the incident light intensity. A mechanical shutter covers the photosensors during vertical blanking and each photosensor transfers its charge to the sensor below until the storage area duplicates the imaging area. The shutter is opened for the next field whilst each sensor in the storage area is horizontally read out in turn. What was a two-dimensional grid of variations in light intensity has been converted into a series of voltage variations.

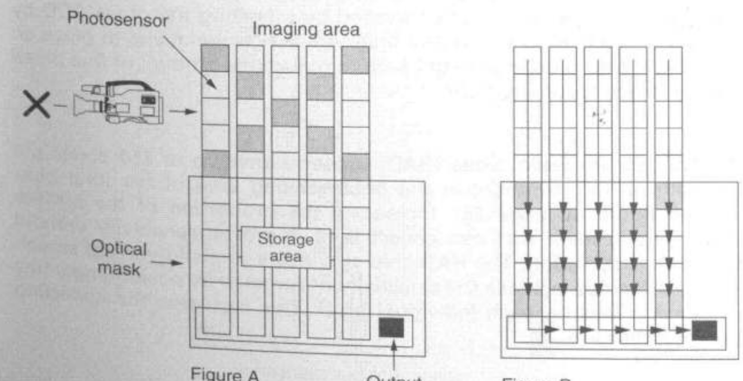


Figure A

Figure B

FIT and HAD CCDs

Vertical smear

One problem with interline transfer is vertical smear. This occurs when a very strong highlight is in the picture and results in a vertical line running through the highlight. It is caused by the light penetrating very deeply into the semiconductor structure and leaking directly into the vertical shift register. Since only longer wavelength light is able to penetrate deeply into the silicon, the vertical smear appears as a red or a pink line.

Frame interline transfer

In an attempt to eliminate the vertical smear the frame interline transfer (FIT) was developed (see figure opposite). This combines the interline method of transferring the charge horizontally to an adjacent storage cell but then moves the charge down vertically at 60 times line rate into a frame store area. The charge is therefore only corrupted for a sixtieth of the time compared to IT CCDs.

Resolution

To reproduce fine detail accurately a large number of pixels are needed. Increasing the number of picture elements in a 2/3-in pick-up device results in smaller pixel size which decreases sensitivity.

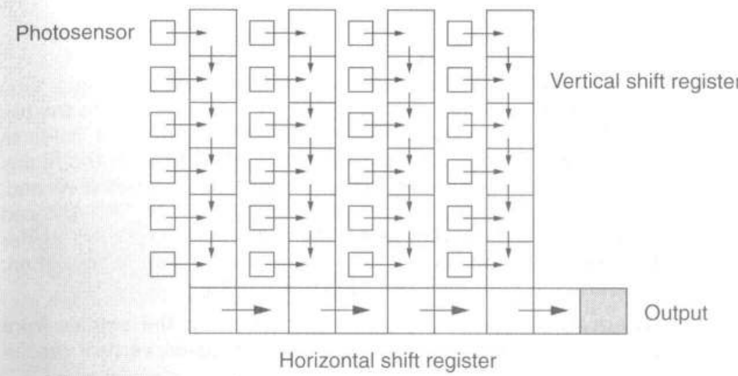
Aliasing

Each pixel 'samples' a portion of a continuous image to produce a facsimile of scene brightness. This is similar to analogue-to-digital conversion and is subject to the mathematical rules established by Nyquist which states that if the input signal is to be reproduced faithfully it must be sampled at a frequency which is greater than twice the maximum input frequency. Aliasing, which shows up as a moiré patterning particularly on moving subjects, is caused by a high input frequency causing a low 'beat' frequency. It is suppressed by offsetting the green CCD by half a pixel compared to red and blue. Another technique is to place an optical low pass filter in the light path to reduce the amount of fine detail present in the incoming light.

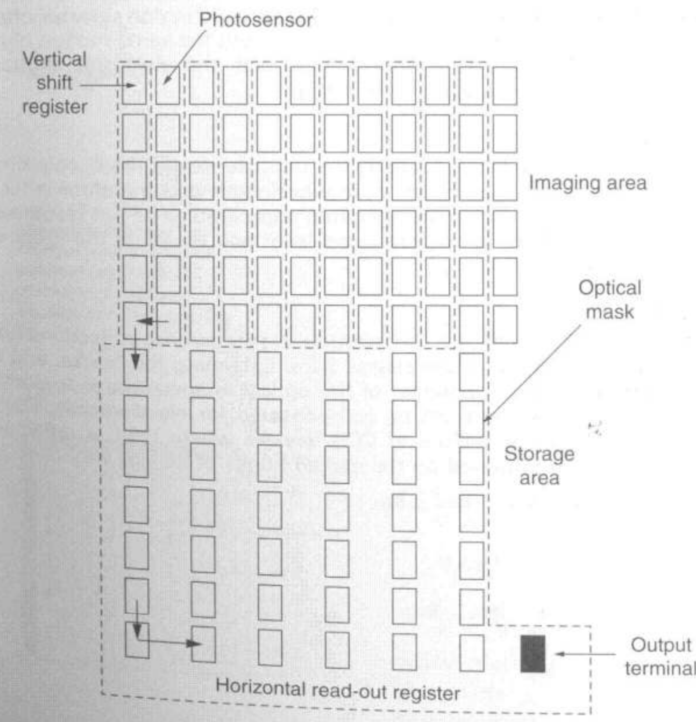
HAD

The hole accumulated diode (HAD) sensor allows up to 750 pixels per line with an improvement in the photosensing area of the total pick-up (see figure on page 23). Increasing the proportion of the surface of the photosensor that can collect light improves sensitivity without decreasing resolution. The HAD chip also helps to avoid vertical smear. Hyper HAD chips increase the sensitivity of cameras by positioning a tiny condensing lens on each individual pixel. This increases the collecting area of light.

Interline transfer



Frame interline transfer



CCD integration

Switched output integration

A PAL television picture is composed of 625 interlaced lines. In a tube camera, the odd lines are scanned first then the beam returns to the top of the frame to scan the even lines. It requires two of these fields to produce a complete picture (frame) and to synchronize with the mains frequency of 50 Hz, the picture or frame is repeated 25 times a second.

CCD frame transfer (FT) devices use the same pixels for both odd and even fields whereas interline transfer (IT) and frame interline transfer (FIT) CCDs use separate pixels with a consequent increase in resolution. There are two methods to read out the stored charge:

- **Field integration:** This reads out every pixel but the signals from adjacent lines are averaged. Although this decreases vertical resolution, motion-blur will be less.
- **Frame integration:** This reads out once every frame (two fields) and therefore will have more motion-blur as the signal is averaged over a longer time span than field integration but may have better vertical resolution on static subjects. Enhanced vertical definition systems offer a higher resolution of frame integration without the same motion blur. It is obtained by blanking off one field with the electronic shutter, reducing camera sensitivity by one stop.

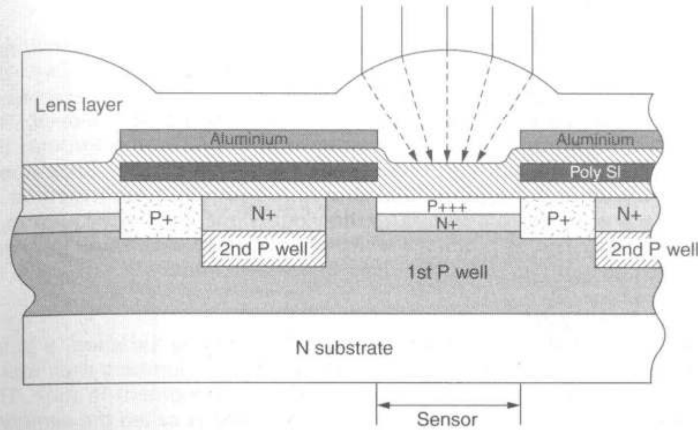
Colorimetry

The transparent polysilicon covering the photosensor of the IT chip progressively filters out the shorter blue wavelength and therefore is less sensitive to the blue end of the spectrum compared to its red response. On HAD sensors there is no polysilicon layer and therefore the spectral response is more uniform.

Flare

Each element in a zoom lens is coated to reduce surface reflections but stray light reaching the prism causes flare, lightening the blacks, and a consequent reduction in contrast of the optical image. Flare is to some extent a linear effect and can be compensated for electronically. Flare can also occur at the surface of CCD devices where light is reflected between layers or scattered by the etched edges of sensor windows.

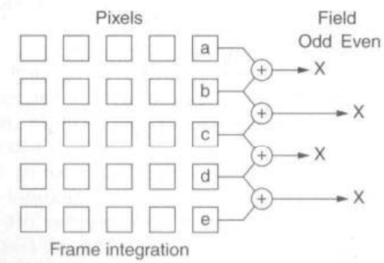
The Hyper HAD



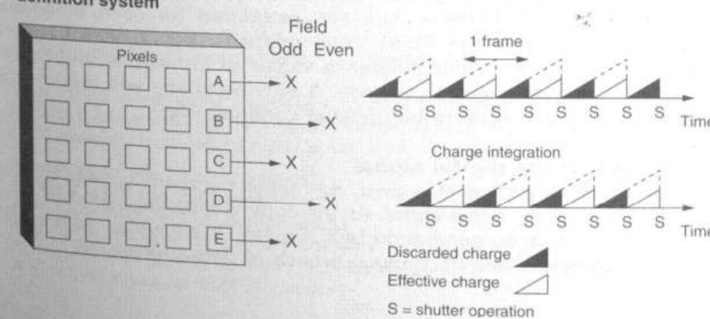
The Hyper HAD has a microlens positioned on each pixel which increases the light-capturing ability of each photosensor area, doubling the camera sensitivity.

Field integration

Field integration (adjacent lines averaged) produces less motion blur than frame integration because the charge is only integrated over one field. Vertical resolution is reduced because two lines are read as one.



Enhanced vertical definition system



The digital signal

Television broadcasting was originated and developed using an analogue signal – a continuous voltage or frequency varying in time. Over the years, engineering techniques overcame many problems associated with this method but there was a limit to what could be achieved. The analogue signal can suffer degradation during processing through the signal chain, particularly in multi-generation editing where impairment to the signal is cumulative. Digital video is an alternative method of carrying a video signal. By coding the video signal into a digital form, a stream of numbers is produced which change sufficiently often to mimic the analogue continuous signal (see figure opposite).

The digital signal

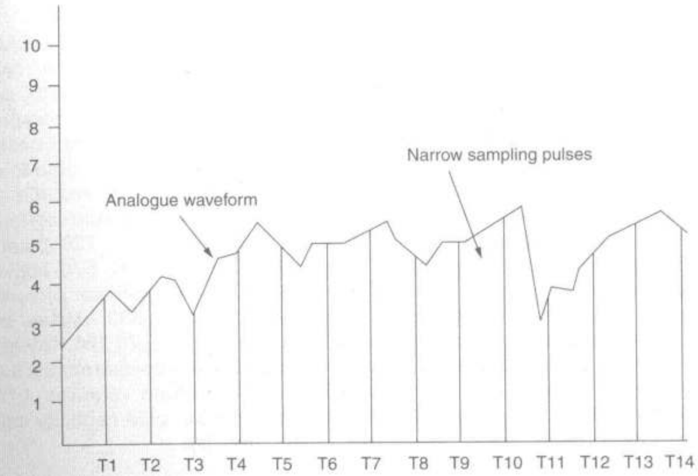
Whereas an analogue signal is an unbroken voltage variation, a pulse coded modulated (PCM) digital signal is a series of numbers each representing the analogue signal voltage at a specific moment in time. The number of times the analogue signal is measured is called the *sampling rate* or sampling frequency. The value of each measured voltage is converted to a whole number by a process called *quantizing*. These series of whole numbers are recorded or transmitted rather than the waveform itself. The advantage of using whole numbers is they are not prone to drift and the original information in whole numbers is better able to resist unwanted change. The method of quantizing to whole numbers will have an effect on the accuracy of the conversion of the analogue signal to digital. Any sampling rate which is high enough could be used for video, but it is common to make the sampling rate a whole number of the line rate allowing samples to be taken in the same place on every line.

A monochrome digital image would consist of a rectangular array of sampled points of brightness stored as a number. These points are known as picture cells or more usually abbreviated to *pixels*. The closer the pixels are together, the greater the resolution and the more continuous the image will appear. The greater the number of pixels the greater the amount of data that will need to be stored with a corresponding increase in cost. A typical 625/50 frame consists of over a third of a million pixels. A colour image will require three separate values for each pixel representing brightness, hue and saturation for each individual sampled point of the image. These three values can represent red, green and blue elements or colour difference values of luminance, red minus luminance and blue minus luminance. A moving image will require the three values of each pixel to be updated continuously.

Advantages of the digital signal

When a digital recording is copied, the same numbers appear on the copy. It is not a dub, it is a clone. As the copy is indistinguishable from the original there is no generation loss. Digital TV allows an easy interface with computers and becomes a branch of data processing.

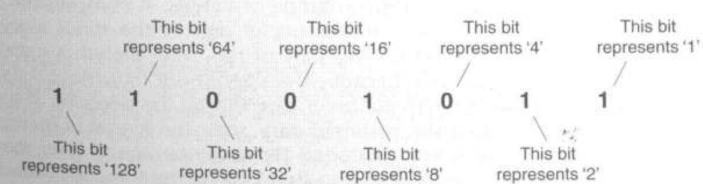
Analogue to digital



The continuously varying voltage of the TV signal (the analogue signal) is measured (or sampled) at a set number of positions per television line and converted into a stream of numbers (the digital signal) which alters in magnitude in proportion to the original signal.

Storing the signal as binary numbers (ones and zeros) has two advantages. It provides a robust signal that is resistant to noise and distortion and can be restored to its original condition whenever required. Second, it enables computer techniques to be applied to the video signal creating numerous opportunities for picture manipulation and to re-order the digital samples for standards conversion.

Binary counting



In this 8-bit word called a byte (abbreviated from 'by eight') each bit position in the word determines its decimal equivalent. This binary number's decimal equivalent (reading from left to right) is 128 + 64 + 0 + 0 + 8 + 0 + 2 + 1 = 203.

A 4-bit word has 16 combinations
An 8-bit word has 256 combinations
A 10-bit word has 1024 combinations
A kilobyte (1 Kbyte) of memory contains 1024 bytes
A megabyte (1 Mbyte) contains 1024 kilobytes
A gigabyte contains 1024 megabytes

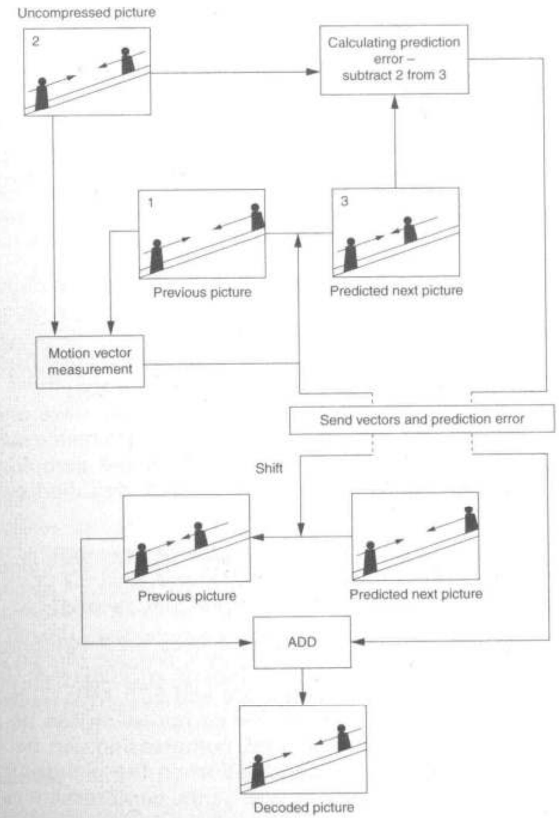
Why compression is needed

Digital television has many advantages compared to the older analogue system. Equipment is generally cheaper and error correction can compensate for signal degradation introduced along the signal path. As digital television deals only with ones and zeros, circuits do not require the sophistication needed to maintain the quality of the continuously varying voltage of the analogue signal. But working on the principle that there are never any free lunches, digital signal routing and storage is required to handle very large packets of data and this does pose certain problems. For 625 line, 4:3 PAL TV, the active picture is: 720 pixels (Y) + 360 pixels (Cr) + 360 pixels (Cb) = 1440 pixels per line. 576 active lines per picture means 1440 pixels/line $\times$ 576 = 829,440 pixels per picture. Sampling at 8 bits, the picture takes 829,440 bytes, or 830 Kbytes, of storage. One second of pictures would require 830 $\times$ 25 = 20,750 Kbytes, or 21 Mbytes. Both 625 and 525 line systems require approximately the same amount of storage for a given time. One minute requires 1.26 Gbytes and 1 hour requires 76 Gbytes. Standard video tape capacity can record only a few minutes of material at this density.

Compression

To reduce the large amounts of data digital television generates, a technique was introduced that looked at each video frame and only passed on the difference between successive frames. With this method of coding it is possible to discard a large percentage of information yet still deliver acceptable TV pictures. The original data rate can be compressed to fit the recording storage capability or to reduce the bandwidth needed for transmission. By eliminating selected data, the signal can be passed through a channel that has a lower bit rate. The ratio between the source and the channel bit rates is called the compression factor. At the receiving end of the channel an expander or decoder will attempt to restore the compressed signal to near its original range of values. A compressor is designed to recognize and pass on the useful part of the input signal known as the *entropy*. The remaining part of the input signal is called the *redundancy*. It is redundant because the filtered-out information can be predicted from what has already been received by the decoder. If the decoder cannot reconstruct the withheld data, then the signal is incomplete and the compression has degraded the original signal. This may or may not be acceptable when viewing the received image. Portions of an image may contain elements that are unchanging from frame to frame. Considerable saving in the amount of data transmitted can be achieved if, on a shot change, all of the image is transmitted and then with each successive frame only that which alters from frame to frame is transmitted. The image can then be reconstructed by the decoder by adding the changing elements of the image to the static or unvarying parts of the image. The degree of compression cannot be so severe that information is lost.

Motion compensation



A picture of a passenger travelling on an up escalator is shot with the camera travelling at the same speed as the passenger (2). The only movement in the frame is another passenger travelling on the down escalator. Motion compensation compression attempts to make movement information 'redundant' by measuring successive areas of pictures which contain movement and producing motion vectors. These are applied to the object and its predicted new position (3) reconstructed. Any errors are eliminated by comparing the reconstructed movement with the actual movement of the original image. The coder sends the motion vectors and the discrepancies along the channel to the decoder which shifts the previous picture by the vectors and adds the discrepancies to reproduce the next picture. This allows a saving in the amount of data that needs to be transmitted along a channel, even with movement.

Providing only the difference between one picture and the next means that at any instant in time, an image can only be reconstructed by reference to a previous 'complete' picture. Editing such compressed pictures can only occur on a complete frame. If there is significant movement in the frame there will be very little redundancy and therefore very little compression possible.

Compression standards

Gains

The main benefits of compressing digital material include:

- a smaller quantity of storage is required for a given quantity of source material;
- digital compression reduces the required bandwidth in terrestrial, satellite and cable transmission and allows cheaper use of data transport (e.g. SNG links), interactive services, etc.

4:2:2

A common sampling rate for 625/50 and 525/60 video is chosen to be locked to the horizontal sync pulses. For the luminance signal this is often 13.5 MHz. Only the active lines (576 lines in the 625 system) are transmitted or recorded. Each line consists of 720 pixels. The 49 field blanking lines are ignored and recreated when required.

In many digital formats the colour difference signals have one half the luminance bandwidth and are sampled at half the luminance sample rate of 13.5 MHz (i.e. 6.75 MHz). The lowest practicable sampling rate is 3.375 MHz – a quarter of the luminance rate and identified as 1. Using this code convention:

1 = 3.375 MHz sample rate (3,375,000 samples per second)
2 = 6.75 MHz sample rate (6,750,000 samples per second)
4 = 13.5 MHz sample rate (13,500,000 samples per second)

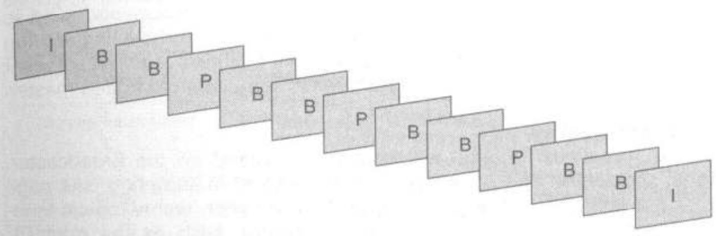
Most component production equipment uses 4:2:2 sampling which indicates that 13.5 MHz (4) is the sample rate for luminance, 6.75 MHz (2) is the sample rate for red minus luminance and 6.75 MHz (2) is the sample rate for blue minus luminance. Higher compression can be achieved (e.g. 4:1:1 or 4:2:0 sampling). In general, compression can be expected to impose some form of loss or degradation on the picture, its degree depending on the algorithm used as well as the compression ratio (ratio of the data in the compressed signal to the original version) and the contents of the picture itself. Applying greater and greater degrees of compression (i.e. eliminating more of the original) results in artifacts such as fast-moving subjects 'pixilating' or breaking up into moving blocks.

Moving Picture Experts Group (MPEG)

MPEG compiled a set of standards describing a range of bitstreams which decoders must be able to handle. MPEG 1 was an earlier specification that is not adequate for broadcast TV. MPEG 2 recommendations for data compression of moving pictures can be abbreviated to a table containing five profiles ranging from Simple (minimum complexity) to High. Each profile can operate at four resolution levels ranging from 352 × 288 pixel image up to 1920 × 1152 pixels. MPEG 2 is not a decoder technique or a method of transmitting bitstreams but a series of benchmarks specifying different degrees of compression.

Compression and video editing

MPEG 2 interframe compression achieves data reduction by grouping a number of pictures together identified as a GOP (group of pictures). When the MPEG compression process begins, an initial I (intraframe or intrapicture) is coded. This frame is complete and uncompressed and can be displayed without degradation. In the group of pictures associated with this I frame are P (predicted) frames which are based on the I frame and cannot exist without the I frame. Interleaved between the I frame and the P frames are B (Bi-directional) frames which are assembled from interpolated data from the closest I and P frames. A new I frame is usually created in response to a change of pixels in the incoming frames although this can occur without change every approximately half second. Compression is achieved because only the I frames require data to be forwarded.



Because only I frames carry complete picture information, an edit point that occurs between a P and a B frame will start with a frame that cannot reconstruct itself as its reference I frame is missing. It is desirable for efficient compression to have the longest practical group of pictures before a new I frame is included whereas flexibility in deciding which frame to cut on requires the smallest practical GOP and still achieves some degree of compression. Dynamic random access memory (DRAM) chip sets perform I, P and B frame searches to identify an I frame edit.

Concatenation

Along the signal path from acquisition, up and down links, format change, editing and then transmission a video signal can be coded and decoded several times. There are many different types of data compression. Degradation of the digital signal can occur if it is repeatedly coded and decoded whilst passing through two or three different manufacturer's processors.

Metadata

Metadata is the data that goes along with video and audio as it is networked digitally. Each clip can carry with it detail of where and when it was shot, what format it was in, how it has been processed or compressed, who has the rights to it, when and where it has been transmitted, and any other information that might be needed. This information can be downloaded into an archive database to allow indexing and searches.

The digital camera

A very basic specification for a digital camera suitable for general programme production could include:

- the ability to interchange the lens (designed for manual focusing/zoom as well as the option of servo control);
- a camera that allows manual adjustment of a number of facilities (e.g. white balance, timecode, audio level, shutter speed) as well as the option of auto control;
- a digital recording format with 4:2:2 video sampling plus audio and timecode tracks.

Essentially all three, lens, camera and recorder components, need to be of broadcast quality (see below), but in addition to their engineering specification, they must have the operational facilities required to cover a range of production techniques from initial acquisition to edited master.

Broadcast quality

What is 'broadcast quality' will ultimately depend on the broadcaster. Digital acquisition and recording allows variation in sampling (see page 28) and a range of compression ratios. Year on year, technological innovation provides new recording formats. Some, such as the mini DV format, were initially designed for the consumer market but are often used in programme making. A minimum quality benchmark is generally agreed to be 4:2:2 sampling, basically because it allows more flexibility in post-production compositing. But the variety of compression systems introduced into the programme chain also has a significant effect on the final picture quality.

It has always been notoriously difficult to achieve standardization of operational features between different makes of broadcast camera. A simple mechanical device such as the tripod adaptor plate needed to mount the camera/recorder on a pan and tilt head appears to exist in as many versions as there are camera manufacturers. From a cameraman's point of view, how the production peripherals of a new camera design (batteries, lens, etc.) dovetail with existing equipment is an important practical (and economic) consideration. Broadcast quality can also mean compatible with standard production techniques and facilities.

One-piece camera/recorders have always been available but two-piece camera/recorders allow the user a choice of which recording format to attach to the camera. In the interests of speed and convenience, many organizations need to acquire and edit all production material on the same format coupled with the need for universal technical back-up support for crews working a long way from base. There is continuous market demand for cheaper, broadcast-quality, non-linear editing, especially in news and magazine programme production. This is combined with the development of multi-skilling in acquisition and editing and the pressure to find solutions to edit video material at journalist work stations.

Basic digital acquisition

Digital cameras are either combined camera/recorder or the camera section can be interchanged to work with most formats. For standard broadcast camerawork a camera should be capable of manual exposure, focus, white balance and manual control of audio with standard XLR audio inputs. Timecode is essential for logging and editing. Choosing a format depends on programme type and where the production will be seen.

Because of the expansion of recording formats and the many hundreds of camera models available, it is not possible to provide a specific guide to the many variations of operational controls to be found. In general, whatever make of camera or individual model, most broadcast cameras have similar facilities. There is a core of camera controls that are standard on nearly every broadcast quality camera (see pages 56–109). What may change from camera to camera is the positioning of individual operational controls.

Camera	Lens/lenses + lens cleaning
Camera accessories	Tape, matte box and filters; good pan/tilt head and tripod; batteries and portable chargers; mains adaptor; repeat timecode reader.
Audio	If working in stereo, a sub-mixer and sufficient selection of microphones, radio mics, mic supports, etc. for the subject.
Lighting	At least a 'flight kit' – 2/3 lightweight lamps, filter and diffuser material, reflector board. The more complex the shoot, the more lighting equipment may be needed.
Transport	For everything you need to take to a location. Easy to underestimate how much this will be.

General production overview

During acquisition

- Log all shots.
- Transfer the material from camera to VHS to review.
- Have the digital material transferred at a post-production house to VHS with burnt in timecode for off-line editing.

Off-line editing

Check that the editing software you intend to use to produce an EDL (edit decision list; the off-line edit decisions are recorded on a floppy disk giving the tape source of the shot and its in and out timecode or duration. In order to work across a range of equipment there are some widely adopted standards such as CMX, Sony, SMPTE, and Avid) is compatible with the post-production facility where the material will be conformed.

In drama there is always the need for post-production audio. Make certain that the right quality (and sound quality continuity) has been recorded on location. Sound dubbing is needed to add effects, music and additional looped dialogue if original audio is of poor quality.

Many high-end digital cameras have scene files. These are microchips that are inserted into the camera to configure the image to provide a particular 'look'. Some hire companies have a range of these.

DV format

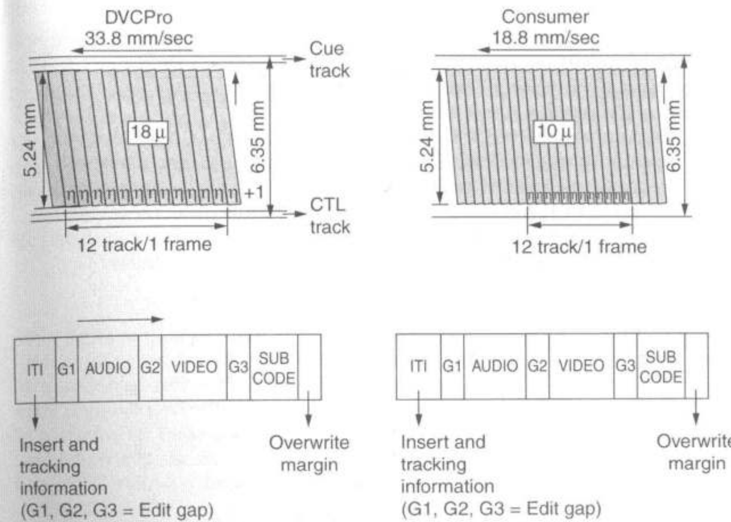
In the early 1990s, a consortium of camera manufacturers collaborated on the development of a new, small, digital tape format. The intention was to reach agreement on a single international format. This was achieved with a consumer format which had a compression standard, a mechanism and tape format, a chip set and a standard family of cassettes. Originally intended for the domestic camcorder market, the first generation of DV cameras did not meet the basic ENG requirements of operational features and ruggedness. Later models, intended for the broadcast market, were of much more robust construction, provided XLR audio inputs and operational controls followed the conventional positioning of ENG camera/recorders. They are also equipped with an internal memory system and will not lose timecode settings when the battery is changed. The picture quality is good enough for broadcasters to use the format in productions that required small, inexpensive lightweight kit.

Broadcast operational weaknesses

There are a number of inherent weaknesses if the standard consumer format cameras are used for broadcast production. Apart from the lower specification (see opposite) the cameras are much lighter and extended hand-held work invariably means unsteady camerawork as arms get tired. To overcome unsteady pictures, 'anti-wobble' devices or picture stabilizers are fitted, some of which affect picture quality. Most of the cameras have colour viewfinders and sometimes the viewfinder menu allows the colour option to be deselected to aid focusing. There is also the debatable value of an auto-focusing facility. Exposure can be set by auto-exposure or manually although some camera models have no zebra facility. The biggest weakness for broadcast camerawork applications is the sound provision. Apart from the lack of manual adjustment of sound level on some cameras, there is often only provision for a single audio input usually using a mini-jack microphone socket when the conventional broadcast audio input is via XLR sockets.

DV can be edited by transferring straight onto disk for non-linear editing. The initial transfer to another format adds to the editing time but this is often preferred by picture editors because the DV format records sound on the FM tracks combined with the pictures. There is no longitudinal sound track and therefore editors cannot hear the digital sound as they shuttle through the tape. Often there is no timecode regeneration facility on consumer DV and placing a cassette into the camera resets the timecode to zero. This could possibly result in several shots on the same tape having the same timecode. This can be avoided by either recording 'black and burst' (continuous timecode and black tape) on tapes prior to use or prior to editing, replacing the original timecode with a continuous edit code for the edit machine. Most DV cameras are designed for occasional domestic use by one careful owner and lack the rugged design necessary for hard ENG usage on location. To overcome some of these production limitations, a 'professional' version of the DV format was developed.

DVCPro and DV (consumer) tape formats



Outline specification of DV and DVCPro

	DV	DVCPro
Video coding	Component digital 13.5 MHz, 8 bit	Component digital 13.5 MHz, 8 bit
Compression	5:1 intraframe DCT-based standard	5:1 intraframe DCT-based standard
Track layout	12 tracks/frame 10 microns track pitch	12 tracks/frame 18 microns track pitch
Tape speed	18.8 mm/s	33.8 mm/s
Tape	6.35 mm Metal evaporated	6.35 mm Metal particle
Max recording time for cassette	270 minutes	123 minutes
Video data rate	24.948 Mbits/s	24.948 Mbits/s
Audio channels	48 kHz, 16 bits, 2 channel	48 kHz, 16 bits, 2 channel 1 analogue cue channel
Recorded data rate	41.85 Mbits/s	41.85 Mbits/s (also 50 Mbps)

DVCPro format

DVCPro and DVCam are upgrades of the DV format originally designed for news acquisition. The two formats have improved recording specifications and a number of broadcast operational facilities not found on consumer DV cameras.

The camera/recorders are smaller, lighter, cheaper, with less power consumption than previous ENG formats, have smaller cassettes and longer recording times. The lightweight cameras allow easier handling in ENG work and have the ability to provide colour playback. With low power consumption, a two-machine editor can provide rapid, portable editing on location and stories can be put to air more quickly.

DVCPro format

A major difference between DVCam and DV is the increase in track pitch from 10 microns to 18 microns which is wider for frame accurate editing on the 6.35 mm/quarter-inch metal particle tape. The first generation of cameras provided for 5:1 DCT compression with 25 Mbps video data rate, 4:1:1 resolution. The maximum tape length allowed 63 minutes of recording on location increased to 123 minutes on studio machines. DVCPro cameras can be obtained with 1/3-, 1/2- and 2/3-inch CCDs and with switchable 4:3/16:9 aspect ratio.

There are two uncompressed audio channels and two longitudinal audio tracks to give audio access when editing as the digital audio is of limited use in shuttle. This linear audio cue channel is also available as a third, lower quality, audio channel.

4:1:1 systems can exhibit errors on chroma edges when applying special effects (e.g. keying, digital effects) or when recording computer generated graphics but there are DVCPro format camera/recorders with 4:2:2 sampling, 3.3:1 DCT compression, a 50 Mbps video data rate using a larger 123 minute (max) cassette recording at twice the tape speed of the 4:1:1 cameras and with interchangeable lenses.

The DV format has auto-tracking mechanisms that eliminate the need for a control track whereas the DVCPro with a control track provides for a faster lock-up and a shorter pre-roll when editing. DVCPro incorporates both VITC and LTC (see page 92) in the helical scan. This enables the tape size to be kept small and both timecodes to be read at any tape speed. The higher DVCPro specification cameras have 10-bit A/D conversion, 16-bit processing, scene file memory with memory card.

One-frame only (compressed entirely within a single frame) means that the video stream is easily editable, robust and impervious to error propagation. The compression scheme provides a digital structure designed for the special requirements of VTR but it is also suitable for disk-based systems. This allows the interchange of audio and video files between equipment from different manufacturers.

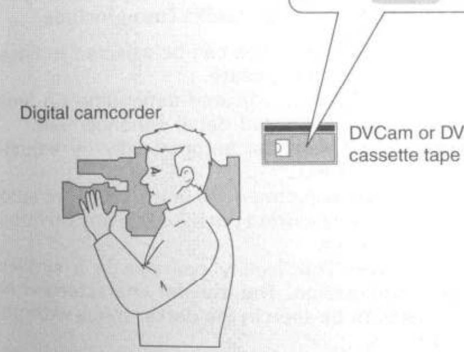
DVCam

DV-based systems use compression in the most cost-effective way to increase tape usage. DVCam has a 4:1:1 compression, 25 Mbps data rate recorded on metal evaporated tape and 4 channels of uncompressed audio to achieve a 40-minute recording on DVCam camera mini-cassette or 184 minutes on a standard cassette. A single DV compression system is used throughout the production process. Non-linear editing is facilitated by high speed transfer at four times the normal speed to a disk recorder.

ClipLink

Basic information in ClipLink data

Scene no.	Index picture	Timecode (IN)	Timecode (OUT)
1		00:01:01	00:05:22
2		00:05:23	00:18:20
3		00:18:21	00:24:13



The zoom lens

The lens as a creative tool

A zoom lens fitted to broadcast camcorders is a complex, sophisticated piece of optical design. Its performance may be described in brochures in impenetrable techno-speak that many, at first glance, may feel has little or nothing to do with the 'real' business of making programmes. To take this view is a mistake, as above all else, the lens characteristics are the most important visual influence on the appearance and impact of an image.

The following pages describe focal length, lens angle, zoom ratio, aperture, depth of field. Altering any one of these zoom settings will have a significant influence on the perspective, the depiction of space and composition when setting up a shot. It is a fallacy to believe that the camera will truthfully record whatever is in shot whenever you put your eye to the viewfinder and press to record. If you are unaware of how the choice of focal length, etc., will affect the chosen image then this important creative decision will be left to chance and accident.

Prime lens or zoom?

Video cameras before the introduction of colour television were usually fitted with four prime lenses (a lens with a fixed focal length), individually mounted on a turret on the front of the camera. A specific focal length lens was chosen for a shot by rotating the turret until the appropriate lens was in front of the pick-up tube. It is still common film practice to select a prime lens to match the needs of the shot. Colour video cameras for technical reasons were almost universally fitted with a zoom lens. A zoom lens allows faster working methods and the option of zooming on shot to capture close-ups without moving the camera. Because of the ease and speed of changing the lens angle of a zoom it is easy to forget exactly what focal length is being used and, as we will discuss later, possibly the space or perspective of the shot will be compromised.

Image size

Because of the different CCD sizes (2/3 inch, 1/2 inch, etc.), the variation in flange-back distance (see page 49), the mechanical connection between lens and camera, and the variation in cable connections with the camera, it is often impossible to interchange lenses between different makes or models of cameras. The image formed by the lens on the face of the CCDs is called the image size of the lens. This must match the size of the camera sensor. Lenses designed for different sized formats (pick-up sensor dimension) may not be interchangeable. The image size produced by the lens may be much smaller than the pick-up sensor (see Image circle and image size opposite) and probably the back focus (flange back) will not have sufficient adjustment. A common lens on a broadcast video camera is a 14 × 8.5 *f* 1.7 zoom with a minimum object distance of 0.8 m or below. The following pages will identify the implication of this specification and its affects on the practical craft of camerawork.

Image circle and image size

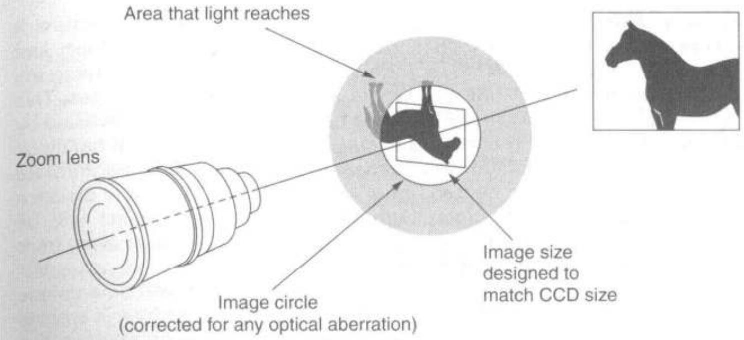
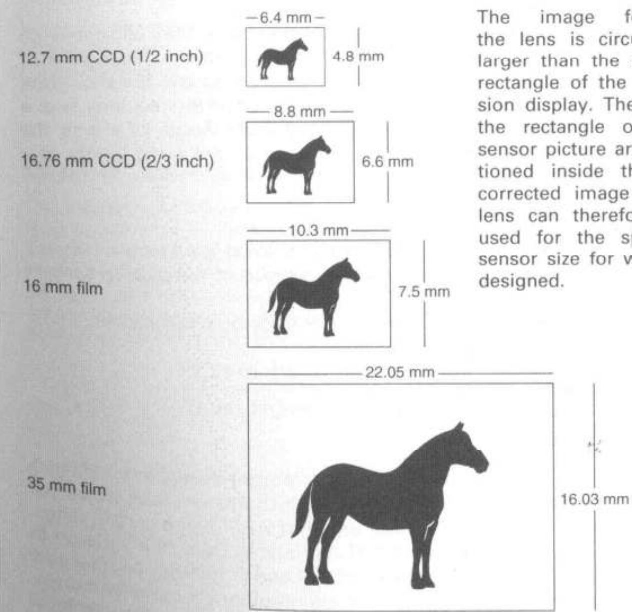


Image sizes for 4:3 aspect ratio TV and film (not to scale)



The image formed by the lens is circular and is larger than the aspect ratio rectangle of the final television display. The corners of the rectangle of the CCD sensor picture area are positioned inside the optically corrected image circle. The lens can therefore only be used for the specific CCD sensor size for which it was designed.

Angle of view

When a camera converts a three-dimensional scene into a TV picture, it leaves an imprint of lens height, camera tilt, distance from subject and lens angle. We can detect these decisions in any image by examining the position of the horizon line and where it cuts similar sized figures. This will reveal camera height and tilt. Lens height and tilt will be revealed by any parallel converging lines in the image such as the edges of buildings or roads. The size relationship between foreground and background objects, particularly the human figure, will give clues to camera distance from objects and lens angle. Camera distance from subject will be revealed by the change in object size when moving towards or away from the lens (see Depiction of space, page 118).

For any specific lens angle and camera position there will be a unique set of the above parameters. The 'perspective' of the picture is created by the camera distance except, of course, where false perspective has been deliberately created.

Focal length

When parallel rays of light pass through a convex lens, they will converge to one point on the optical axis. This point is called the focal point of the lens. The focal length of the lens is indicated by the distance from the centre of the lens or the principal point of a compound lens (e.g. a zoom lens) to the focal point. The longer the focal length of a lens, the smaller its angle of view will be; and the shorter the focal length of a lens, the wider its angle of view.

Angle of view

The approximate horizontal angle of view of a fixed focal length lens can be calculated by using its focal length and the size of the pick-up sensors of the camera.

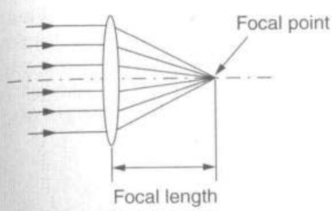
For a camera fitted with 2/3-inch CCDs the formula would be:

$$\text{Angle of view i.e.} = 2\tan^{-1}\frac{8.8\text{ mm (width of CCD)}}{2\times\text{focal length (mm)}}$$

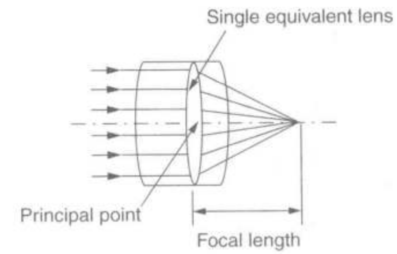
Zoom

Although there are prime lenses (fixed focal length) available for 2/3-inch cameras, the majority of cameras are fitted with a zoom lens which can alter its focal length and therefore the angle of view over a certain range. This is achieved by moving one part of the lens system (the variator) to change the size of the image and by automatically gearing another part of the lens system (the compensator) to simultaneously move and maintain focus. This alters the image size and therefore the effective focal length of the lens. To zoom into a subject, the lens must first be fully zoomed in on the subject and focused. Then zoom out to the wider angle. The zoom will now stay in focus for the whole range of its travel. If possible, always pre-focus before zooming in.

Focal length of a lens



Focal length of a single lens



Focal length of a compound lens

Focal length and angle of view for a 2/3" 14:1 zoom (4:3 aspect ratio)

Focal length in mm	8.5	10	20	50	75	100	150	200	300	400
Horizontal angle of view in degrees	54.7	46.5	24.8	10	6.7	5.04	3.3	2.5	1.7	1.2

Minimum object distance

The distance from the front of the lens to the nearest subject that can be kept in focus is called the minimum object distance (MOD). A 14 × 8.5 zoom would have a MOD of between 0.8 m and 0.65 m, whereas a larger zoom ratio lens (33:1) may have an MOD of over 2 m. Many zooms are fitted with a macro mechanism which allows objects closer than the lens MOD to be held in focus. The macro shifts several lens groups inside the lens to allow close focus, but this prevents the lens being used as a constant focus zoom.

Depth of field

The depth of field, how much of scene in shot is in acceptable focus, is a crucial element in shot composition and controlling how the viewer responds to the image. Cinemagraphic fashion has alternated between deep focus shots (Greg Toland's work on *Citizen Kane* (1941)) to the use of long focal lenses with a very limited depth of field only allowing the principal subject in the frame to be sharp. The choice of focal length and *f* number control depth of field.

f number

The *f* number of a lens is a method of indicating how much light can pass through the lens. It is inversely proportional to the focal length of the lens and directly proportional to the diameter of the effective aperture of the lens. For a given focal length, the larger the aperture of the lens the smaller its *f* number and the brighter the image it produces. *f* numbers are arranged in a scale where each increment is multiplied by $\sqrt{2}$ (1.414). Each time the *f* number is increased by one stop (e.g. *f*2.8 to *f*4), the exposure is decreased by half:

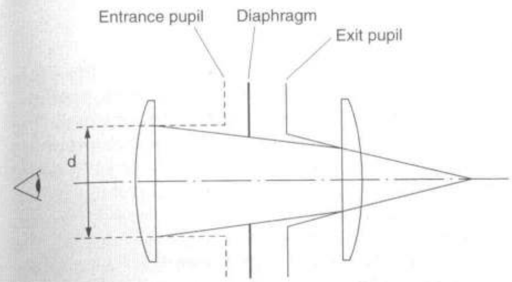
*f*1.4 *f*2 *f*2.8 *f*4 *f*5.6 *f*8 *f*11 *f*16 *f*22

The effective aperture of a zoom is not the actual diameter of the diaphragm, but the diameter of the portion of the diaphragm seen from in front of the lens. This is called the entrance pupil of the lens (see diagram opposite). When the lens is zoomed (i.e. the focal length is altered) the diameter of the lens which is proportional to focal length alters and also its entrance pupil. The effective aperture is small at the wide angle end of the zoom and larger at the narrowest angle. This may cause *f* number drop or ramping at the telephoto (longest focal length) end when the entrance pupil diameter equals the diameter of the focusing lens group and cannot become any larger. To eliminate *f* drop (ramping) completely the entrance pupil at the longest focal length of the zoom must be at least equal to the longest focal length divided by the largest *f* number. This increases the size, weight and the cost of the lens and therefore a certain amount of *f* drop is tolerated. The effect only becomes significant when working at low light levels on the narrow end of the zoom.

Depth of field

Changing the *f* number alters the depth of field – the portion of the field of view which appears sharply in focus. This zone extends in front and behind the subject on which the lens is focused and will increase as the *f* number increases. The greater the distance of the subject from the camera, the greater the depth of field. The depth of field is greater behind the subject than in front and is dependent on the focal length of the lens. *f* number and therefore depth of field can be adjusted by altering light level or by the use of neutral density filters.

Ramping (*f*-drop)



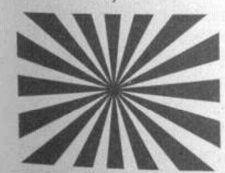
The entrance pupil of a zoom lens changes in diameter as you zoom in. When the entrance pupil diameter equals the diameter of the lens focusing group it cannot become any larger and *f*-drop or ramping occurs.

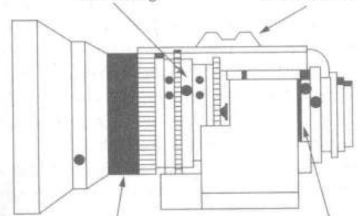
Flange back

Flange back (commonly called back focus) is the distance from the flange surface of the lens mount to the image plane of the pick-up sensor. Each camera type has a specific flange-back distance (e.g. 48 mm in air) and any lens fitted to that camera must be designed with the equivalent flange back. There is usually a flange-back adjustment mechanism of the lens with which the flange back can be adjusted by about ±0.5 mm. It is important when changing lenses on a camera to check the flange-back position is correctly adjusted and to white balance the new lens.

Adjusting the back focus

Lens chart or any fine detail/high contrast subject





1 Open lens to its widest aperture and adjust exposure as necessary by adding ND filters or adjusting shutter speed.
2 Select the widest lens angle.
3 Adjust for optimum focus with the flange-back control on the lens.
4 Zoom the lens in to its narrowest angle on a distant object from the camera and adjust the zoom focus for optimum sharpest.
5 Zoom out and repeat steps 2–4 of the above procedure until maximum sharpness is achieved at both ends of the zoom range.
6 Lock off the flange-back control taking care that its sharpest focus position has not been altered.

Zooming

Variable lens angle

A zoom lens has a continuously variable lens angle and is therefore useful for adjusting the image size without moving the camera position. When operating with a monocular viewfinder on a portable camera, the zoom lens can be controlled manually, or from a rocker switch mounted on the lens, or by a thumb control remoted to the pan bar or on a pistol grip. A good servo zoom should allow a smooth imperceptible take-up of the movement of the zoom which can then be accelerated by the thumb control to match the requirements of the shot. In general, the zoom is used in three ways – to compose the shot, to readjust the composition on shot, to change the shot size in vision.

Readjustment on shot

The zoom lens angle is often used to trim or adjust the shot to improve the composition when the content of the shot changes. Someone joining a person 'in shot' is provided with space in the frame by zooming out. The reverse may happen when they leave shot – the camera zooms in to re-compose the original shot. Trimming the shot 'in vision' may be unavoidable in the coverage of spontaneous or unknown content but it quickly becomes an irritant if repeatedly used. Fidgeting with the framing by altering the zoom angle should be avoided during a take.

Zoom ratio

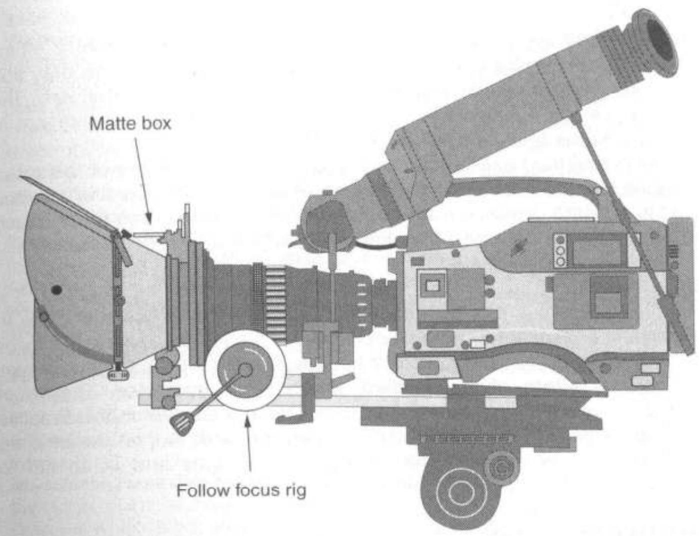
A zoom lens can vary its focal length. The ratio of the longest focal length it can achieve (the telephoto end) with the shortest focal length obtainable (its wide-angle end) is its zoom ratio. A broadcast zoom lens will state zoom ratio and the wide angle focal length in one figure. A popular zoom ratio is a 14 × 8.5. This describes a zoom with a 14:1 ratio starting at 8.5 mm focal length (angle of view = 54° 44') with the longest focal length of 14 x 8.5 mm = 119 mm (angle of view = 4° 14').

Lenses with ratios in excess of 50:1 can be obtained but the exact choice of ratio and the focal length at the wide end of the zoom will depend very much on what you want to do with the lens. Large zoom ratios are heavy, often require a great deal of power to operate the servo controls and have a reduced *f* number. A 14:1 8.5 mm zoom lens, for example, will give sufficient length at the narrow end to get good close-ups in sport or at the back of a conference hall, but still provide a reasonable wide angle for close interviewing work in crowds.

Extender

A zoom lens can be fitted with an internal extender lens system which allows the zoom to be used on a different set of focal lengths. A 2× extender on the 14 × 8.5 zoom mentioned above would transform the range from 8.5–119 mm to 17–238 mm but it will lose more than two stops of sensitivity.

Follow focus rig



A follow focus rig is attached to the focus ring on the lens to provide controlled manual movement of focus. It usually consists of support bars which are fastened to the base of the camera and a hand-wheel with marker scale. The hand-wheel on the lens can be replaced by a remote control Bowden cable.

The focus rig may have interchangeable pitch gears (0.5 mm, 0.6 mm and 0.8 mm) to match the lens model. Also the support bars must be designed or be adjustable to the particular combination of lens and camera in use to correctly position the rig to the lens focus ring.

Matte box

A matte box is an adjustable bellows supported on bars attached to the camera and is used in front of the lens as a flexible lens hood to eliminate flares and unwanted light and to hold and position front of lens filters. There is usually one large pivoting ray shield (French flag) and two or more filter holders, one of which is rotatable so that polarizing filters can be positioned.

There are 3 × 3 (3-inch or 75 mm square) or 4 × 4 (4-inch or 100 mm square) filters available for camcorder lenses but the choice will be governed by the focal length range of the lens and whether the filter holder comes into shot on the widest angle. Some lenses have a moving front element when focused. Check for clearance between filter and lens at all points of focus when attaching matte box.

Focus

Focusing is the act of adjusting the lens elements to achieve a sharp image at the focal plane. Objects either side of this focus zone may still look reasonably sharp depending on their distance from the lens, the lens aperture and lens angle. The area covering the objects that are in acceptable focus is called the depth of field.

The depth of field can be considerable if the widest angle of the zoom is selected and, whilst working with a small aperture, a subject is selected for focus at some distance from the lens. When zooming into this subject, the depth of field or zone of acceptable sharpness will decrease.

Follow focus

Television is often a 'talking head' medium and the eyes need to be in sharp focus. Sharpest focus can be checked 'off-shot' by rocking the focus zone behind and then in front of the eyes. As camera or subject moves there will be a loss of focus which needs to be corrected. The art of focusing is to know which way to focus and not to overshoot. Practise following focus as someone walks towards the lens. Adjust the peaking control on the viewfinder which emphasizes edges and is an aid to focusing and does not affect the recorded image.

Zoom lens and focus

A zoom lens is designed to keep the same focal plane throughout the whole of its range (provided the back focus has been correctly adjusted). Always pre-focus whenever possible on the tightest shot of the subject. This is the best way of checking focus because of the small depth of field and it also prepares for a zoom-in if required.

Pulling focus

Within a composition, visual attention is directed to the subject in sharpest focus. Attention can be transferred to another part of the frame by throwing focus onto that subject. Match the speed of the focus pull to the motivating action.

If the focus is on a foreground person facing camera with a defocused background figure and the foreground subject turns away from camera, focus can be instantly thrown back to the background. A slower focus pull would be more appropriate in music coverage, for example, moving off the hands of a foreground musician to a background instrumentalist. Avoid long focus pulls that provide nothing but an extended defocused picture before another subject comes into sharp focus unless this is motivated by the action (e.g. the subjective visual experience of someone recovering consciousness).

Differential focus

Differential focus is deliberately using a narrow depth of field to emphasize the principal subject in the frame in sharp focus which is contrasted with a heavily out of focus background.

Focus problems

- **Back focus:** If, after focusing on a subject in close-up, you zoom out and discover the picture loses definition, it is likely that the back focus of the lens has not been properly set up or has been knocked out of adjustment. See page 52 on adjusting back focus.
- **Lens centring:** If you need to pan or tilt the camera when zooming to a subject in the centre of the frame with the camera horizontal, it is likely that the lens is not optically centred to the CCDs. The optical axis of the lens must line up with the centre of the CCDs to ensure that the centre of the frame is identical when zooming from the widest to the narrowest angle without camera pan/tilt compensation.
- **Resolution:** A television camera converts an image into an electrical signal that will eventually be transmitted. The resolving power required from a TV zoom lens will therefore be related to the maximum frequency of the bandwidth of the signal transmitted plus the specification of the imaging device and line structure. The finesse of detail transmitted will depend on the particular TV standard in use (e.g. 625 PAL; 525 NTSC).
- **Spatial frequency:** Spatial frequency counts the number of black-white pairs of lines contained in 1 mm of the optical image and is a method of quantifying fine detail in a TV picture. Lack of resolution in a recorded image may be due to the limitation of the lens design, CCD design or the choice of recording format.
- **Modulating transfer function:** Modulating transfer function (MTF) measures the range of spatial frequencies transmitted through the lens by focusing on a chart on which black-white lines become progressively more closely spaced until the contrast between black and white can no longer be detected. The modular transfer function is 100 per cent when the transition between white and black is exactly reproduced and zero when the image is uniformly grey and no contrast can be detected. The MTF curve plots reproducibility of contrast against spatial frequency. Different television systems (625, 16:9, 1105 progressive scan, etc.) require a lens design which matches the maximum resolution achievable with the bandwidth of the chosen system.
- **Fluorite and infinity focusing:** Fluorite is used in the manufacture of some zoom lenses to correct chromatic aberrations at the telephoto end. As the refractive index of fluorite changes with temperature more than the refractive index of glass, there is provision when focusing on infinity at low temperatures (e.g. below 0°C) to allow the focus point to go beyond the infinity marking on the lens.

Essential camera controls

There are a number of mechanical and electronic controls that are found on most broadcast camcorders. The position on the camera of some of these controls will vary between make and model but their function will be similar. The essential operational controls have a significant effect on the recorded image and their function must be understood if the operator is to fully exploit the camcorder's potential. Each switch and function is discussed as a separate topic in the following pages but their effects may interact with other control settings (e.g. white balance and colour temperature filters). The newcomer to digital camerawork should experiment with a range of settings and observe the effect on the recorded image. Camerawork is a craft not a science and a video camera is simply a means to a production end.

Exposure, for example, can be described as a procedure that satisfies certain technical requirements. In those terms it appears to be a mechanical procedure that is objective and unaffected by the person carrying out the operation. But quite often exposure is customized to a specific shot and the engineering quest to produce a perfect electronic reproduction of a subject may be ignored to satisfy more important subjective criteria. Subjective production choices influence whether a face is in semi-silhouette or is fully lit and exposed to see every detail in the shadows.

It is this 'subjective' element that often confuses someone new to camerawork in their search for the 'right way' to record an image. A useful first aim is to achieve fluency in producing television pictures that are sharp, steady, with a colour balance that appears normal to the eye and with a contrast range that falls within the limitation of a television display. The pictures should be free from noise and with a continuity in skin tones between shots of the same face. Similar basic aims are required in recording audio. When this is achieved, the means of customizing an image or audio to serve a specific production purpose can be learnt. Quite often the standard basic picture can be produced with the aid of the auto features on the camera. To progress beyond this point an understanding of how to manipulate the operational controls needs to be gained.

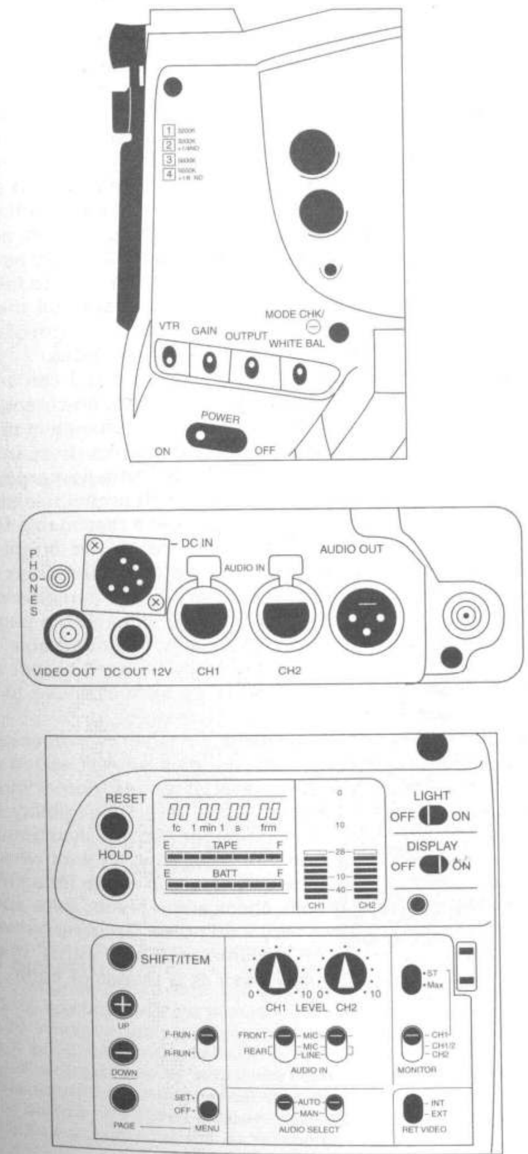
Operational controls

There are a few controls that need adjustment or at least checking on their existing setting before every shot. These include:

- tape remaining and state of battery charge;
- focus, exposure, colour temperature correction filter position, white balance setting;
- gain, shutter speed and timecode;
- adjustment of audio recording level.

The camera set-up controls such as gamma, onset of zebra setting, auto exposure settings, etc., are unlikely to be regularly adjusted unless there is a production need. They can be left at their factory setting until more experience is gained in video recording.

Typical camera control layout



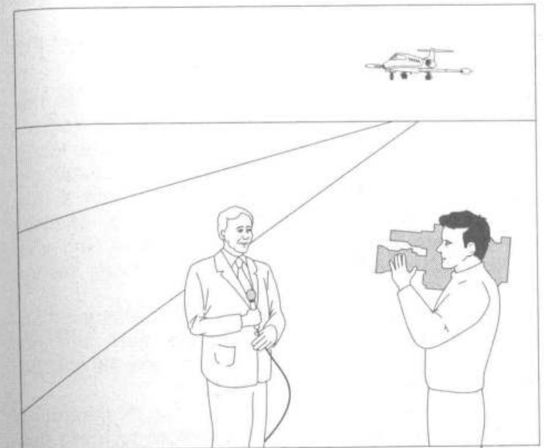
Auto and manual controls

If you have ever used a spell checker on a word processor and found the auto device consistently queries correct words such as your address then you will understand why it is important to intelligently use and monitor the auto features available on a camcorder. A spell checker can be taught new words but the auto features on a camera remain as originally programmed although digital processing now allows much more flexibility in customizing auto facilities. An auto interpretation of what is the main subject in the frame may frequently be at odds with your own requirements. This is why a camcorder used for broadcast production purposes should have manual override on all auto facilities as there are going to be many occasions when the cameraman needs to take control and customize the image the way he/she wants it and not the way the auto feature is programmed to deliver. Auto control is a form of computer control and is stubbornly unintelligent in many situations.

Auto-exposure (see pages 82–3) has advantages and can sometimes accommodate rapid changes in light level faster than any manual correction. But the downside to this is the obvious visual change in the picture. For example, an interviewee may be wearing a white dress in sunlight. Using manual exposure it may be possible to find a compromise aperture setting that provides detail in the dress with acceptable skin tones. If cloud obscures the sun, the light level falls and a reasonable face exposure may need nearly a stop open compared to the bright sunlight condition. If this is done, as soon as the sun appears the dress will burn out and the lens needs to be stopped down. Some cameras provide a 'soft' transition between two auto-exposure conditions (see page 40), so that the sudden, auto-exposure adjustment is not so noticeable. Opening up and stopping down can be done manually to avoid abrupt exposure changes but the cameraman will need to be very attentive to follow a number of rapid light level changes.

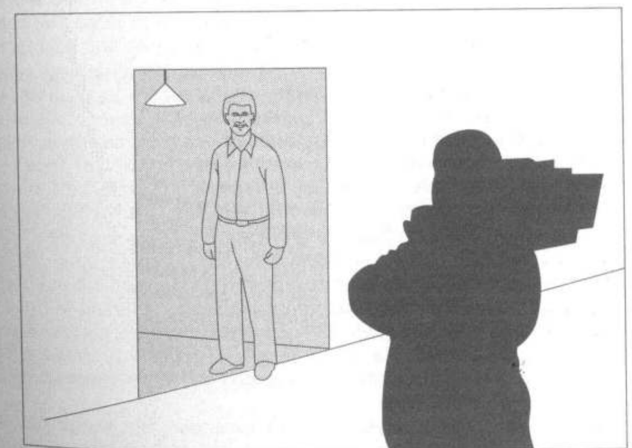
Audio auto-gain can be convenient in one-man operations but produces too rapid an attenuation of the main subject sound if a loud background sound occurs. The voice level of a street corner interviewee using audio auto-gain can be pushed down to unintelligibility if a lorry passes close to the live side of the microphone. Obviously manual control is the better option in this situation. But if covering an item where a loud explosion is going to occur (e.g. a twenty-one-gun salute for a VIP), where there is no opportunity to manually check audio levels, auto audio level should accommodate the sudden very loud noise. Deciding between auto and manual control depends on circumstance and either operational technique should not be continually used as a matter of habit.

Manual control



The voice level of the reporter is manually set. The approaching aircraft will eventually force the sound level into the clip level (see page 202) but the reporter's voice level will remain consistent throughout the shot. Television is often a compromise and by staging the item at the end of the runway the appropriate shot is obtained at the expense of far from acceptable sound.

Good auto control



To follow someone from an exterior which has been correctly white balanced with a daylight colour correction filter into a tungsten-lit interior would produce a big change in the appearance of the picture – it would become very yellow. One technique is to work on auto-exposure and switch between two white balance positions A and B which have been set on the same filter in exterior and interior. Many digital cameras have an 'auto white balance correction' and this can achieve a better adjustment when moving between light of different colour temperature. The colour balance is instantly adjusted moving into tungsten light although the adjustment to exposure may still be noticeable.

Lens controls

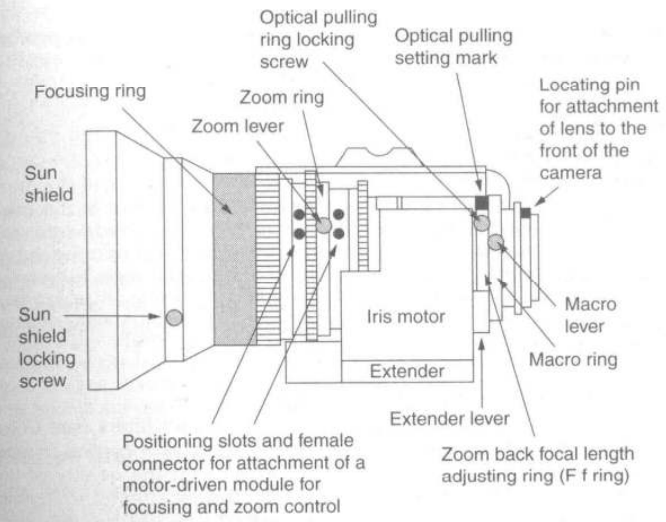
The three main operational controls on the lens are focus, zoom and the lens aperture (*f* number).

- **Focus:** Sharp focus of the image is achieved by looking at the viewfinder image and either manually adjusting the focusing ring on the lens or by connecting a cable to the lens and controlling the focus by servo control mounted on a pan bar. Usually there is a switch on the zoom rocker module marked M (for manual control) and S (for servo control). On some DV format cameras there is the option of auto-focusing. As with other auto facilities, its value is limited and will depend on the shot and if it is sufficiently well designed and set up so that it does not continually hunt to check focus.

  As we have discussed on page 52, the zoom must be prefocused on its narrowest angle before recording a zoom into a subject, and the back focus of the lens must be correctly aligned (see page 49) for the sharpest focus to be maintained throughout the zoom.

  If the required object in frame is closer to the lens than its minimum object distance (MOD, see page 47), it may be possible to bring the subject into sharp focus by adjusting the macro ring on the back of the lens. The macro device alters several lens groups inside the lens and prevents the zoom operating as a constant focus lens. The macro after use should always be returned to its détente position and locked.
- **Zoom:** Altering the variable lens angle on the zoom (zooming) can be achieved either by means of the rocker switch servo (or a pistol grip if fitted beneath the lens), or manually by using the zoom lever on the lens. Switching between the two methods of use is by a switch marked S (servo) and M (manual). In a similar way to control of focus, the zoom servo can also be controlled by a hand control attached to a pan bar. Pan bar servo control of zoom and focus is used when a larger viewfinder (possibly 5-inch display) replaces the monocular viewfinder.
- **Aperture:** Opening up or closing down the lens aperture changes light level reaching the CCDs and therefore is the prime method of controlling exposure. Control of the aperture is via a switch marked M (manual control), A (auto-exposure, which is electronically determined) or R (remote – when the camera's image quality is adjusted remotely from the camera to match the pictures produced by other cameras at the event).
- **Extender:** If the lens is fitted with an extender, the range of focal lengths from widest to narrowest lens angles can be altered dependent on the extender factor.

Typical zoom lens controls



- **Record button/lens electrics:** The cable connecting the lens to camera varies between makes and models of equipment. It is important to match the correct lens cable to the camera it is working with so that the correct drive voltages are connected to avoid lens motors being damaged. Conversion cables are available if lens and camera cable pins do not match.
- **Lens hood:** A ray shield is essential for limiting the effect of degradation from flares. It is designed for the widest lens angle of the zoom but can be augmented on a narrower lens angle by the judicious use of gaffer tape if flare on this angle is a problem. Matte box and effects filters are discussed on page 62.
- **UV filter – skylight filter:** This absorbs short wavelength ultraviolet (UV) rays that the eye cannot see. On a clear day these rays produce a bluish green cast to foliage. A zoom lens has so many lens components that almost all ultraviolet light is absorbed inside the lens. A UV filter is still advisable as a protection filter screwed on to the front of the lens to prevent damage or dirt reaching the front element.

Effects filters

Digital video has an enormous potential for manipulating the appearance of the image in post-production, but there are also the opportunities, when appropriate, to refashion the recorded image at the time of acquisition (see Scene files, page 100). Alongside the need for faithful reproduction, photographers have often attempted to customize the image to suit a particular emotional or aesthetic effect. In their hands the camera was not a 'scientific' instrument faithfully observing reality, but the means of creating a subjective impression. One simple method is in the use of filters usually placed in a filter holder/matte box positioned in the front of the lens. These are used for various reasons such as to control light, contrast or part of the subject brightness, to soften the image or to colour the image. Most camcorders also have one or two filter wheels fitted between lens and prism block carrying colour correction filters and/or neutral density filters.

Altering the appearance of the image

Filters fall into three main groups – colour correction filters (see Colour temperature, page 64), neutral density filters (used as a control in exposure) and effects and polarizing filters. They all alter the quality of light reaching the CCDs, but whereas the first two groups attempt to invisibly make the correction, effects filters are intended to be visually obvious in their impact on the appearance of the image. They are employed to change the standard electronic depiction of a subject. Filters can be chosen to bring about a number of visual changes including reduction in picture sharpness, a reduction in picture contrast, lightening or 'lifting' blacks, to induce highlight effects such as halos or star bursts and to modify the rendition of skin tones. Many of these effects are not reversible in post-production although improvement in picture matching can be attempted.

Factors that affect the filter influence

Many of the effects filters such as black and white dot, frosts, nets, fog, soft and low contrast achieve their results by introducing a varying degree of flare. The potential influence on the picture is identified by grading the effects filter on a scale of 1 to 5 where 1 has the smallest effect and 5 has the largest. Some filters are also available in smaller, more subtle increments and are graded as 1/8th, 1/4 or 1/2. Choosing which grade and which filter to use depends on the shot, lens angle, aperture and the effects of under- or over-exposure. In general, effects filters work more effectively on longer lens and wider apertures (e.g. *f*2 and *f*2.8). To ensure continuity of image over a long sequence of shots it may be necessary to vary the grade of filter depending on lens angle, camera distance and aperture. It is prudent to carry out a series of tests varying the above settings before production commences. Filters mounted on the front of the lens are affected by stray light and flares which can add to the degradation.

Filters that affect the blacks in an image

A strong black makes a picture appear to have more definition and contrast. Diffusion filters reduce the density of blacks by dispersing light into the blacks of an image. This effectively reduces the overall contrast and creates an apparent reduction in sharpness. *White nets* provide a substantial reduction in the black density and whites or any over-exposed areas of the image tend to bloom. If stockings are used stretched across the lens hood, the higher their denier number (mesh size) the stronger the diffusion. A *fog filter* reduces black density, contrast and saturation. The lighter parts of the scene will appear to have a greater fog effect than the shadows creating halos around lights. A double *fog filter* does not double the fog effect and possibly creates less of a fog than the standard fog filter, but does create a glow around highlights. Because of lightening of the blacks, the picture may appear to be over-exposed and the exposure should be adjusted to maximize the intended effect. *Low contrast* filters reduce contrast by lightening blacks and thereby reducing the overall contrast. Strong blacks appear to give the image more definition and low contrast filters may appear soft. They are sometimes employed to modify the effects of strong sunlight. *Soft contrast* filters reduce contrast by pulling down the highlights. Because blacks are less affected, soft contrast filters appear sharper than low contrast filters and do not create halation around lights. As highlights are reduced the picture may appear under-exposed.

Effect on highlights

Some filters cause points of light, highlights or flare to have a diffused glow around the light source. The *black dot filter* limits this diffusion to areas around the highlights and avoids spreading into the blacks. *Super frosts, black frosts, promist, black promists* and *double mists* diffusion work best on strong specular light or white objects against a dark background. The weak grades leave the blacks unaffected providing an apparent sharp image whilst the strong grades cause a haze over the whole image which leaks into the black areas of the picture. *Black, white* and *coloured nets* have a fine mesh pattern causing a softening of the image and a reduction in the purity and intensity of the image's colour. This 'desaturated' look is thought by some to give video images more of a film appearance.

- ***Neutral density filters:*** These reduce the amount of light reaching the lens and can be used to produce a specific *f* number and therefore depth of field.
- ***Graduated filters:*** These can help to control bright skies by having a graduated neutral density from the top to clear filter at the bottom. The graduation can be obtained as a hard or a soft transition. There are also filters with a graduated tint to colour skies or the top part of the frame. They are positioned in the matte box for optimum effect but once adjusted the camera can rarely be tilted or panned on shot without disclosing the filter position.
- ***Polarizing filters:*** These reduce glare reflections, darken blue skies and increase colour saturation. They are useful in eliminating reflections in glass such as shop windows, cars and shooting into water. The filter must be rotated until the maximum reduction of unwanted reflection is achieved. This changes the colour balance (e.g. can affect the 'green' of grass) so a white balance should be carried out when correct filter position has been determined. Moving the camera (panning or titling) once the polarizing filter is aligned may reduce or eliminate the polarizing effect.
- ***Star and sunburst filters:*** These produce flare lines or 'stars' from highlights. Star filters are cross hatched to produce 2, 4, 6, 8 or 10 points whilst sunburst produces any number of points. They are more effective when placed between lens and prism block and can produce an unwanted degradation of definition when in front of the lens.

Colour temperature

Two sounds cannot be combined to produce a third pure sound but as we have discussed in Light into electricity (page 12), by combing two or more colours a third colour can be created in which there is no trace of its constituents (red + green = yellow). The eye acts differently to the ear. The eye/brain relationship is in many ways far more sophisticated than a video camera and can be misleading when attempting to analyse the 'colour' of the light illuminating a potential shot.

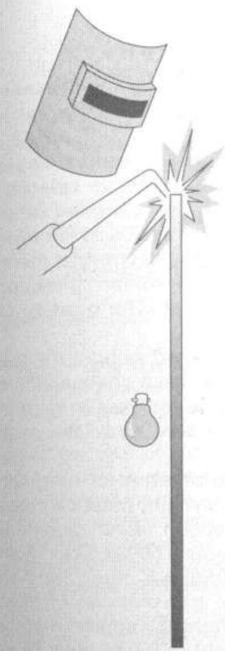
The camera has no brain

In discussing the conversion of a colour image into an electrical system by the three-filter system we overlooked this crucial distinction between how we perceive colour and how a camera converts colour into an electrical signal. Human perception filters sensory information through the brain. The brain makes many additions and adjustments in deciding what we think we see, particularly in observing colour.

A 'white' card will appear 'white' under many different lighting conditions. Without a standard reference 'white', a card can be lit by pink, light blue or pale green light and an observer will adjust and claim that the card is 'white'. The card itself can be of a range of pastel hues and still be seen as white. The brain continually makes adjustments when judging colour. A video camera has no 'brain' and makes no adjustment when the colour of light illuminating a subject varies. It accurately reproduces the scene in the field of view. A person's face lit by a sodium street lamp (orange light) will be adjusted by the brain and very little orange will be seen. The camera will reproduce the prevailing light and when displayed on a screen the face will have an orange hue.

Colour temperature

Because of the fidelity with which the camera reproduces colour, it is important to have a means of measuring colour and changes in colour. This is achieved by using the Kelvin scale – a measure of the colour temperature of light (see opposite). Across a sequence of shots under varying lighting conditions, we must provide continuity in our reference white. Just as the brain makes the necessary adjustment to preserve the continuity of white, we must adjust the camera when the colour temperature of the shot illumination changes (see White balance, page 68).



Blue skylight	9500–20,000K
Overcast sky	6000–7500K
HMI lamps	5600K
Average summer sunlight	5500K
Fluorescent daylight tubes*	5000K
Early morning/late afternoon	4300K
Fluorescent warm white tubes*	3000K
Studio tungsten lights	3200K
40–60 watt household bulb	2760K
Dawn/dusk	7000K
Sunrise/sunset	2000K
Candle flame	1850–2000K
Match flame	1700K

*All discharge sources are quoted as a correlated colour temperature, i.e. it 'looks like', for example, 5000K.

A piece of iron when heated glows first red and then, as its temperature increases, changes colour through yellow to 'white hot'. The colour of a light source can therefore be conveniently defined by comparing its colour with an identical colour produced by a black body radiator (e.g. an iron bar) and identifying the temperature needed to produce that colour. This temperature is measured using the Kelvin scale** (K) which is equivalent to the Centigrade unit plus 273 (e.g. 0° Centigrade = 273 Kelvin). This is called the colour temperature of the light source although strictly speaking this only applies to incandescent sources (i.e. sources glowing because they are hot). The most common incandescent source is the tungsten filament lamp. The colour temperature of a domestic 40–60 watt tungsten bulb is 2760K, while that of a tungsten halogen source is 3200K. These are not necessarily the operating temperatures of the filaments but the colour temperature of the light emitted. Although we psychologically associate red with heat and warmth and blue with cold, as a black body radiator becomes hotter, its colour temperature increases but the light it emits becomes bluer.

****Kelvin scale**: The physicist William Thomson, 1st Baron of Kelvin, first proposed an absolute temperature scale defined so that 0K is absolute zero, the coldest theoretical temperature (–273.15°C), at which the energy of motion of molecules is zero. Each absolute Kelvin degree is equivalent to a Celsius degree, so that the freezing point of water (0°C) is 273.15K, and its boiling point (100°C) is 373.15K.

Colour temperature correction filters

Colour camera processing is designed to operate in a tungsten-lit scene. Consequently the output from the red, green and blue CCDs are easily equalized when white balancing a scene lit with tungsten lighting (3200K). When the camera is exposed to daylight, it requires significant changes to the red channel and blue channel gains to achieve a 'white balance'. Many cameras are fitted with two filter wheels which are controlled either mechanically, by turning the filter wheel on the left-hand side at the front of the camera, or by selecting the required filter position from a menu displayed in the viewfinder. The filter wheels contain colour correction and neutral density filters and possibly an effects filter. The position of the various filters varies with camera model.

Variation in colour temperature could be compensated without the use of colour correction filters by adjusting the gains of each channel. With some colour temperatures this would require a large increase in gain in one channel and increase the noise to an unacceptable level (see page 88 for the relationship between gain and noise).

Cameras could be normalized to the colour temperature of tungsten or daylight. Because of the greater light levels of daylight, most cameras are designed to be operated with no colour correction under tungsten. The 3200K filter position is a clear glass filter whereas a 5600K filter (with no ND) is a minus blue filter to cut out the additional blue found in daylight. All colour correction filters decrease the transmission of light and therefore the minus blue filter cuts down the light (by approximately one stop) where most light is available – in daylight. A white balance is required after changing filter position.

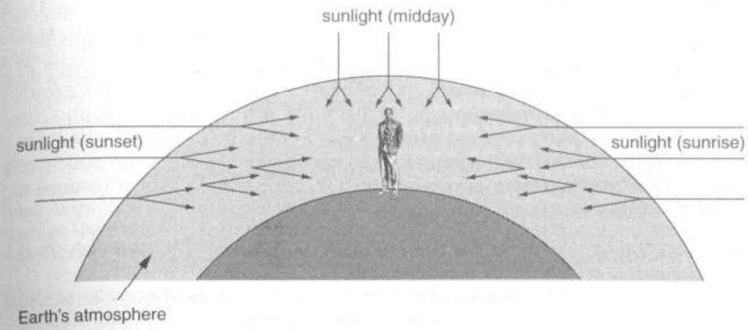
In addition to the colour correction filter for daylight, many cameras also provide neutral density filters in the filter wheel. Neutral density filters are used when there is a need to reduce the depth of field or in circumstances of a brightly lit location.

Filter selection

Set the filter to match the colour correction filter appropriate to the light source and light intensity.

- **3200K filter:** When this filter position is selected an optical plain glass filter is placed between the lens and the prism block to maintain back focus. Although the position is marked as 3200K, no colour correction filter is used because the camera is designed to work in a tungsten lit environment with sufficient gain variation of red and blue to cope with 'tungsten' colour temperature.
- **5600K filter:** This position in the filter wheel has the required colour temperature correction filter needed for daylight exposure. The minus blue filter reduces the transmission of blue light but also reduces the exposure by about one stop. This is not usually a problem as daylight light levels are considerably higher than the output of tungsten light.

The colour of the sky



Sunlight is scattered as it passes through the atmosphere and combined with clouds and the orbit of the earth around the sun, the human perception of the 'colour' of the sky is constantly changing. At midday, visible solar radiation is scattered by air molecules, particularly at the blue end of the spectrum where 30–40 per cent of blue light is dispersed producing a 'blue' sky. The scattering decreases to a negligible amount at the red end. At sunrise/sunset when light from the sun passes through a greater amount of atmosphere, light scattering occurs across the whole of the spectrum and the sky appears redder. The amount of sunlight scattered by the earth's atmosphere depends on wavelength, how far light has to travel through the atmosphere, and atmospheric pollution.

A common combination of colour correction and neutral density filters is:

position (1) 3200K	sunrise/sunset/tungsten/studio
position (2) 5600K + 1/4ND	(neutral density) exterior – clear sky
position (3) 5600K	exterior/cloud/rain
position (4) 5600K + 1/16ND	(neutral density) exterior exceptionally bright

NB 1/4ND is a filter with a transmission of 1/4 or 25%, i.e. 0.6 ND *not* 0.25ND!

White balance

Whenever there is a change in the colour temperature of the light illuminating a potential shot it is necessary to adjust the white balance of the camera. Some cameras will compensate for colour temperature variation but often it is necessary to carry out a white balance set-up. The white balance switch may be marked 'auto white balance' but this does not mean the camera will automatically compensate unless the specified white balance procedure is carried out. To successfully white balance a simple routine needs to be followed:

- Select the correct filter for the colour temperature of light being used (e.g. tungsten 3200K or daylight 5600K).
- Select either white balance position A or B. These positions memorize the setting achieved by the white balance. On each filter position there can be two memories (A or B). If *preset* is selected no setting will be memorized. This position always provides the factory default setting of 3200K.
- Fill the frame with a white matte card that is lit by same lighting as the intended shot. Make sure the card does not move during the white balance and that there are no reflections or shading on the card. Avoid any colour cast from surrounding light sources and ensure that you white balance with the main source of shot illumination and that the card is correctly exposed.

A progress report may appear in the viewfinder during white balance, including a number indicating the colour temperature that has been assessed. If this is much higher or lower than your anticipated estimate of the colour temperature then check the white card position and the other requirements of white balance. It could also indicate the camera is either not properly lined-up or malfunctioning. During the white balance procedure, the auto-iris circuit adjusts exposure to make the output of the green signal correct, then the gain of the red and blue channels are adjusted to equal the output of green (see Figure 1 on page 13). This establishes the 'white' of the card held in front of the lens as the reference 'white' and influences all other colour combinations. The fidelity of colour reproduction is therefore dependent on the white balance procedure.

Black balance

Many cameras do not require a manual black balance and this adjustment is carried out automatically when required. Black balance sets the black levels of the R, G and B channels so that black has no colourcast. It is normally only required if the camera has not been in use for some time, or if the camera has been moved between radically different air temperatures or the surrounding air temperature has significantly altered or, on some cameras, when the gain selector values have been changed. If a manual black balance needs to be done, first, white balance to equalize the gains and then black balance; then white balance again.

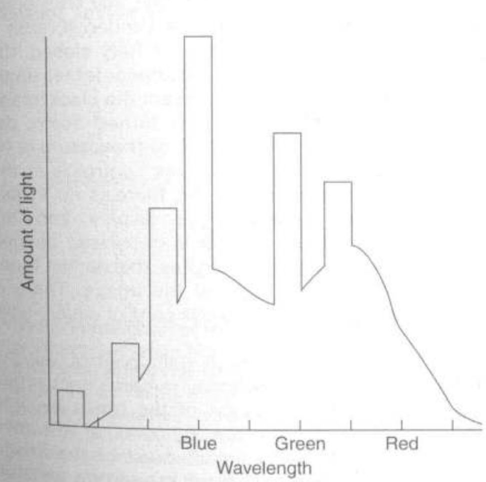
Light output

In tungsten light sources, light is produced from the heating effect of an electric current flowing through the tungsten filament. The visible spectrum from these sources is continuous and produces a smooth transition of light output between adjacent wavelengths. The intensity of light output will vary if the current is altered (dimming) which also affects the colour temperature although this is usually kept to within acceptable limits (see Continuity of face tones, page 76).

A discharge light source produces light as a byproduct of an electrical discharge through a gas. The colour of the light is dependent on the particular mixture of gas present in the glass envelope or by the phosphor coating of the fluorescent tube. Discharge light sources that are designed for film and television lighting such as HMIs are not as stable as tungsten but have greater efficacy, are compact and produce light that approximates to daylight.

Pulsed light sources

Fluorescent tubes used in the home, office and factory, and neon signs, do not produce a constant light output but give short pulses of light at a frequency depending on the mains supply (see Shutter and pulsed lighting, page 90).



Light output of a typical daylight-type fluorescent tube. Normal eyesight does not register the high intensity blue and green spikes, but they give a bluish green cast to a tungsten-balanced camera.

In recent years the development of improved phosphors has made the fluorescent tube (cold light) acceptable for television and film. Phosphors are available to provide tungsten matching and daylight matching colour temperatures. High frequency operation (>40 kHz) results in a more or less steady light output.

Colour rendition index (Ra)

A method of comparing the colour fidelity and consistency of a light source has been devised using a scale of 0 to 100. The colour rendition index (Ra) can be used as indication of the suitability for use in television production, with an Ra of 70 regarded as the lower limit of acceptability for colour television.

Viewfinder

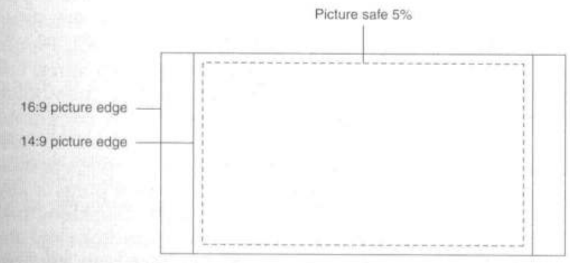
The monocular viewfinder is the first and often the only method of checking picture quality for the camcorder cameraman. The small black and white image (often colour LCD, liquid crystal display viewfinders on DV format cameras) has to be used to check framing, focusing, exposure, contrast and lighting. It is essential, as the viewfinder is the main guide to what is being recorded, to ensure that it is correctly set up. This means aligning the brightness and contrast of the viewfinder display. Neither control directly affects the camera output signal. Indirectly, however, if the brightness control is incorrectly set, manual adjustment of exposure based on the viewfinder picture can lead to under- or over-exposed pictures. The action of the brightness and contrast controls therefore needs to be clearly understood.

- **Brightness:** This control is used to set the correct black level of the viewfinder picture and alters the viewfinder tube bias control. Unless it is correctly set up, the viewfinder image cannot be used to judge exposure. The brightness control must be set so that any true black produced by the camera is just not seen in the viewfinder. If, after a lens cap is placed over the lens and the aperture is fully closed, the brightness is turned up, the viewfinder display will appear increasingly grey and then white. This obviously does not represent the black image produced by the camera. If the brightness is now turned down, the image will gradually darken until the line structure of the picture is no longer visible. The correct setting of the brightness control is at the point when the line structure just disappears and there is no visible distinction between the outside edge of the display and the surrounding tube face. If the brightness control is decreased beyond this point, the viewfinder will be unable to display the darker tones just above black and distort the tonal range of the image. There is therefore only one correct setting of the brightness control which, once set, should not be altered.
- **Contrast:** The contrast control is in effect a gain control. As the contrast is increased the black level of the display remains unchanged (set by the brightness control) whilst the rest of the tones become brighter. This is where confusion over the function of the two viewfinder controls may arise. Increasing the contrast of the image increases the brightness of the image to a point where the electron beam increases in diameter and the resolution of the display is reduced. Unlike the brightness control, there is no one correct setting for the contrast control, other than that an 'over-contrasted' image may lack definition and appear subjectively over-exposed. Contrast is therefore adjusted for an optimum displayed image which will depend on the picture content and the amount of ambient light falling on the viewfinder display.
- **Peaking:** This control adds edge enhancement to the viewfinder picture as an aid in focusing and has no effect on the camera output signal.

Setting up the viewfinder

1. Select aspect ratio if using a switchable format camera. Check that the viewfinder image is in the selected aspect ratio.
2. Switch CAMERA to BARS or place a lens cap on the lens.
3. Check the picture in the viewfinder and then reduce contrast and brightness to minimum.
4. Increase brightness until just before the raster (line structure) appears in the right-hand (black) segment of the bars.
5. Adjust contrast until all divisions of the bars can be seen.
6. Use the bars to check viewfinder focus and adjust the focus of the viewfinder eyepiece to produce the sharpest picture possible.
7. With the camera switched to produce a picture, recheck contrast with correctly exposed picture. Although the contrast control may occasionally need to be adjusted depending on picture content and ambient light change, avoid altering the brightness control.
8. Set peaking control to provide the minimum edge-enhancement that you require to find focus and adjust the eyepiece focus to achieve maximum sharpness of the viewfinder image. Adjust the position of the viewfinder for optimum operating comfort.

Aspect ratios and safety zones



With the introduction of widescreen digital TV and the use of dual format cameras (see Widescreen, page 106), programme productions may be shot in 16:9 aspect ratio but transmitted and viewed on 4:3 television receiver. To ease the transition between the two aspect ratios, many broadcasters use a compromise 14:9 aspect ratio for nominally 4:3 sets, but transmit the whole of the 16:9 frame to widescreen sets.

This requires the cameraman to frame up a 16:9 picture with these competing requirements in mind. Any essential information is included in the 14:9 picture area although the whole of the 16:9 frame may be transmitted in the future. A 14:9 graticule superimposed on the 16:9 viewfinder picture reminds the cameraman of this requirement. For the foreseeable future, actuality events such as sport may be covered for dual transmission – 16:9 and 14:9 – and therefore framing has to accommodate the smaller format if some viewers are not to be deprived of vital action.

Viewfinder indicators

There are usually a number of indicators available to be displayed in the viewfinder in addition to menus which provide information and adjustment to the camera (see Menus, page 98). These include:

- A red cue light or icon when recording.

(continued on page 73)

Exposure

When viewing a film or television image, it is often easy to accept that the two-dimensional images are a faithful reproduction of the original scene. There are many productions (e.g. news, current affairs, sports coverage, etc.) where the audience's belief that they are watching a truthful representation unmediated by technical manipulation or distortion is essential to the credibility of the programme. But many decisions concerning exposure involve some degree of compromise as to what can be depicted even in 'factual' programmes. In productions that seek to interpret rather than to record an event, manipulating the exposure to control the look of a shot is an important technique.

As we have discussed in Colour temperature (page 64), human perception is more complex and adaptable than a video camera. The eye/brain can detect subtle tonal differences ranging, for example, from the slight variations in a white sheet hanging on a washing line on a sunny day to the detail in the deepest shadow cast by a building. The highlights in the sheet may be a thousand times brighter than the shadow detail. The TV signal is designed to handle (with minimum correction) no more than approximately 40:1 (see Contrast range, page 74).

But there is another fundamental difference between viewing a TV image and our personal experience in observing a subject. Frequently, a TV image is part of a series of images that are telling a story, creating an atmosphere or emotion. The image is designed to manipulate the viewer's response. Our normal perceptual experience is conditioned by psychological factors and we often see what we expect to see; our response is personal and individual. A storytelling TV image is designed to evoke a similar reaction in all its viewers. Exposure plays a key part in this process and is a crucial part of camerawork. Decisions on what ranges of tones are to be recorded and decisions on lighting, staging, stop number, depth of field, etc., all intimately affect how the observer relates to the image and to a sequence of images. The 'look' of an image is a key production tool.

A shot is one shot amongst many and continuity of the exposure will determine how it relates to the proceeding and the succeeding images (see Matching shots, page 156).

Factors which affect decisions on exposure include:

- the contrast range of the recording medium and viewing conditions;
- the choice of peak white and how much detail in the shadows is to be preserved;
- continuity of face tones and the relationship to other picture tones;
- subject priority – what is the principal subject in the frame (e.g. a figure standing on a skyline or the sky behind them?);
- what electronic methods of controlling contrast range are used;
- the lighting technique applied in controlling contrast;
- staging decisions – where someone is placed affects the contrast range.

Exposure overview

- An accurate conversion of a range of tonal contrast from light into an electrical signal and back into light requires an overall system gamma of approximately 1.08 (see Gamma and linear matrix, page 102).
- Often the scene contrast range cannot be accommodated by the five-stop handling ability of the camera and requires either the use of additional lamps or graduated filters or the compression of highlights is necessary.
- The choice of what tones are to be compressed is decided by the cameraman by altering the iris, by a knowledge of the transfer characteristics of the camera or by the use of highlight control.
- Automatic exposure makes no judgement of what is the important subject in the frame. It exposes for average light levels plus some weighting to centre frame. It continuously adjusts to any change of light level in the frame.
- Exposure can be achieved by a combination of *f* number, shutter speed and gain setting. Increasing gain will increase noise (see page 88). Shutter speed is dependent on subject content (e.g. the need for slow motion replay, shooting computer displays, etc., see page 90). *F* number controls depth of field and is a subjective choice based on shot content (see below).

Depth of field

Choosing a lens aperture when shooting in daylight usually depends on achieving the required exposure. Depth of field is proportional to *f* number and if the in-focus zone is a significant consideration in the shot composition (e.g. the need to have an out of focus background on an MCU of a person or alternatively, the need to have all the subject in focus) then the other factors affecting exposure may be adjusted to meet the required stop such as:

- neutral density filters;
- altering gain (including the use of negative gain);
- altering shutter speed;
- adding or removing light sources.

There is often more opportunity to achieve the required aperture when shooting interiors by the choice of lighting treatment (e.g. adjusting the balance between the interior and exterior light sources), although daylight is many times more powerful than portable lighting kits (see Lighting levels, page 176).

Sometimes there may be the need to match the depth of field on similar sized shots that are to be intercut (e.g. interviews). Lens sharpness may decrease as the lens is opened up but the higher lens specification required for digital cameras usually ensures that even when working wide open, the slight loss of resolution is not noticeable. Auto-focus and anti-shake devices usually cause more definition problems, especially when attempting to extend the zoom range with electronic magnification.

(*continued from page 71*).

- Tape remaining time with a visual warning when tape is close to its end.
- Battery indicator will also warn a few minutes before the battery voltage drops below the minimum level needed to operate the camera/recorder and will remain continually lit when battery voltage is inadequate.
- Gain, shutter, contrast control, selected filter, white balance preset, audio metering, etc. can also be displayed plus error or 'OK' messages when white balancing and fault reports such as tape jammed, humidity, etc.

Contrast range

Every shot recorded by the camera/recorder has a variation of brightness contained within it. This variation of brightness is the contrast range of the scene. The ratio between the brightest part of the subject and the darkest part is the contrast ratio. The average exterior contrast ratio is approximately 150:1 but it can be as high as 1000:1. Whereas the contrast ratios of everyday locations and interiors can range from 20:1 to 1000:1, a video camera can only record a scene range of approximately 32:1. Peak white (100%) to black level (3.125%) is equivalent to five stops. The contrast range can be extended by compressing the highlights using a non-linear transfer characteristic when translating light into the television signal (see Electronic contrast control, page 80).

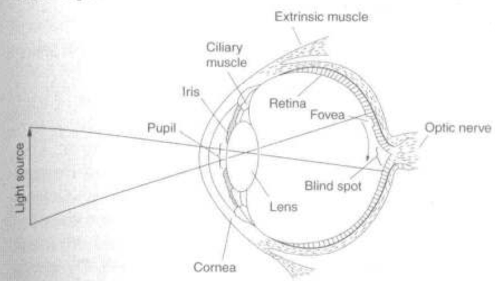
The result of recording a contrast range greater than the camera can handle is that highlights of the scene will appear a uniform white – details in them will be burnt out – and the darker tones of the scene will be a uniform black. The limiting factor for the reproduction of the acquired image is ultimately the display monitor on which it is viewed. The design, set-up and viewing conditions of the viewer's display monitor and the design of the signal path to the viewer all affect the final contrast range displayed. The darkest black that can be achieved will depend on the amount of light falling on the screen. The viewer also has the ability to increase the contrast on their set which will distort any production preference of image contrast.

The majority of image impairment in discriminating between tones occurs in highlights such as windows, skies, etc., but whether such limitations matter in practice will depend on how important tonal subtlety is in the shot. Loss of detail in a white costume may be noticeable but accepted as a subjective expression of a hot sunny day. A sports arena where a stadium shadow places half the pitch in darkness and half in bright sunlight may cause continuous exposure problems as the play moves in and out of the shadow. Either detail will be lost in the shadows or detail in sunlight will be burnt out.

Often, exposure is adjusted to allow the contrast range of the scene to be accurately reproduced on the recording. The aim is to avoid losing any variation between shades and at the same time to maintain the overall scene brightness relationships. Achieving the correct exposure for this type of shot therefore requires reproducing the detail in the highlights as well as in the shadows of the scene. Additionally, if a face is the subject of the picture then the skin tones need to be set between 70 and 75 per cent of peak white (may be a wider variation depending on country and skin tones; see Exposure continuity, page 76).

Alternatively, many productions require images that create a visual impression. The 'correct' exposure is less a matter of accurately reproducing a contrast range than the technique of setting a mood. Selecting the exposure for this type of shot is dependent on choosing a limited range of tones that creates the desired atmosphere that is appropriate to the subject matter.

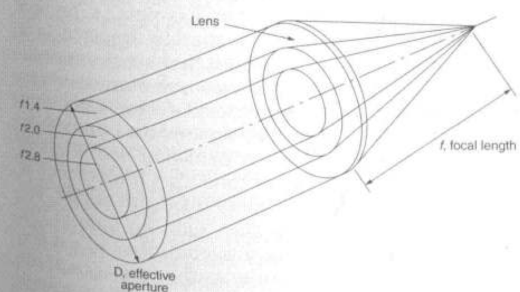
The eye



The eye perceives gradations of brightness by comparison. It is the ratio of one apparent brightness to another (and in what context) that determines how different or distinct the two appear to be. The just noticeable difference between the intensity of two light sources is discernible if one is approximately 8 per cent greater/lesser than the other, regardless of them both being of high or low luminous intensity (see Measurement of light, page 173). The amount of light entering the eye is controlled by an iris and it is also equipped with two types of cells; rods, that respond to dim light, and cones, receptor cells that respond to normal lighting levels. For a given iris opening, the average eye can accommodate a contrast range of 100:1, but visual perception is always a combination of eye and brain. The eye adapts fast to changing light levels and the brain interprets the eye's response in such a way that it appears as if we can scan a scene with a very wide contrast range (e.g. 500:1), and see it in a single glance.

The lens

The aperture of a zoom lens is the opening through which light is admitted. The maximum aperture is limited by the design of the lens (see Ramping, page 49). Adjusting the aperture controls the amount of light that reaches the CCDs. Aperture is identified by *f* number, the ratio of the focal length of the lens to the diameter of the effective aperture and is an indication of the amount of light passing through the lens and therefore an exposure control. An aperture set to *f*2 on a 50 mm lens would have an effective aperture of 25 mm. Increasing the *f* number (stopping down to *f*4) reduces the amount of light entering the camera. A wider aperture (opening up to *f*1.4) lets in more light (see Depth of field, page 48). Different designs of lenses may have variations in the configuration of lens elements and type of glass and may operate with identical *f* numbers but admit unequal amounts of light. The T number is a formula which takes into account the transmittance of light and therefore lenses with similar T numbers will give the same image brightness.



Exposure continuity

A 'talking head' is probably the most common shot on television. Because the audience is usually more critical in their judgement of correct reproduction of skin tones, video pictures of faces are the most demanding in achieving correct exposure and usually require exposure levels that are high but are free from burn-out in highlight areas. The reflectivity of the human face varies enormously by reason of different skin pigments and make-up. In general, Caucasian face tones will tend to look right when a 'television white' of 60 per cent reflectivity is exposed to give peak white. White nylon shirts, white cartridge paper and chrome plate for example have reflectivity of above 60 per cent which is TV peak white. Without highlight compression (see page 80), these materials would lack detail if the face was exposed correctly. Average Caucasian skin tones reflect about 36 per cent of the light. As a generalization, face tones are approximately one stop down on peak white. If a scene peak white is chosen that has a reflectivity of 100 per cent, the face tones at 36 per cent reflectivity would look rather dark. To 'lift' the face to a more acceptable level in the tonal range of the shot, a scene peak white of 60 per cent reflectivity is preferable. This puts the face tone at approximately half this value or one stop down on the peak white.

Continuity of face tones

An important consideration when shooting the same face in different locations or lighting situations is to achieve some measure of continuity in face tones. There is a small amount of latitude in the colour temperature of light on a face. When white balanced to daylight sources (5500K), a 400K variation can be tolerated without being noticeable. There is a smaller latitude of colour temperature (150K) when white balanced to tungsten sources (3200K). As the viewer is unaware of the 'true' colour of the setting, a greater variation is acceptable in changes in colour temperature in this type of wide shot.

Continuity of face tone can be achieved if it is exposed to same value in different shots. The problem comes with variation in background and a variation in what is chosen as peak white. For example, a person wearing dark clothing positioned beside a white marble fireplace in a panelled room in one shot could have an exposure that set the marble surround at or near peak white so that the face was one stop down on this with the surrounding panelling showing no detail. If a reverse shot was to follow of the same person now seen only against dark panelling, the exposure could be set to show detail in the panelling and 'lift' the picture but this would push the face to a lighter tone than the preceding shot. To maintain continuity of face tone, the same exposure setting for the face would be needed as in the previous shot, with no tone in the frame achieving peak white. It may be necessary to control or adjust the contrast range of the shot to preserve the priority of the face tone at an acceptable level. In the above example, a more acceptable picture would be to light the background panelling to a level that showed some detail and texture whilst maintaining face tone continuity.

The 'film' look

A cinema screen is a highly reflective surface and the audience watch the giant projected images in a darkened auditorium. A television set is a small light box that emits its picture usually into a well-lit room often provided by high intensity daylight. The initial brightness ratio between black and white tones of a subject before a video camera often exceeds the dynamic range of any display monitor. This problem is exacerbated (because of the regulations imposed on the design of the transmission path) by a lower contrast ratio handling ability than is theoretically possible and because television is viewed in less than favourable lighting conditions.

These are simply the differences in viewing conditions between film and video. There are also a number of inherent differences in technology and technique. When film is recorded on 35 mm emulsion it can achieve (if desired) a much higher resolution and contrast range (e.g. some film negative can handle 1000:1) than is possible with standard video broadcasting. Video systems such as 24P 1080 lines (see Widescreen, page 106) are attempting to provide a transparent match between film and video but, to date, HDTV systems are making slow progress with consumers.

Two of the key distinctions between film and video is the use of detail enhancement in video to compensate for lower resolution compared to film and video's handling of highlights and overloads. Digital acquisition and processing allows more selective and subtle control of detail enhancement (see page 87) and CCDs with 600,000 pixels have such good resolution they hardly need contour correction. Digital acquisition allows manipulation of the soft shoulder of the video transfer characteristic to mimic the D log E (density versus the logarithm of exposure) curve of a film negative transfer characteristic. Digital video acquisition also allows the manipulation of gamma and linear matrix to customize the image (see Scene files, page 100). A 'non-video' look is attempted by techniques such as adjusting aperture correction, contour, auto knee, gamma, detail correction, and limited depth of field.

There are many attempts by video to imitate the film look. But which film? The deep focus and wide angle shots of *Citizen Kane* (1940)? The use of a long lens, shooting against the light with out of focus background and misty blobs of foreground colour of *Une Homme et une Femme* (1966)? The amber glow of *Days of Heaven* (1978), where cinematographer Nestor Almendros used the 'magic hour' (actually only 20–25 minutes) after the sun has set each day to produce a sky with light but no sun giving very soft-lit pictures without diffusion?

There are endless variations of style in the history of film making and contemporary fashion often dictates the 'look' at any particular time. Possibly there is a misunderstanding about the so-called 'film look' and the standard video 'look' that ignores the link between production budget and working techniques. Many feature films made for cinema release have a much larger budget than a video programme made for one or two transmissions. Money and customary film-making conventions, for example, allow a production technique that spends time staging action for a prime lens camera position developing a shot that is precisely lit, framed and with camera movement that is perfect or there is a retake. The stereotype multi-camera video production usually has 'compromise' written all over it, basically because television requires 24 hours to be filled day on day across a wide range of channels in the most cost-effective way possible. Zooming to accommodate unrehearsed action, compromise lighting for three/four camera shooting and a recording or transmission schedule that allows little or no time to seek production perfection. Plus a television content that has neither the high audience appeal or high profile performers presented with pace, tension and gloss achieved by editing over an extended post-production process. The 'look' of film may be more about the techniques of acquisition than the technology of acquisition.

Contrast control

The control of the contrast range can be achieved by several methods:

- The simplest is by avoiding high contrast situations. This involves selecting a framing that does not exceed the 32:1 contrast range the camera can handle. This obviously places severe restrictions on what can be recorded and is frequently not practical.
- A popular technique is to stage the participants of a shot against a background avoiding high contrast. In interiors, this may mean avoiding daylight, windows or closing curtains or blinds, or, in exteriors, avoiding shooting people in shadow (e.g. under a tree) with brightly lit backgrounds or against the skyline.
- If luminaries or reflectors of sufficient power and numbers are available they can be used to lighten shadows, modify the light on faces (see Lighting a face, page 180), etc. Even a lamp mounted on a camera can be a useful contrast modifier at dusk on an exterior or in some interior situations.

Staging

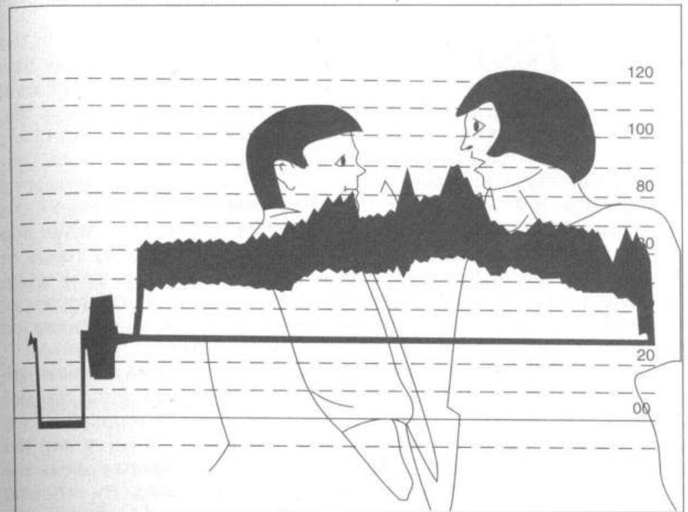
The rule of thumb that claims you should expose for the highlights and let the shadows look after themselves may give bright colourful landscapes but becomes very limited advice when shooting a face lit by sunlight under a cloudless summer sky. There may be more than three to four stops difference between the lit and the unlit side of the face. Ways of controlling the contrast in a shot need to be found if there is to be no loss of detail in highlights or shadows. A simple but effective method is to frame the shot to avoid areas of high contrast. Stage people against buildings or trees rather than the sky if there are bright sunlight conditions. Avoid direct sunlight on faces unless you can lighten shadows. With interiors, use curtains or blinds to reduce the amount of light entering windows and position people to avoid a high-contrast situation.

The problem of a bright sky can be controlled by a ND graduated filter if the horizon allows and other important elements of the shot are not in the top of frame. Low contrast filters and soft contrast filters may also help (see Effects filters, page 62).

Avoid staging people, if possible, against an even white cloud base. Either the overcast sky is burnt out or the face is in semi-silhouette if exposure for detail in the clouds is attempted.

Methods of altering contrast range by additional lamps or reflector boards are discussed in Lighting a face, page 180.

Portable waveform monitor



Diagrammatic representation of waveform supered on picture.

A portable waveform test measurement device will allow a waveform signal to be superimposed on a monitor screen. For example, a particular face tone signal level can be marked by a cursor. When the same signal level is required for another shot with the same face, the exposure, lighting, etc., can be adjusted so that the signal level signifying the face tone matches up to the memory cursor.

Electronic contrast control

As we discussed in Charge-coupled devices (page 18), the CCDs in the camera respond to light and convert the variations of brightness into variations in the electrical signal output. There is a minimum light level required to produce any signal (see Gain, noise and sensitivity, page 88). Below this level the camera processing circuits produce a uniform black. This is called black clip (see figure opposite). As the intensity of light increases, the signal increases proportionally until a point is reached when the signal is limited and no further increase is possible even if the light intensity continues to increase. This point is called the white clip level and identifies the maximum allowable video level. Any range of highlight tones above this level will be reproduced as the peak white tone where the signal is set to be clipped. Variation in the brightness of objects will only be transferred into a video signal if they are exposed to fall between the black clip level and white clip level.

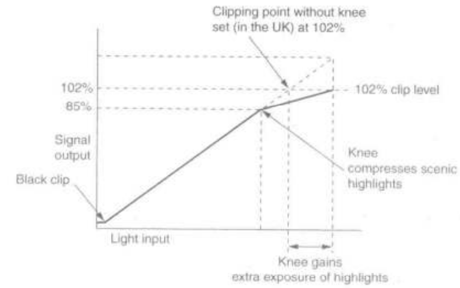
This straight line response to light is modified to allow a greater range of brightness to be accommodated by reducing the slope of the transfer characteristic at the top end of the CCD's response to highlights (see figure opposite). This is called the knee of the response curve and the point at which the knee begins and the shape of the response above the knee alters the way the video camera handles highlights. By reducing the slope of the transfer characteristic a greater range of highlights can be compressed so that separation remains and they do not go into 'overload' above the white clip level and become one featureless tone. If the shape of this portion of the graph is more of a curve, the compression of highlights is non-linear and the transition to overload is more gradual.

Modifying this transfer slope provides the opportunity to alter the gamma of the camera (see Gamma and linear matrix, page 102) and a method of handling contrast scenes which exceed the 32:1 contrast range of the standard video camera response.

Exposing for highlights

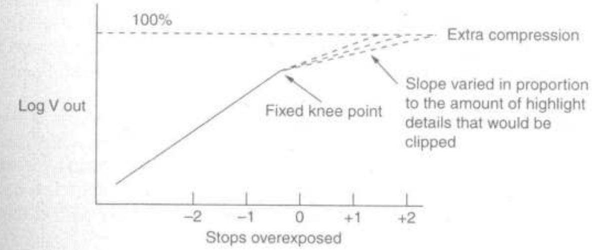
A highlight part of the shot (e.g. white sheets on a washing line in bright sun) which may produce a signal five times peak white level can be compressed into the normal video dynamic range. With the above example this means that the darker areas of the picture can be correctly exposed whilst at the same time maintaining some detail in the sheets.

If someone was standing in a room against a window and it was necessary to expose for exterior detail and the face, without additional lighting or filtering the windows, it would not be possible to reproduce detail in both face and exterior. Using highlight compression, the highlights outside the window would be squashed and although their relative brightness to each other would not be faithfully reproduced, the compression would allow the reproduction of detail across a greater range to be recorded.

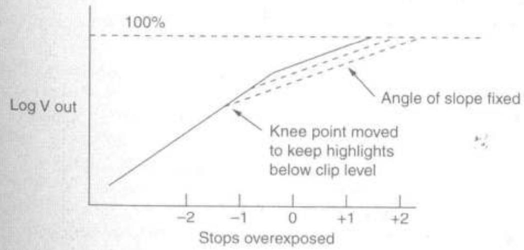


The 'knee' which is introduced in the camera head amplifiers progressively compresses highlights which otherwise would be lost in the peak white clipper. It extends the camera's response to a high contrast range but with some loss of linearity. Many cameras also provide a black stretch facility which helps to reveal detail in the black areas, but will also introduce some extra noise.

Variable slope highlight control



Variable knee point highlight control



Transient highlights

One type of contrast control uses average feedback and avoids unnecessary compression by not responding to transient high intensity light such as car headlamps. If highlight compression is used with a normal contrast range scene (below 40:1) there is the risk that highlights will be distorted and the compression may result in a lower contrast reproduction than the original. Low contrast pictures have little impact and are visually less dynamic.

Adjusting exposure

There are various ways of deciding the correct exposure:

- using the zebra exposure indicator in the viewfinder (see page 84);
- manually adjusting the iris setting whilst looking at the viewfinder picture;
- using the auto iris-exposure circuit built into the camera.

Many cameramen use a combination of all three and some cameramen use a light meter.

Manual adjustment

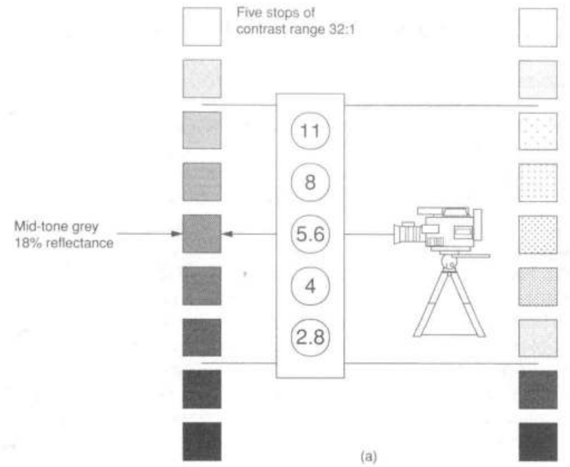
The simplest method is to look at the viewfinder picture (make certain that it is correctly set up – see page 70) and turn the iris ring on the lens to a larger *f* number (this reduces the amount of light reaching the CCDs) if the brightest parts of the scene have no detail in them, or to a smaller *f* number (increasing the amount of light reaching the CCDs) if there is no detail in important parts of the subject. In some situations there may be insufficient light even with the iris wide open to expose the shot. Check that no ND filter is being used and then either switch in additional gain (see page 88), change the shutter if it is set to a faster speed than 1/50th or 1/60th (depending on country) or add additional light (see Lighting topics, pages 172–85).

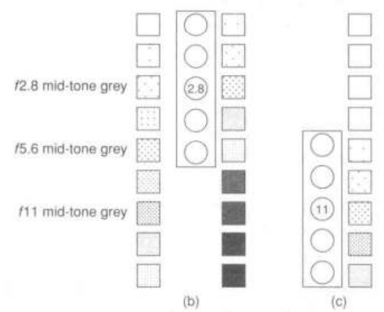
If you are uncertain about your ability to judge exposure with this method (and it takes time to become experienced in all situations) then confirm your exposure setting by depressing the instant auto-exposure button which gives the camera's auto-exposure estimation of the correct *f* number. When the button is released you can either stay at the camera setting or return to your manual estimation.

The camera as light meter

A television camera has been called the most expensive light meter produced. If auto-exposure is selected, the feedback to the iris can be instantaneous and the auto circuit will immediately stop down the lens if any significant increase of scene brightness is detected. Auto-exposure works by averaging the picture brightness (see figures opposite) and therefore needs to be used intelligently. In some cameras, different portions of the frame can be monitored and the response rate to the change of exposure can be selected. In general, expose for the main subject of the shot and check that the auto-iris is not compensating for large areas of peak brightness (e.g. overcast sky) in the scene.

The lens iris is controlled by the highest reading from the red, green or blue channel and therefore the auto circuit reacts whenever any colour combination approaches peak signal. This auto decision making about exposure may have disadvantages as well as advantages. The rate of response of the auto-iris system needs to be fast enough to keep up with a camera panning from a bright to a dark scene, but not so responsive that it instantly over- or under-exposes the picture for a momentary high-light brightness (e.g. a sudden background reflection).





Auto exposure averages the scene brightness and in the lighting conditions in Figure (a) has selected *f*5.6 to expose 18 per cent reflectance mid-tone grey. If the light increases (Figure (c)) the auto exposure circuit now selects *f*11 to expose for a mid-tone grey. If the light decreases (Figure (b)), *f*2.8 is chosen to expose for a mid-tone grey.

Auto-exposure problems

A common problem with auto-exposure occurs when an interview is being recorded and auto-exposure has been selected and left on. The interviewee may be correctly exposed at the start of the interview but if any highly reflective object enters the background of the frame then the auto-exposure circuit may be triggered and will stop down the iris to expose for detail. The interviewee's face will be underexposed. Additionally, there may be a problem with changing light conditions such as intermittent sunlight requiring significant and rapid changes in face exposure which may be intrusive and visible if controlled by an auto-exposure rapid exposure. If using auto-exposure, check that the rate of pan is in step with the ability of the auto-iris to change exposure. Some cameras have switchable auto-iris response rates to suit the changing requirements of camera movement. If working with a camera for the first time check that the auto-iris is correctly aligned.

Zebra exposure indicators

The zebra pattern is a visual indicator in the viewfinder when areas of the picture have reached a certain signal level. If the zebra exposure indicator is switched on, those elements of the image that are above this pre-set level are replaced by diagonal stripes in the picture. The cameraman can respond by closing the iris to adjust the exposure until part or all of the zebra diagonals have been removed.

Onset of zebra level

The level at which the zebra indicator is triggered is obviously a critical factor in this method of assessing exposure and can be adjusted to suit particular operational preferences. Some camera designs have their zebra stripe indicator driven by the luminance signal. The zebra stripe warning is then only valid for nearly white subjects and exposure of strongly coloured areas may go into over-exposure without warning. Other systems use any of the red, green or blue outputs which exceed the selected signal level to trigger the zebra indicator.

Selecting zebra level

The exposure point at which the zebra indicator is triggered can be a personal operational preference but criteria to consider when setting that point are:

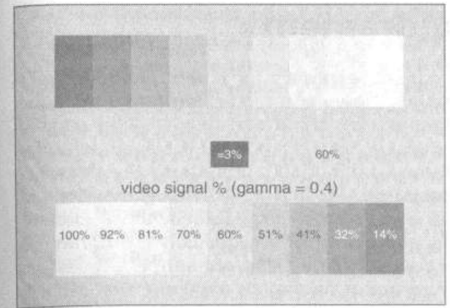
- If there is a 'pool' of cameras in use then that point should be standard on all cameras.
- The onset point should be close to full exposure but should warn before full burn-out occurs.
- The zebra stripe indicator should not obscure important picture information such as the face but it should indicate when flesh tones are in danger of going into over-exposure.

Some UK zebra onset levels are 90–95 per cent for RGB-driven systems and 68–70 per cent for luminance systems, but the final limiting factor on exposure level is loss of detail, either to noise in the blacks or burn-out in the peak white clipper. Both losses are irrecoverable.

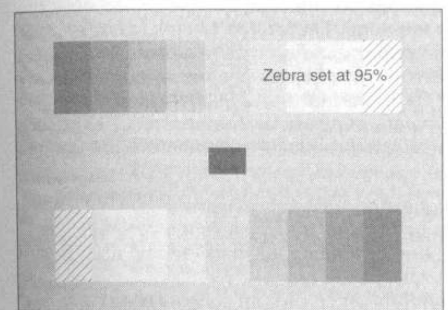
Adjusting *f* number

Controlling the light through the lens can be by aperture or ND filter. The *f* number is defined as a ratio between focal length and the effective diameter of the lens aperture (see Depth of field, page 48).

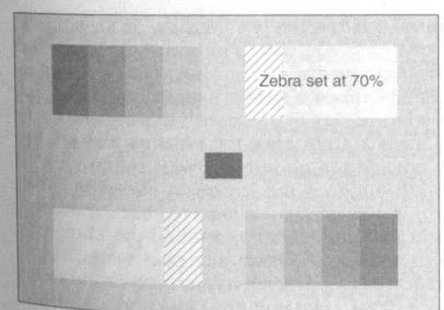
The *f* number is not an accurate indication of the speed of the lens because the *f* number formula is based on the assumption that the lens transmits 100 per cent of the incident light. Because of the variation in the number of elements in the lens and the variation in lens design, different lenses may have different transmittance. Two lenses with the same *f* number may transmit different amounts of light to the prism block.



A nine-step wedge chart + a 'super black' in the centre. The peak white wedge has 60% reflectance. The wedge tones are graded as a % of peak white of the video signal and form equal changes in signal output when displayed on a waveform monitor. The background tone is 60% of peak white representing a tone with 18% reflectivity. The wedges are displayed with a gamma correction of 0.4.



With a zebra setting triggered by any part of the signal going above 95%, only nearly peak white picture areas such as the 100% wedge on the grey scale will display the diagonal pattern.



With a zebra setting triggered by any part of the signal falling between 70% (approximate reflectivity of the average Caucasian face tone) and 80%, the appropriate step wedge will display the diagonal pattern.

Using a properly lined-up and exposed camera on a grey scale will give a rough indication of how the zebra setting has been set up. The signal displayed on a waveform will allow more accurate measurement. On most cameras, the zebra setting can be adjusted to suit individual requirements.

If a grey scale with a 32:1 contrast is correctly exposed, a reduction in exposure by five stops will reduce the signal to almost zero, confirming the five-stop dynamic range of a camera with no electronic contrast control.

Production requirements

It is easy to chase after the 'correct' exposure for a shot and lose sight of the purpose of the production. News and factual programmes have the fairly simple visual requirement of 'see it and hear it'. This usually requires a technique that produces a neutral record of the event with the least discernible influence of the cameraman's attitude to the material. The choice of exposure is based on the aim of providing the clearest possible image of the action. The 'correct' exposure in these circumstances is the one that produces clarity of image. Other programme genres have more diverse production aims. It is not simply a question of finding the 'correct' exposure but of finding an exposure that reflects a mood, emotion or feeling.

The appearance of the image has an important influence on how the audience reacts to the visual message. The choice of lens, camera position and framing play a crucial part in guiding that response. The choice of exposure and the resultant contrast of tones is another powerful way to guide the viewer's eye to the important parts of the frame.

The cameraman can manipulate contrast by the choice of exposure and gamma setting (see page 100), to produce a range of different images such as:

- stark contrasty pictures suggesting a brutal realism;
- pictures with no highlights or blacks – simply a range of greys;
- low key pictures with a predominance of dark tones and heavy contrast;
- high key pictures with a predominance of light tones, little depth and contrast.

If the production is aiming at a subjective impression of its subject, then the choice of the style of the image will require a high degree of continuity. The viewer will become aware if one shot does not match and may invest the content of that shot with special significance as apparently attention has been drawn to it.

A television engineer may have a preference for pictures that have a peak white with no highlight crushing, a good black with shadow detail and an even spread of tones throughout the image. Along with other correct engineering specifications, this is often called a technically acceptable picture. Using a low contrast filter, flares and filling the shot with smoke may lift the blacks to dark grey, eliminate any peak white, cause highlights to bloom and definition to be reduced. It may also be the exact requirement for the shot at that particular production moment. Remember that the term broadcast quality comes from the engineering requirements for the video signal, not the way the picture looks. There are no hard-and-fast rules to be followed in the creative use of exposure. Although resultant images may lack sparkle because of low contrast and fail to use the full contrast range that television is capable of providing, if the pictures create the required mood, then the aims of the production have been satisfied.

Image enhancement and contour correction

As we have discussed, the resolution of the video image is partly limited by the CCD design (although this is continuously improving), and partly by the constraints of the video signal system. In most camera/recorder formats, image enhancement is used to improve picture quality. One technique is to raise the contrast at the dark-to-light and light-to-dark transitions, to make the edges of objects appear sharper, both horizontally and vertically. This is done electronically by overshooting the signal at the transition between different tones to improve the rendering of detail. This edge enhancement is often applied to high-frequency transitions and can be controlled by adjusting various processing circuits such as aperture correction, contour, detail correction, etc.

It is important to remember that the degree of artificial enhancement is controllable with, for example, separate controls for vertical and horizontal enhancement. When overdone, artificial enhancement of picture resolution is often the main distinguishing characteristic between a video and a film image. Because an audience may connect this type of image quality with multi-camera coverage of sport or actuality events, an electronic image is often paradoxically considered more realistic and credible.The amount of enhancement is a subjective value and will vary with production genre and production taste. It is difficult to remove image enhancement in post-production although it may be added.

Detail enhancement and skin tone detail

The degree of electronic manipulation of edge detail is variable, but one limiting factor in the amount of enhancement that can be used is the adverse effect on faces. When pictures are 'over-contoured' skin detail can appear intrusive and unnatural; every imperfection is enhanced and becomes noticeable.

To overcome this problem, some cameras provide for selective reduction in skin detail to soften the appearance of faces. While variable electronic 'sharpening' or image enhancement may be applied to the overall shot, skin tone detail control allows for the separate handling of the specific degree of enhancement on any selected facial tones within that scene.

This is achieved by a circuit that separates facial skin colour from all other colours in a given shot, and its electronic detail level can be reduced without affecting other areas of the picture. The specific skin colour to be treated in this way is selectable and can be memorized to follow movement or recalled for subsequent shots. Some cameras have as many as three independent skin tone detail circuits.

Gain, noise and sensitivity

Camera sensitivity is usually quoted by camera manufacturers with reference to four interlinking elements:

1. A subject with peak white reflectivity.
2. Scene illumination.
3. *f* number.
4. Signal-to-noise ratio for a stated signal.

It is usually expressed as being the resulting *f* number when exposed to a peak white subject with 89.9 per cent reflectance lit by 2000 lux quoting the signal/noise ratio. For most current digital cameras this is at least *f* 8 or better with a signal/noise ratio of 60 dB. This standard rating is provided to allow different camera sensitivity to be compared and is not an indication of how much light or at what stop the camera should be used (see page 176).

Noise

The sensitivity of the camera could be increased by simply greater amplification of weak signals but this degrades the picture by adding 'noise' generated by the camera circuits. The signal/noise ratio is usually measured without contour or gamma correction. As manufacturers vary in the way they state camera sensitivity, comparison between different models often require a conversion of the specification figures. In general, with the same *f* number, the higher the signal/noise ratio and the lower the scene illuminance (lux), the more sensitive the camera.

Gain

The gain of the head amplifiers can be increased if insufficient light is available to adequately expose the picture. The amount of additional gain is calibrated in dBs. For example, switching in +6 dB of gain is the equivalent of opening up the lens by one *f* stop, which would double the amount of light available to the sensors. The precise amount of switched gain available differs from camera to camera. A camera may have a +9 dB and +18 dB switch with an additional +24 dB available from a pre-set inside the camera. Other camera designs allow a user pre-set to programme the value of each step of switchable gain. Some cameras allow a specific *f* number (aperture priority) to be selected and then automatically increase gain if the light level decreases. This may increase noise to an unacceptable level without the cameraman being aware of how much gain is switched in. Cameras may have a negative gain setting (i.e. a reduction in gain). This reduces noise and is a way of controlling depth of field without the use of filters. For example, an exposure is set for an aperture setting of *f* 2.8 with 0 dB gain. If 6 dB of negative gain is switched in, the aperture will need to be opened to *f* 2 to maintain correct exposure and therefore depth of field will be reduced.

Gain and stop comparison

+3 dB is equivalent to opening up 0.5 stop.
+6 dB is equivalent to opening up 1 stop.
+9 dB is equivalent to opening up 1.5 stops.
+12 dB is equivalent to opening up 2 stops.
+18 dB is equivalent to opening up 3 stops.
+24 dB is equivalent to opening up 4 stops.

The extra gain in amplification is a corresponding decrease in the signal-to-noise ratio and results in an increase in noise in the picture. For an important news story shot with insufficient light, this may be an acceptable trade-off.

Calculating the ASA equivalent for a video camera

A video broadcast camera/corder with a good auto-exposure system is in effect a very reliable light meter. Most cameramen use a combination of manual exposure, instant auto-exposure and/or the zebra exposure indicator (see pages 84–5), but some cameramen with a film background often feel more comfortable using a light meter to check exposure level. In order to achieve this, the sensitivity of the camera requires an equivalent ASA rating which is logarithmic, e.g. doubling ASA numbers allows a decrease of one stop. There are several methods to determine the rating, including the following formula:

- The sensitivity of the video camera is quoted using a stated light level, signal-to-noise level, a surface with a known reflectance value and with the shutter set at 1/50 (PAL working).
- Japanese camera manufacturers use a standard reflectance of 89.9% as peak white while UK television practice is to use a 60% reflectance value as peak white therefore an illuminance level of 3000 lux must be used when transposing a rating of 2000 lux with 89.9% reflectance to 60% peak white working.

The formula below is for 60% reflectance, 1/50th shutter speed.

$$\text{ASA} = \frac{(f\ \text{number})^2 \times 1250\ \text{(a mathematical constant)}}{\text{illuminance in ft candles*}}$$

*(10.76 lux = 1 foot candle, e.g. 3000 lux/10.76 = 278.81 ft candles)

Year-on-year video camera sensitivity has increased. In the last few years, a negative gain setting has begun to appear on cameras. Why not have the negative figure as 0 dB gain? One reason may be that manufacturers like to advertise their cameras as more sensitive than their competitors and a higher notional '0 dB' allows a smaller stop. Another suggestion is that on a multi-camera shoot, lights can be set for a 0 dB exposure and thereafter, if a lower depth of field is required, negative gain can be switched in and the iris opened without resorting to the use of an ND filter.

Image intensifiers

When shooting in very low light levels (e.g. moonlight) image intensifiers can be fitted between camera and lens to boost sensitivity. The resultant pictures lack contrast and colour but produce recognizable images for news or factual programmes.

Electronic shutters

One complete frame of the standard PAL television signal is made up of two interlaced fields with a repetition rate of 50 fields per second (25 complete frames per second). The CCD scans the image 50 times a second which is the 'normal' shutter speed of a PAL video camera. CCDs can be adjusted to reduce the time taken to collect light from a field (see figure opposite), and reducing the length of the read-out pulse is equivalent to increasing the shutter speed. This electronic shutter reduces the time the CCDs are exposed to the image by switched steps, improving reproduction of motion but reducing sensitivity.

Movement blur

The standard shutter speed (PAL) is set to 1/50th second. A fast-moving subject in front of the camera at this shutter speed will result in a blurred image due to the movement of the subject during the 1/50th of a second exposure. Reducing the time interval of exposure by increasing the electronic shutter speed improves the image definition of moving subjects and is therefore particularly useful when slow motion replay of sporting events is required. But reducing the time interval also reduces the amount of light captured by the CCD and therefore increasing shutter speed requires the aperture to be opened to compensate for the reduction in light.

Shutter speeds

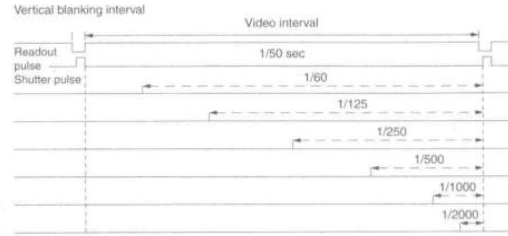
The shutter speed can be altered in discrete steps such as 1/60, 1/125, 1/500, 1/1000 or 1/2000 of a second or, on some cameras, continuously varied in 0.5 Hz steps. Often, when shooting computer displays, black or white horizontal bands appear across the computer display. This is because the scanning frequencies of most computer displays differ from the (50 Hz) frequency of the TV system (PAL). Altering the shutter speed in discrete steps allows the camera exposure interval to precisely match the computer refresh scanning frequency and reduce or even eliminate the horizontal streaking.

Pulsed light sources and shutter speed

Fluorescent tubes, HMI discharge lamps and neon signs do not produce a constant light output but give short pulses of light at a frequency dependent on the mains supply (see figure, page 69). Using a 625 PAL camera lit by 60 Hz mains fluorescent (e.g. when working away from the country of origin mains standard) will produce severe flicker. Some cameras are fitted with 1/60th shutter so that the exposure time is one full period of the lighting.

If a high shutter speed is used with HMI/MSR light sources, the duration of the pulsed light may not coincide with the 'shutter' open and a colour drift will be observed to cycle, usually between blue and yellow. It can be eliminated by switching the shutter off. FT sensors have a mechanical shutter which cannot be switched off and therefore the problem will remain.

Shutter pulse



shutter I/f-number

Shutter	f-number	Shutter	f-number
1/50		1/500	approx. 3 stops
1/125	approx. 1 stop	1/1000	approx. 4 stops
1/250	approx. 2 stops	1/2000	approx. 5 stops

Time-lapse controls

Time lapse is a technique where at specified intervals the camera is programmed to make a brief exposure. Depending on the type of movement in the shot, the time interval and the time the camera is recording, movement which we may not be aware of in normal perceptual time is captured. The classic examples are a flower coming into bloom with petals unfolding, clouds racing across the sky or car headlights along city streets at night shot from above, comet tailing in complex stop/start patterns. Time lapse can also be used as an animation technique where objects are repositioned between each brief recording. When the recording is played at normal speed, the objects appear to be in motion. The movement will be smooth if sufficient number of exposures and the amount of movement between each shot has been carefully planned.

The crucial decisions when planning a time-lapse sequence is to estimate how long the sequence will run at normal speed, how long the real-time event takes to complete the cycle that will be speeded up and the duration of each discrete 'shot'. For example, do you shoot every minute, every hour, or once a day? These decisions will be influenced by the flexibility of the time-lapse facility on the camera in use. Some models will allow you to compile time-lapse sequences with shots lasting just an eighth of a second; others will only allow you to fit in three shots on each second of tape.

For example, a speeded-up sequence is required of an open air market being set up, then filled with shoppers and finally the market traders packing away to end on a deserted street. If you plan to have a normal running time of 5 seconds to set up, 5 seconds of shopping during the day and 5 seconds of clearing away you need to time how long the market traders take to open and close their stalls. If this takes 30 minutes in the morning and the same in the evening, and your camera will record 0.25 second frames, the total number of shots will be 15 seconds divided by 0.25 = 60 separate shots. The time lapse will be shot in three separate sequences. Sequence 1 (opening) will require 30 minutes divided by 20 shots equals a shot every minute and a half. Sequence 2 can be shot any time during the day when the market is crowded and will be the same ratio of 1 shot every 1.5 minutes for 30 minutes. The end sequence will be a repeat of sequence 1 taken at the end of the day. The light level may well change within and between sequences and can be compensated by using auto-iris or, if the change in light is wanted, setting a compromise exposure to reveal the changing light levels.

Timecode

Timecode enables every recorded frame of video to be numbered. A number representing hours, minutes, seconds and frame (television signal) is recorded. There are 25 frames per second in the PAL TV signal and so the frame (PAL television signal) number will run from 1 to 25 and reset at the end of every second. In a continuous recording, for example, one frame may be numbered 01:12:45:22, with the following frame numbered 01:12:45:23. This allows precise identification of each frame when editing. The camera operator arranges, at the start of a shoot, the method of frame numbering by adjusting the timecode controls which are usually situated on the side of the camera on the video recorder part of the unit (see figure on page 95).

The choice is between numbering each frame with a consecutive number each time the camera records. This is called 'record run' timecode. Alternatively, the camera's internal clock can be adjusted to coincide with the actual time of day and whenever a recording takes place, the time at that instant will be re-coded against the frame. This is usually called 'time of day' or 'free run' recording. The decision on which type of timecode to record will depend on editing and production requirements (see Timecode and production, page 94).

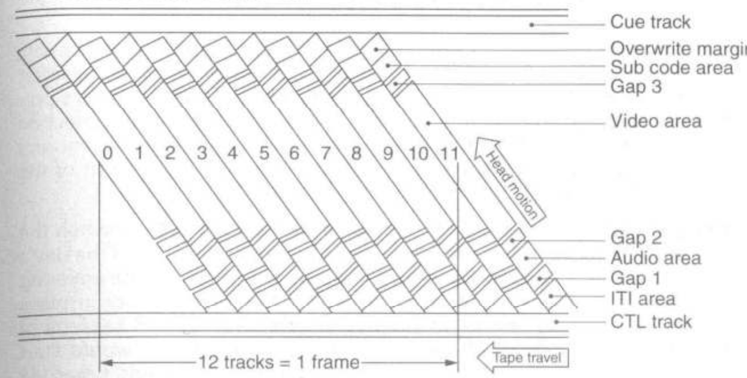
Historically there have been two methods of recording this identification number:

- **Longitudinal timecode:** Longitudinal timecode (LTC) is recorded with a fixed head on a track reserved for timecode. It can be decoded at normal playback speed and at fast forward or rewind but it cannot be read unless the tape is moving as there is no replayed signal to be decoded.
- **Vertical interval timecode:** Vertical interval timecode (VITC) numbers are time-compressed to fit the duration of one TV line and recorded as a pseudo video signal on one of the unused lines between frames. It is recorded as a variation in signal amplitude once per frame as binary digits. 0 equals black and 1 equals peak white. Although they are factory set, if needed, some cameras can be adjusted to insert VITC on two non-consecutive lines. Unlike longitudinal timecode, VITC timecode is recorded as a pseudo TV signal and can be read in still mode which is often required when editing. Longitudinal timecode is useful when previewing the tape at speed. For editing purposes, the two timecode recording methods have complemented each other.

Digital timecode

Digital signal processing has allowed timecode to be stored as digital data in the sub code track of DVCPro and Digital-S tape formats. Because this is written as data it can be read in still mode as well as fast forward/rewind. During editing, timecode can be read when shuttling through the tape to find a shot but can still be read in still mode.

Timecode track (DVCPro)



DVCPro Track Pattern

The sub-code area of the DVCPro track is used to record timecode and user-bit data. It can be read in still mode and during high-speed fast-forward and rewind of the tape.

CTL: control track

This is a linear track recorded on the edge of the tape at frame frequency as a reference pulse for the running speed of the replay VTR. It provides data for a frame counter and can be displayed on the camera's LCD (liquid crystal display). It is important for editing purposes that the recorded cassette has a continuous control track and it is customary to reset to zero at the start of each tape.

When CTL is selected to be displayed, the numbers signifying hours, minutes, seconds and frames are a translation of the reference pulse into a convenient method of displaying tape-elapsed time. Although equivalent, this time is not a read-out of the recorded timecode and if CTL is reset to zero in mid-cassette and the tape rewound, the displayed numbers would count backwards with a minus sign. One of the main purposes of striping a tape for editing purposes is to record a continuous control track (see Editing technology, page 146). To ensure a continuous control track on acquisition, see page 97 for procedure when changing a battery or using a partially recorded cassette. Also be aware that if CTL is selected in mid-cassette and the Reset button is depressed, the control track will reset to zero and will no longer indicate tape-elapsed time.

Timecode and production

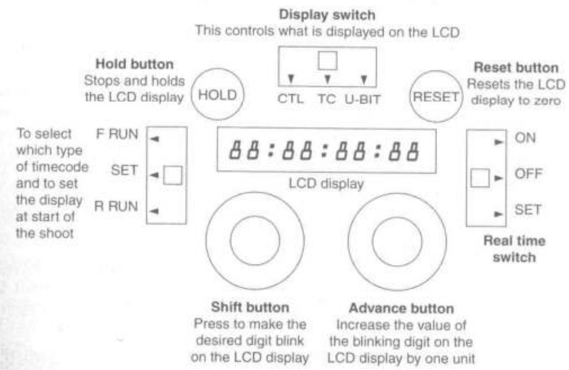
Timecode is an essential tool for editing a programme (see Camerawork and editing, page 144). If a shot log has been compiled on acquisition or in post-production review, the timecode identifies which shots are preselected and structures off-line editing. There are two types of timecode available to accommodate the great diversity in programme content and production methods. The cameraman should establish at the start of the shoot which method is required.

- **Record run:** Record run only records a frame identification when the camera is recording. The timecode is set to zero at the start of the day's operation and a continuous record is produced on each tape covering all takes. It is customary practice to record the tape number in place of the hour section on the timecode. For example, the first cassette of the day would start 01.00.00.00 and the second cassette would start 02.00.00.00. Record run is the preferred method of recording timecode on most productions.
- **Free run:** In free run, the timecode is set to the actual time of day and when synchronized is set to run continuously. Whether the camera is recording or not, the internal clock will continue to operate. When the camera is recording, the actual time of day will be recorded on each frame. This mode of operation is useful in editing when covering day-long events such as conferences or sport. Any significant action can be logged by time as it occurs and can subsequently be quickly found by reference to the time of day code on the recording. In free run (time of day), a change in shot will produce a gap in timecode proportional to the amount of time that elapsed between actual recordings. Missing timecode numbers can cause problems with an edit controller when it rolls back from intended edit point and is unable to find the timecode number it expects there (i.e. the timecode of the frame to cut on, minus the pre-roll time).

Shot logging

An accurate log of each shot (also known as a dope sheet) with details of content and start and finish timecode is invaluable at the editing stage and pre-editing stage. It requires whoever is keeping the record (usually a PA, production assistant) to have visual access to the LCD display on the rear of the camera. As the timecode readout is often situated behind the cameraman's head, it is often difficult for the PA to read although the Hold button will freeze the LCD readout without stopping the timecode. There are a number of repeat timecode readers which are either attached to the camera in a more accessible position, or fed by a cable from the timecode output socket away from the camera or fed by a radio transmitter which eliminates trailing cables. A less precise technique is sometimes practised when using time of day timecode. This requires the camera and the PA's stopwatch to be synchronized to precisely the same time of day at the beginning of the shoot. The PA can then refer to her stopwatch to record timecode shot details. It is not frame accurate and requires occasional synchronizing checks between camera and watch, with the watch being adjusted if there has been drift.

Setting timecode



To set record run timecode

1. Set DISPLAY switch to TC.
2. Set REAL TIME switch to OFF.
3. Set F-RUN/R-RUN to SET position. The display will stop at its existing value, and the first numeral (representing hours) will start to flash.
4. Press RESET to zero counter if required.
5. Switch F-RUN/SET/R-RUN to R-RUN position.
6. The timecode will increase each time the camera records.

If you wish to use the hour digit to identify each tape (e.g. 1 hour equals first tape, 2 hours equals second tape, etc.), set the hour timecode with the SHIFT and ADVANCE button.

SHIFT: Press to make the hour digit blink.

ADVANCE: Press to increase the value of the blinking digit by one unit to equal the cassette tape in use.

If the F-RUN/R-RUN switch should be accidentally knocked to the SET position, the timecode will not increase during a recording and only the static number will be recorded. Also, if display is switched to CTL and SET is selected, timecode will be displayed and ADVANCE and SHIFT will alter its value but leave the CTL value unaffected. CTL can only be zeroed, otherwise it will continue to increase irrespective of tape changes.

Real time

1. Set DISPLAY switch to TC.
2. Set REAL TIME switch to OFF.
3. Set F-RUN/R-RUN to SET.
4. Press RESET to zero counter.
5. Set the time of day with the SHIFT and ADVANCE buttons until the timecode reads a minute or so ahead of actual time. The numeral that is selected to be altered by the SHIFT button will blink in the SET position:

   SHIFT: Press to make the desired digit blink.

   ADVANCE: Press to increase the value of the blinking digit by one unit.
6. When real time equals 'timecode time', switch to F-RUN and check that timecode counter is increasing in sync with 'real' time. If you switch back to SET the display stops, and does not continue until you return to F-RUN (i.e. the clock has been stopped and is no longer in step with the time of day it was set to).

User-bit: If any USER-BIT information is required, then always set up user-bit information first. Wait approximately 20 seconds after camera is turned on.

Timecode lock

So far we have discussed setting the timecode in one camera but there are many occasions when two or more camcorders are on the same shoot. If each camera simply recorded its own timecode there would be problems in editing when identifying and synchronizing shots to intercut. The basic way of ensuring the timecode is synchronized in all cameras in use is by cables connected between the TC OUT socket on the 'master' camera to the TC IN socket on the 'slave' camera. Another cable is then connected to the TC OUT of the first 'slave' camera and then connected to the TC IN of the second 'slave' camera and so on although in a multi-camera shoot, it is preferable to genlock all the cameras to a central master sync pulse generator. This is essential if, as well as each camera recording its own output, a mixed output selected from all cameras is also recorded.

The TC OUT socket provides a feed of the timecode generated by the camera regardless of what is displayed on the LCD window. A number of cameras can be linked in this way but with the limitation of always maintaining the 'umbilical' cord of the interconnecting cables. They must all share the same method of timecode (i.e. free run or record run) with one camera generating the 'master' timecode and the other cameras locked to this. The procedure is:

- Cable between cameras as above.
- Switch on the cameras and select F-Run (free run) on the 'slave' cameras.
- Select SET on the 'master' camera and enter the required timecode information (e.g. zero the display if that is the production requirement). Then switch to record-run and begin recording.
- In turn start recording on the first 'slave' camera, and then the second and so on. Although recording can start in any order on the 'slave' cameras, the above sequence routine can identify any faulty (or misconnected!) cables.
- All the cameras should now display the same timecode. Check by audibly counting down the seconds on the 'master' whilst the other cameramen check their individual timecode read-out.
- During any stop/start recordings, the 'master' camera must always run to record before the 'slave' cameras. If there are a number of recording sessions, the synchronization of the timecode should periodically be confirmed.

Often it is not practical and severely restricting to remain cable connected and the cameras will need to select free run after the above synchronization. Some cameras will drift over time but at least this gives some indication of the time of recording without providing 'frame' accurate timecode. Alternatively, a method known as 'jam sync' provides for a 'rough' synchronization over time without cables (see opposite).

Jam sync

The set-up procedure is:

- From the 'master' TC OUT socket connect a cable with a BNC connector to the 'slave' TC IN.
- Power up the cameras and select free run on the 'slave' camera.
- On the 'master' camera select SET and enter 'time of day' some seconds ahead of the actual time of day.
- When actual time coincides with LCD display switch to free run.
- If both cameras display the same timecode, disconnect the cable.
- Because of camera drift, the above synchronization procedure will need to be repeated whenever practical to ensure continuity of timecode accuracy.

Pseudo jam sync

Pseudo jam sync is the least accurate timecode lock, but often pressed into service as a last resort if a BNC connector cable is damaged and will not work. The same time of day in advance of actual time of day is entered into all cameras (with no cable connections), and with one person counting down from their watch, when actual time of the day is reached, all cameras are simultaneously (hopefully) switched to F-RUN. This is obviously not frame accurate and the timecode error between cameras is liable to increase during the shoot.

Reviewing footage

Broadcast camcorders are equipped with a memory, powered by a small internal battery similar to the computer EPROM battery. It will retain some operational values for several days or more. There should be no loss of timecode when changing the external battery but precautions need to be taken if the cassette is rewound to review recorded footage or the cassette is removed from the camera and then reinserted.

After reviewing earlier shots, the tape must be accurately reset to the point immediately after the last required recorded material. On many cameras, timecode will be set by referring to the last recorded timecode. Reset to the first section of blank tape after the last recorded material, and then use the return or edit search button on the lens or zoom control so that the camera can roll back and then roll forward to park precisely at the end of the last recorded shot. This is an edit in-camera facility. CTL will not be continuous unless you record from this point. There will be a gap in record-run timecode if you over-record material as the timecode continues from the last recorded timecode (even if this is now erased), unless you reset timecode. CTL cannot be reset to follow on continuously but can only be zeroed. Allow 10 seconds after the start of the first recording to ensure CTL stability in post-production.

Recording on a partly recorded cassette

Insert the cassette and replay to the point at which the new recording is to start. Note the timecode at this point before you stop the replay, otherwise, with the tape stopped, the timecode will read the last timecode figure from the previous tape/shot. Select SET and enter a timecode that is a few seconds in advance of the noted timecode so it will be obvious in editing that timecode has been restarted. CTL cannot be adjusted other than zeroed. To ensure edit stability, post-production requires a 10-second run-up on the next recorded shot before essential action. (See also page 99.)

Menus

Digital signal processing allows data to be easily manipulated and settings memorized. In nearly all digital camera/recorder formats, all the electronic variables on the camera can be stored as digital values in a memory and can be controlled via menu screens displayed in the viewfinder. These values can be recalled as required or saved on a removable storage file. This provides for greater operational flexibility in customizing images compared to analogue work. Menus therefore provide for a greater range of control with the means to memorize a specific range of setting. There are, however, some disadvantages compared to mechanical control in day-to-day camerawork. Selecting a filter wheel position is a simple mechanical operation on many cameras. If the selection is only achievable through a menu (because the filter wheel position needs to be memorized for a set-up card), time is taken finding the required page and then changing the filter wheel setting.

Adjustment

Access to the current settings of the electronic values is by way of menus which are displayed, when required, on the viewfinder screen. These menus are accessed by using the menu switch on the camera. Movement around the menus is by button or toggle switch that identifies which camera variable is currently selected. When the menu system is first accessed, the operation menu pages are usually displayed. A special combination of the menu controls allows access to the user menu which, in turn, provides access to the other menus depending on whether or not they have been unlocked for adjustment. Normally only those variables associated with routine recording (e.g. gain, shutter, etc.) are instantly available. Seldom used items can be deleted from the user menu to leave only those menu pages essential to the required set-up procedure. Menu pages are also available on the video outputs. The values that can be adjusted are grouped under appropriate headings listed in a master menu.

Default setting

With the opportunity to make adjustments that crucially affect the appearance of the image (e.g. gamma, matrix, etc.), it is obviously necessary that the only controls that are adjusted are ones the cameraman is familiar with. As the cliché goes, if it ain't broke, don't fix it. If you have the time and are not under recording pressure, each control can be tweaked in turn and its effect on the picture monitored. This may be a valuable learning experience which will help you customize an image should a special requirement occur. There is obviously the need to get the camera back to square one after experimenting. Fortunately there is a safety net of a factory setting or default set of values so that if inadvertently (or not) a parameter is misaligned and the image becomes unusable, the default setting can be selected and the camera is returned to a standard mode of operation.

A typical set of sub-menus would provide adjustment to:

- **Operational values:** The items in this set of menus are used to change the camera settings to suit differing shooting conditions under normal camera operations. They would normally include menu pages which can alter viewfinder display, viewfinder marker aids such as safety zone and centre mark, etc., gain, shutter selection, iris, format switching, monitor out, auto-iris, auto-knee, auto set-up, diagnosis.
- **Scene file:** These can be programmed to memorize a set of operational values customized for a specific camera set-up and read to a removable file.
- **Video signal processing:** This menu contains items for defining adjustments to the image (e.g. gamma, master black level, contour correction, etc.) and requires the aid of a waveform monitor or other output device to monitor the change in settings.
- **Engineering:** The engineering menu provides access to all of the camera set-up parameters, with only selected parameters available in the master menu to avoid accidental changes to the settings.
- **Maintenance:** This menu is mainly for initial set-up and periodic maintenance, and normally not available via the master menu.
- **Reference file (or system configuration):** This file contains factory settings or initial customization of reference settings to meet the requirements of different users. It is the status quo setting for a standard operational condition. This menu is not usually accessible via the master menu and should never be adjusted on location except by qualified service personnel. Never try to adjust camera controls if you are unsure of their effect and if you have no way of returning the camera set-up to a standard operational condition.

(continued from page 97)

Battery changes when timecode locked

A battery change on the 'master' camera requires all cameras to stop recording if synchronous timecode is an essential production requirement. A battery change on a 'slave' camera may affect any camera that is being supplied by its timecode feed. If synchronous timecode is critical, either all cameras use mains adaptors if possible, or arrange that a battery change occurs on a recording break at the same time on all cameras. Check timecode after re-powering up.

Mini DV cameras

DV timecode circuitry is less sophisticated than many broadcast formats and if a cassette is parked on blank tape in mid-reel, the camera assumes that it is a new reel and resets the timecode to 00:00:00. There may not be an edit search/return facility and so after reviewing footage, park the tape on picture of the last recorded material and leave an overlap for the timecode to pick up and ensure continuous timecode. In all formats after rewinding and reviewing shots, inserting a partially used cassette, changing batteries or switching power off, use the edit search/return facility to check at what point the tape is parked. Reset timecode and zero CTL as required.

Scene files

A scene file is a method of recording the operational settings on a digital camera. In use it is like a floppy disk on a computer and can be removed from the camera with the stored values and then, when required, loaded back into the camera to provide the memorized values. The operational variables on a camera such as filter position, white balance, gain, speed of response of auto-exposure, shutter speed, electronic contrast control, the slope of the transfer characteristic (gamma), and its shape at the lower end (black stretch) or the upper end (highlight handling and compression), and the matrix, all affect the appearance of the image. The same shot can change radically when different settings of several or many of the above variables are reconfigured. If for production reasons these variables have been adjusted differently from their standard settings (e.g. a white balance arranged to deliberately warm up the colour response), it may be necessary, for picture continuity, to replicate the customized appearance over a number of shots recorded at different locations, or on different days. The scene file allows an accurate record to be kept of a specific set of operational instructions.

An additional useful feature of a removable record of a camera set-up occurs when a number of cameras (of the same model) are individually recording the same event and their shots will be edited together (see also Timecode, page 92). Normal multi-camera coverage provides for each camera's output to be monitored, matched and adjusted before recording or transmission. Individual camcorders, if they not aligned, could produce very noticeable mismatched pictures when intercut. To avoid this, all cameras can be configured to the same set-up values by transferring a file card and adjusting each camera with the same stored values. A file card can be compiled, for example, that allows an instant set-up when moving between location and a tungsten-lit studio.

Programming the camera

The flexibility of memorized values has led to the creation of a range of software cards for specific makes of cameras which provide a set 'look' instantly. Among the choices available, for example, are sepia, night scenes or the soft image of film. Other cards produce a warm ambience or a colder-feeling atmosphere. Scene files that duplicate the appearance of front-of-lens filters are also available and these electronic 'gels' provide a quick way of adding an effect. There are also pre-programmed scene files that help to 'normalize' difficult lighting conditions such as shooting under fluorescent lighting or scenes with extreme contrast. Low-contrast images can also be produced with the option to selectively control contours in areas of skin, offering more flattering rendition of close-ups. Fundamentally altering the look of an image at the time of acquisition is often irreversible and unless there is the opportunity to monitor the pictures on a high-grade monitor in good viewing conditions, it may be prudent to leave the more radical visual effects to post-production.

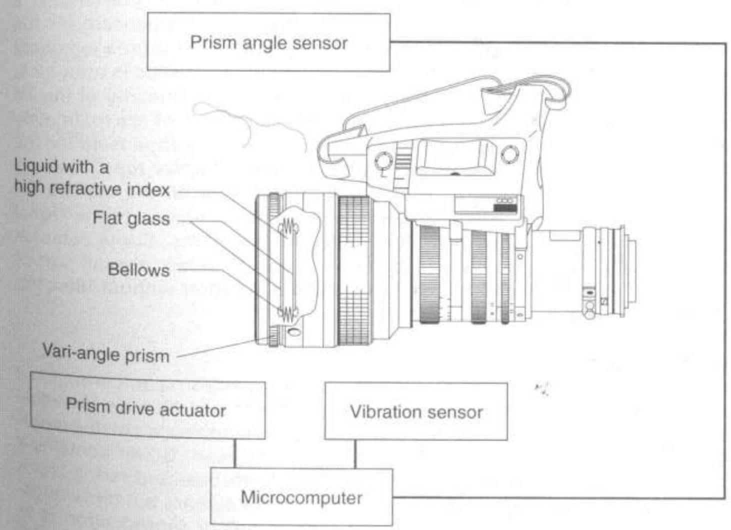
Image stability

Many DV format cameras have an electronic image stabilization facility. This is intended to smooth out unintended camera shake and jitter when the camera is operated hand-held. Usually these devices reduce resolution. Another method of achieving image stability, particularly when camera shake is the result of consistent vibration, is by way of optical image stabilization.

The optical image stabilizer on the CanonXL1 is effected by a vari-angle prism formed from two glass plates separated by a high-refracted-index liquid. A gyro sensor in the camera detects vibration and feeds data to the prism, which reacts by changing shape. This bends the rays of light to keep the image stable when it reaches the CCDs. The CCD image is examined to check for any low-frequency variations that have not been compensated for by the gyro. This data is fed back to the prism to further reduce vibration. Other devices can be 'tuned' to a consistent vibration such as produced when mounting a camera in a helicopter. Some forms of image stabilization add a slight lag to intended camera movement giving an unwanted floating effect.

Other equipment uses a variety of techniques to track a moving target such as off-shore power boat racing from a moving camera to keep the main subject in the centre of frame. The camera can be locked-on to a fast-moving subject like a bobsleigh and hold it automatically framed over a designated distance.

A schematic showing the principles of image stabilization



ew

The nature of sound

What is sound?

When there is a variation of air pressure at frequencies between approximately 16 to 16,000 Hz, the human ear (depending on age and health) can detect sound. The change in air pressure can be caused by a variety of sources such as the human voice, musical instruments, etc. Some of the terms used to describe the characteristics of the sounds are:

Sound waves are produced by increased air pressure and rarefaction along the line of travel.

Frequency of sound is the number of regular excursions made by an air particle in 1 s (see figure opposite).

Wavelength of a pure tone (i.e. a sine wave, see figure opposite) is the distance between successive peaks.

Harmonics are part of the sound from a musical instrument which are a combination of frequencies that are multiples of the lowest frequency present (the fundamental).

Dynamic range is the range of sound intensities from quietest to loudest occurring from sound sources. This may exceed the dynamic range a recording or transmission system is able to process without distortion.

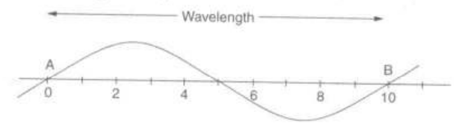
Decibels: Our ears do not respond to changes in sound intensity in even, linear increments. To hear an equal change in intensity, the sound level must double at each increase rather than changing in equal steps. To match the ear's response to changes in sound intensity, it is convenient to measure the changes in the amplitude of the audio signal by using a logarithmic ratio – decibels (dB). Decibels are a ratio of change and are scaled to imitate the ear's response to changing sound intensity. If a sound intensity doubles in volume then there would be a 3 dB increase in audio level. If it was quadrupled, there would be a 6 dB increase. To hear an equal change in intensity, the sound level must double at each increase rather than changing in equal steps.

Loudness is a subjective effect. An irritating sound may appear to be a great deal louder than a sound we are sympathetic to (e.g. the sound of a neighbour's cat at night compared to our own practice session on a violin!).

Phase of a signal becomes important when signals are combined. Signals in phase reinforce each other. Signals out of phase subtract from or cancel out each other (see figure opposite).

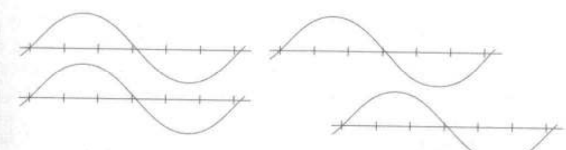
Pitch is the highness or lowness of the frequency of a note.

Wavelength and frequency



The time taken for a complete cycle of pure tone (A) to begin to repeat itself (B) is the frequency of the signal and is measured in cycles per second (Hz), e.g. 50 Hz = 50 cycles per second. Frequency is inversely proportional to wavelength. For example, a high-frequency sound source of 10,000 Hz produces sound with a short wavelength of 3.4 cm. A low-frequency sound source of 100 Hz produces sound with a longer wavelength of 3.4 m. Frequency multiplied by wavelength equals the speed of sound (335 m/sec) in cold air. It is faster in warm air.

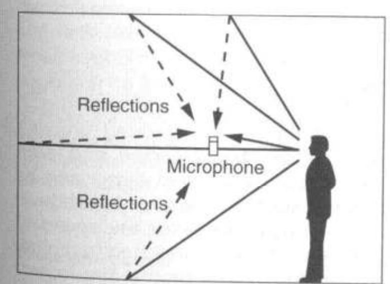
Phase



In-phase signal

Out-of-phase signal

Acoustics



- **Reverberation** relates to the time delay before sounds reflected from the wall and other surfaces reach the microphone.
- **Standing waves** effect is due to the room having resonances where the parallel walls enhance certain frequencies.

Audio requires processing in order for it to be recorded or transmitted. This may include:

- **Equalization:** the process of adjusting the frequency response of the signal usually banded into control of high, medium and low frequencies. Switched filters are used to remove low-frequency rumble, etc.
- **Limiters:** these prevent the signal from exceeding a predetermined level.
- **Compression:** the dynamic range (see page 205) of some sound sources (e.g. an orchestral concert) can exceed that which can be transmitted. If manually riding the level is not always feasible, sound compression can be used. The aim is to preserve as much of the original dynamic range by judicious use of 'threshold' – the level at which compression starts; 'slope or ratio', which controls the amount of adjustment; and 'attack and release', which determines the speed at which the compression equipment will react to changes.

Digital audio

It is important to have a basic understanding of how the audio is converted into digital information so that errors are not made in setting up the equipment. The audio signal is sampled at a constant rate like a series of pulses. For each of these pulses, the level of the sound is checked and this value is given a number. This number is transferred into binary code and this code is recorded as the digital information. The actual recording is therefore a string of codes, each representing the level of the audio at a particular moment in time. In order to achieve a good frequency response, the sampling is carried out at a very high frequency; 48,000 samples per second (48 kHz) is used for most professional systems. The level of the sound to be converted into binary numbers must also have sufficient steps to ensure accuracy, which is called quantizing. With the 16-bit system employed by most camera/recorders, 65,536 finite levels can be represented. Put simply, this means that in order to encode and decode the signals, all the systems must operate at the same sampling rate and the signal level must never exceed the maximum quantization step or no value will be recorded.

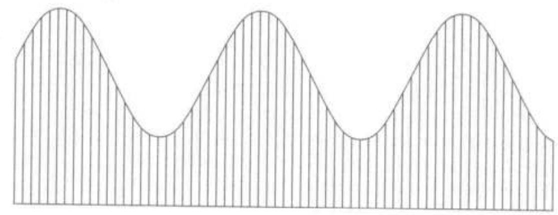
Digital audio recording

Video recording resolved the problem of recording a much higher frequency spectrum than analogue audio on tape by means of a rotating record/replay head as well as moving the tape. Digital stereo audio needs to record at 1.4 MHz and the DAT (digital audio tape) system was developed to meet this criteria. For editing purposes, an identical analogue audio track is added (sometimes called cue track) as rocking a slow moving digital signal past a head produces no sound, unlike an analogue signal. The frequency response and signal-to-noise ratio of digital recorders are superior to analogue machines and repeated copying results in far less degradation. Drop out can be corrected and print through has less significance or is eliminated. Wow and flutter can be corrected by having a memory reservoir system from which data is extracted at a constant rate eliminating any variation in the speed at which it was memorized. In general, when a signal is converted to digital, there is more opportunity to accurately rebuild and rectify any imperfections (see Error correction opposite), and to allow signal manipulation.

Sampling and the conversion of the amplitude of each sample (quantizing) is carried out at precisely regulated intervals. The precision of these intervals must be faithfully preserved in order to accurately mimic the original analogue signal. The binary data produced by the quantization must be accurately timed. Coding converts the data into a regular pattern of signals that can be recorded with a clock signal. When the signal is replayed, the recorded clock information can be compared with a stable reference clock in the replay equipment to ensure the correct timing of the digital information. The timing and reference information not only ensures an accurate decoding of the signal, but also allows error correction techniques to be applied to the samples.

Simplified audio digital process

Sampling



The analogue audio signal is split into samples at a fixed rate of 48,000 samples per second (48 kHz). The height (amplitude) of each sample (each vertical line in the figure) is then measured in a process known as quantizing. The high number of samples is to ensure that the analogue signal is faithfully mimicked because changes in signal amplitude between samples would be lost and distortion would occur in the digitalizing process. The sampling frequency needs to be at least twice the maximum audio frequency that it is required to reproduce. Filtering the audio signal is required to ensure that no audio exists at more than half the sample frequency.

Typical sampling rates that have been chosen include: for the transmission systems such as NICAM 728, the system design uses 32 kHz giving a practical limit to the audio of 15 kHz; for compact disc the rate has been set at 44.1 kHz whilst many broadcasting stations set the rate at 48 kHz.

Quantization

The amplitude of each sample needs to be converted into a binary number. The greater the range of numbers, the more accurately each sample can be measured. To simplify this measurement, each sample is converted into a whole number and the accuracy of this conversion will depend on how many divisions are chosen to make the representation. For example, the height of people could be measured in metres ignoring centimetres. There would be 2 metre high people or 3 metre high people and no heights in between. This would not reflect the variation in people's height. In quantization, if there are a greater number of levels used in the encoding process the decoded signal will be nearer to the original sound (see Binary counting, page 25).

Error correction

In addition to quantizing errors, other defects can occur in analogue/digital conversions.

- **Burst error** is the loss of a number of consecutive samples when recorded. It is possible to minimize this by arranging the data in a non-sequential order by a controlled code that can be reassembled in its correct temporal order when decoding. This effectively separates the missing data, ensuring that consecutive values are less likely to be lost.
- **Random error** is the loss of single samples due to noise or poor signal quality. Correction systems can either replace the missing sample with a copy of the preceding sample (although this is only useful for a very few consecutive samples), or replace it with an average of the preceding and succeeding data. If the error cannot be resolved the system will mute until sufficient samples are available for the conversion to continue.

Camcorder audio facilities

Most professional systems have four digital audio tracks. These all have the same specifications and can all be recorded with the picture or used for insert editing. The camera/recorder will have the ability to select any of these as mic or line inputs and will provide phantom voltages for the mics if required. On many digital camera/recorders, audio input/channel selections are not made with switches on the camera but are enabled via a menu displayed on an LCD screen positioned on the side of the camera. Many allow for adjustments such as noise reduction, bass filters, equalization, signal limiting, routeing to tracks 3 and 4, routeing to cue track, monitor signal and level, timecode adjustment. These settings can be memorized on scene files.

Cue track

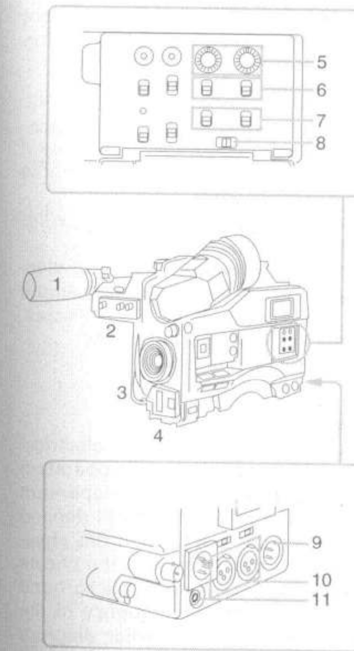
As well as the four digital audio tracks, the digital formats also allow for a longitudinal audio cue track. This can be used for timecode or have a guide version of the sync, or feature audio to assist in editing. This track will be easier to listen to when the tape is being played at a non-standard speed whereas digital tracks will be decoded in bursts, omitting material when played faster than standard and repeating material when slower. The cue track can be recorded at any time, either with the picture or inserted separately. The information to be recorded on the cue track is normally set via the set-up menu in the viewfinder or on the camera/recorder output.

On the higher specification camera/recorders, a return output of audio from the camera/recorder to separate audio mixer no longer needs to come from the tiny headphone socket. Instead it is fitted with a male XLR socket on the rear of the camera. The track or mix of tracks and the level of the signal to be fed from this socket may also be adjusted via the menu-driven software on the camera/recorder.

Audio inputs

- **Mic (front):** When an audio channel is switched to this position, any microphone connected to the front audio input can be selected.
- **Mic (rear):** This position enables the user to plug a microphone into the connector at the rear of the camera. On some camera/recorders, a separate switch can be found under the mic input marked +48 V (phantom power) that supplies power to the microphone if required.
- **Line:** When an audio channel is switched to this position, an external audio mixer can be connected. All microphones to be used are connected and controlled via this mixer and its input sensitivity to the Betacam is 0 dB, that is known as line level. Line input can also be used for a feed from a public address system mixer before amplification.

Digital camera audio controls (position and facilities will vary depending on make and model)



1 **On-camera microphone.**
2 **Audio channel recording level indicator switch**: This switch determines whether the recording level of audio channel is displayed on the viewfinder screen.
3 **On-camera microphone cable input.**
4 **MIC (microphone) AUDIO LEVEL control**: If the AUDIO IN switches are both set to FRONT, you can adjust the recording level of the microphone. If the AUDIO IND switch is set to ON, you can watch the audio level display in the viewfinder while adjusting the level.
5 **AUDIO LEVEL CH-1/CH-2** (audio channel 1 and channel 2 recording level) controls: These controls adjust the audio level of channels 1 and 2 when you set the AUDIO SELECT CH-1/CH-2 switches to MAN.
6 **AUDIO SELECT CH-1/CH-2** (audio channel 1 and channel 2 select) switches: These switches set the audio level adjustment for channels 1 and 2 to MANUAL or AUTO.
7 **AUDIO IN** (audio input) switches: These switches select the audio input signals for audio channels 1 and 2. The input signal source is either:
FRONT: The input signal source is the MIC IN connector.
REAR: The input signal source is the AUDIO IN CH-1/CH-2 connectors.
8 **CUE IN** (cue track input) switch: This switch selects the input signals for recording the cue track.
CH-1: Channel 1 input signal MIX; Mixed input signal of channels 1 and 2;
CH-2: Channel 2 input signal.
9 **AUDIO OUT** (audio output) connector (XLR type, 3-pin, male): This connector outputs the sound selected by the MONITOR switch.
10 **AUDIO IN CH-1/CH-2** (audio channel 1 and channel 2 input) connectors (XLR type, 3-pin, female) and LINE/MIC/+48 V ON (line input/microphone input/external power supply +48 V on) selectors: These are the audio input connectors for channels 1 and 2, to which you can connect a microphone or other audio sources.
The LINE/MIC/+48 V ON selectors select the audio input signal source connected to these connectors, as follows:
LINE: Line input audio equipment.
MIC: A microphone with internal batteries.
+48 V ON: A microphone with an external power supply system.
11 **DC OUT** (DC power output) connector: This connector supplies power for a portable tuner. Do not connect anything other than a UHF portable tuner to this connector.

Microphones

Choosing which microphone to use in a specific production environment will require consideration to be given to some or all of the following factors affecting a microphone's performance:

- nature of the sound source (e.g. speech, pop group drums, bird song, etc.);
- matching the technical characteristics of the microphone to the sound source (e.g. frequency response, transient response, ability to handle high/low levels of sound (sensitivity) and directional properties);
- mechanical characteristics such as size, appearance, robustness, wind shields, affected by humidity, stability, reliability, etc.;
- compatibility – cable plugs, connectors and adaptors, matching electrical impedance, cable run required, interface with other audio equipment;
- powering arrangements (see condenser microphone opposite);
- programme budget, microphone cost/hire and availability.

Frequency response of a microphone

Microphones convert acoustical energy (sound waves) into electrical power, either by exposing one side of a diaphragm (pressure-operated) to air pressure variations or by exposing both sides of the diaphragm (pressure-gradient). Directional response of the microphone will depend upon which method is chosen or a combination of both and the physical design of the microphone. This is an important factor in the choice of microphone on location to avoid or reduce unwanted background sound. Response of the microphone is also related to frequency of the audio signal. Directional response can be plotted on a polar diagram which places the microphone in the centre of a circular graph indicating the sensitivity at each angle with respect to the front axis of the microphone (see polar diagram opposite).

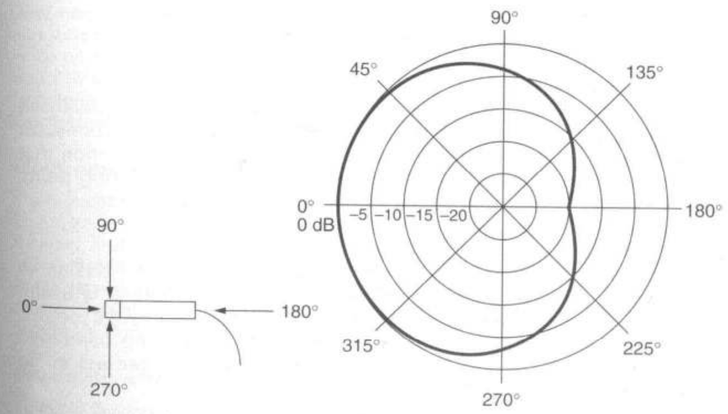
There are three basic types of microphone: moving coil, ribbon, and condenser.

- **The moving coil or dynamic:** The polar diagram of this microphone can be omni-directional or cardioid, i.e. having a dead side to the rear of the microphone. This type of microphone can be used as a reporter's 'hand held' but care must be taken in its handling. They are less sensitive to wind noise than other microphones and are often fitted with wind protection within the body of the unit although they may need extra protection in extreme conditions, where foam windshields should be sufficient. Windshields give some protection against rain and provide the microphone with a waterproof cover for short periods.
- **The ribbon:** This microphone's polar response is 'figure of eight' – open front and rear, but closed to the sides. This microphone has been used mainly in radio studios with the interviewer and interviewee sitting across a table facing one another.

- **The condenser:** The condenser microphone achieves the best quality of the three and requires a power supply to make it operate. This can be supplied by an 'in-line' battery supply although many condenser microphones can be powered directly from the camera or audio mixer unit, the supply being known as the 48 V phantom power. There are other forms of condenser microphone power supply known as 12 V A/B and T power. Always check that the mic power supply matches the microphone to be used *before* connection.

Microphone sensitivity

The sensitivity or output of a microphone is expressed in units of millivolt/Pascal (mV/Pa) but more commonly quoted in comparison to 0 dB line level in decibels (dB). The more negative the dB figure the less sensitive the microphone. For example, the output of a hand-held moving coil microphone will be in the region of –75 dB and is less sensitive than the output of a short condenser microphone which will be around –55 dB. Usually the camera microphone input sensitivity is around –70 dB, therefore most types of microphone can be used directly into the camera.



Power supplies to microphones

Before plugging a microphone into an audio input, check the position of the phantom power switch. Switch the supply to ON only if the condenser microphone requires a 48 V supply. For an 'in-line' condenser microphone (one fitted with a battery) check the condition and charge of the batteries in the microphone. Some condenser microphones require 12 V A/B, sometimes known as T power. These are not compatible with phantom systems as the voltage is supplied on different pins of the XLR connector. A convertor can be placed in the line, or the mic could be powered by a separate unit.

Audio levels

Sound monitoring

Monitoring audio quality is difficult in single person camera/recorder operations. If there is time, a double-sided headset can be used to check quality but more often time is at a premium and single-sided headsets (or none) are used. It is only by listening to the sound that an evaluation can be made. Audio level meters in the viewfinder and on the recorder side panel only asses loudness and do not identify the source of the sound. The least one can achieve with the intelligent use of a meter is to avoid a sound overload pushing the audio into the limiting circuit when its level exceeds the maximum permissible recording level. Beyond this point, the audio will be progressively distorted with no increase in loudness. Listening to the audio establishes production priorities (subject prominence, disturbing background, sound perspective, etc.). Metering the audio allows the correct technical requirements to be fulfilled. The very least that can done is to have an audible sound check to confirm that audio is being recorded. There is usually provision for a confidence audio check on the camera speaker by switching between the audio tracks or combining (mix). E-E (electronics to electronics) is a facility that allows a check to be made on the signal before it is recorded.

Audio meters

There are two types of mechanical meter used to measure analogue audio levels. A peak programme meter (PPM) measures peaks of sound intensity. A programme volume meter (VU) measures average level of sound and gives a better indication of loudness but at the expense of missing brief high-intensity peaks that could cause distortion. Many digital cameras are fitted with electronic bargraph metering. These may have LED, plasma or liquid crystal displays that appear to be continuous from top to bottom. These are peak response meters but some have the facility to switch their response to VU mode where they will imitate the scale and ballistic response of a VU meter.

Sound monitoring through the viewfinder

If you are using a single microphone, use track one (although check the post-production audio policy of the commissioning agent). Having connected the mic and selected mic position, turn the gain control at the side panel of the camera to maximum. Select the viewfinder for metering of audio. Obtain a sound level and adjust the front gain control on the viewfinder to register normal audio level on the viewfinder audio indicator. Reduce rear audio gain on side panel if sufficient attenuation cannot be achieved. You now have attenuation and gain should it be required on the front audio control.

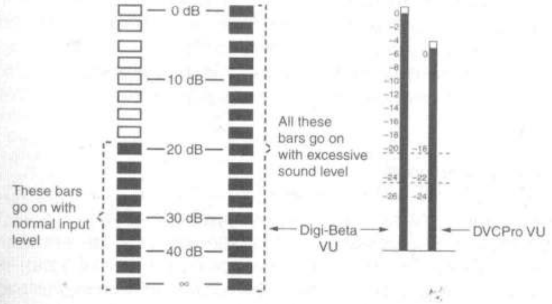
Zero level voltage

Just as light is converted into a TV signal with a standard peak amplitude of 0.7 V so sound energy when it is converted into electrical energy requires a standard signal, a baseline voltage to which all changes can be referred. This is known as zero level and the standard voltage selected is 0.775 V – the voltage across 600 Ω (a common input and output impedance of audio equipment) when 1 mW is developed. 1000 Hz is the frequency of the standard zero level signal. Increasing or decreasing sound intensity will alter the level of this voltage.

Digital audio meters

The audio meter on a digital camera is very different to that on an analogue device as it shows values up to the maximum signal that can be encoded. This is calibrated from infinity (no signal) to zero (maximum level). It will also be noted that a line-up level (–20 dB) is marked with a solid diamond shape or square on the scale (see figure). This –20 dB point is used as the reference when aligning an external device such as a separate mixer. When taking a level prior to recording, it is safe to allow peaks to be well below 0 (maximum level). –12 dB to –8 dB is fine for normal peaks, ensuring the signal is properly encoded and the safety margin allows for any unexpected peak. Limiters are built into the system to prevent loss of signal should levels become too high, but as signal noise is not a problem (unlike analogue systems) holding the levels down is acceptable.

If the audio level is too high it will automatically be limited. Sound level increasing above this preset point will be progressively distorted with no increase in loudness. The gain of the audio system must be reduced at the point where the level is going into the clipper. Adjustment of level further down the audio chain will not correct the distortion.



Zero level on Digi-Beta VU = 20 dB. On the DVCPro VU it is 18 dB.

Dynamic range

The intensity of sound is a function of the pressure variation set up in the atmosphere. Intensity is proportional to pressure squared. A microphone is used to convert sound energy into electrical energy and the voltage produced is proportional to the sound pressure. The range of intensities from quietest to loudest is the dynamic range of that sound situation. For example, the ratio of the loudest sound produced by an orchestra to the quietest sound can be as much as 60–70 dB in an orchestral performance. This dynamic range is greater than can be transmitted and therefore sound control and possibly sound compression is required when recording large variations in sound levels.

Location safety

Individual responsibility

Health and safety legislation obliges you to take reasonable care of your own health and safety and that of others who may be affected by what you do or fail to do. You also have a responsibility to cooperate, as necessary, to ensure satisfactory safety standards. If you comply with the requirements for safety and something goes wrong, then your employer will be held to account. If you fail to comply, you may lose any claim for compensation for injury and could even be prosecuted as an individual. What you must do is:

- Follow the safety requirements and any instructions you are given, especially in relation to emergencies (e.g. know the location of fire exits).
- Ask for further information if you need it and report accidents (or a near miss!) and any dangerous situations or defects in safety arrangements.
- Do not interfere with or misuse safety systems or equipment.
- Work within the limits of your competence which means a knowledge of best practice and an awareness of the limitations of one's own experience and knowledge.

Assessing risk

The key to good, safe working practices is to assess any significant risk and to take action to eliminate or minimize such risks. The procedure is:

- identify precisely what is required in the production;
- identify any potential hazards in that activity;
- identify the means by which those risks can be controlled.

The key terms in risk assessment are:

- **Hazard:** the inherent ability to cause harm.
- **Risk:** the likelihood that harm will occur in particular circumstances.
- **Reasonably practicable:** the potential improvement in safety is balanced against the cost and inconvenience of the measures that would be required. If the costs and inconvenience do not heavily outweigh the benefits, then the thing is reasonably practicable and should be done.
- **Residual risk:** the risk remaining after precautions have been taken.

An example

It is proposed to shoot from a camera hoist near overhead power lines. The power lines are a **hazard**. Touching them could result in death. What is the likelihood (**risk**) that harm will occur in particular circumstances? There may be the risk of a high wind blowing the hoist onto the power lines. Is the weather changeable? Could a high wind arise? What is **reasonable and practical** to improve safety? The obvious action is to reposition the hoist to provide a usable shot but eliminate all risk of it touching the power lines. As weather is often unpredictable, the hoist should be repositioned as the costs and inconvenience do not heavily outweigh the benefits. There remains the **residual risk** of operating a camera on a hoist which can only be partially reduced by wearing a safety harness.

A checklist of potential location safety hazards

- **Boats**: It is essential to wear life lines and life-jacket when operating on a boat or near water such as on a harbour wall.
- **Confined spaces:** Check the quality of air and ventilation when working in confined spaces such as trenches, pipes, sewers, ducts, mines, caves, etc.
- **Children** are a hazard to themselves. When working in schools or on a children's programme, check that someone is available and responsible to prevent them touching or tripping over cables, floor lamps, camera mountings, etc.
- **Explosive effects and fire effects** must be regulated by a properly trained effects operator and special care should be taken with those effects that cannot be rehearsed.
- **Excessive fatigue** is a safety problem when operating equipment that could cause damage to yourself or others and when driving a vehicle on a long journey home after a production has finished.
- **Forklift trucks** must have a properly constructed cage if they are to carry a cameraman and camera.
- **Lamps:** All lamps should have a safety glass/safety mesh as protection against exploding bulbs. Compact source discharge lamps must always be used with a UV radiation protective lens. Lamps rigged overhead must be fitted with a safety bond. Check that lamp stands are secured and cabled to avoid being tripped over and that they are securely weighted at the base to prevent them being blown over.
- **Location safety:** In old buildings, check for weak floors, unsafe overhead windows, derelict water systems and that the electrical supply is suitable for the use it is put to. Check the means of escape in case of fire and the local methods of dealing with a fire. Check for the impact of adverse weather and in remote locations, the time and access to emergency services.
- **Noise:** High levels of location noise (machinery, etc.), effects (gunshots, explosions) as well as close working to foldback speakers can damage hearing. Stress will be experienced attempting to listen to talkback with a very high ambient noise. Wear noise-cancelling headsets. If wearing single-sided cans, use an ear plug in the unprotected ear.
- **Stunt vehicles:** Motor vehicles travelling at speed involved in a stunt are likely to go out of control. Leave the camera locked-off on the shot and stand well away from the action area in a safe position agreed with the stunt-coordinator.
- **Filming from a moving vehicle:** Cameras must be either securely mounted or independently secured on safety lanyards. Operators should be fitted with seat belts or safety harnesses attached to safety lines securely anchored.
- **Roadside working:** Wear high-visibility gear and get the police to direct traffic if required. Police may give permission for a member of the crew to direct traffic but motorists are not obliged to obey such instructions.
- **Adverse weather:** A cameraman setting out for the day needs to equip himself with a choice of clothing to match any changing weather conditions. Those who work regularly out of doors must make themselves aware of the risks involved and how to protect themselves against sunburn, skin cancer, heat stress and heat stroke, hypothermia, white finger and frost bite. A check on the effects of any extreme weather forecast must be assessed each day on exposed camera positions. Individual safety requires a personal assessment and only the individual on a scaffold tower or hoist can judge when it is time to call it a day and retreat from the threat of lightning.