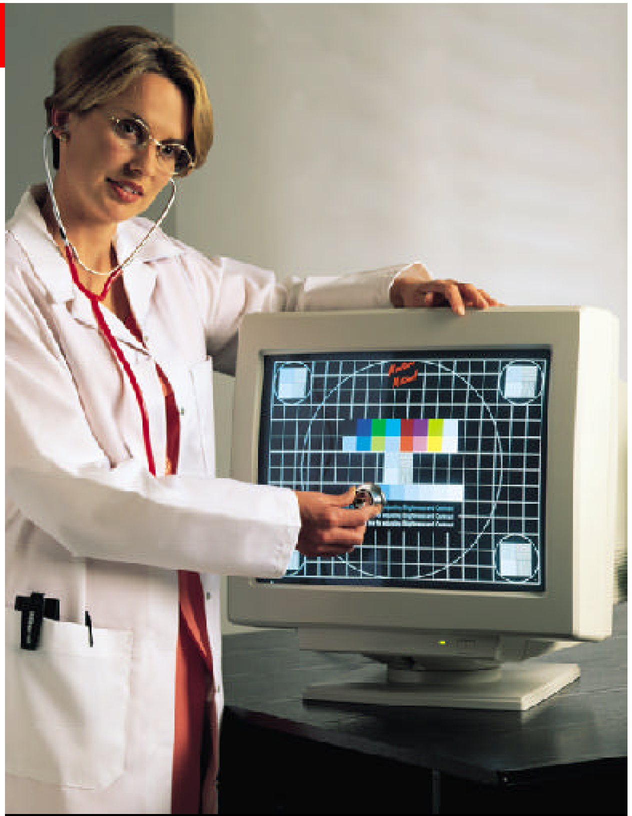
Monitors Matter!



The Definitive Guide to a Healthy Monitor

Free Software

see 'Further Information' on page 30

Monitors Matter!

"Monitors Matter" is a user education initiative sponsored by a group of CSF members to advise and educate computer users about the importance of correct display selection when purchasing or upgrading a computer system. Users or prospective users of display products may seek help and advice from the Federation through its Information Line.

To contact the Information Line, call:

+44 (0)1905 727610 or fax +44 (0)1905 727619 or email on info@csf.org.uk

CSF

The Computing Suppliers Federation is a professional association representing specialist sectors of the Information and Communications Technologies industry in the UK. The Federation has supplier forums covering Monitors, Data Storage, Digital AV, Document Management, Engineering Solutions and Design Technology. There are around 200 member companies and these include most of the world's leading monitor suppliers. Formed in 1985, the Federation is a not-for-profit body, owned by it's members and constituted as a company limited by guarantee.

Member companies comply with a strict code of conduct which covers their product sales, service and support. Any complaints received by the Federation are investigated thoroughly to maintain the highest trading standards. By this approach the Federation believes that people can "Buy with Confidence" from a member of the CSF.

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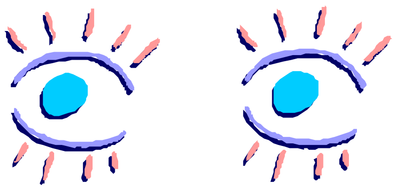
Why Do Monitors Matter?

'How my computer talks to me'

You probably communicate with your computer using the keyboard or the mouse. Your computer communicates with you through your monitor. That dialogue must be comfortable and easy if you are going to get the best out of your system.

Potential to affect your working comfort

As a user you may well spend a great proportion of your time in front of your monitor. A well adjusted monitor will reduce the possibility of eyestrain or other unwanted effects.



Cost

The monitor is probably the most expensive single component of your system, and in many cases may cost as much as the whole of the rest of the system, so it's very important that you get good value for your money.

Legal obligation on Employers

Because of the increasing importance of monitors in the workplace, there are legal obligations on employers to ensure that the use of monitors does not pose a health risk.

Monitor Size

With monitors, bigger is often better, but not always. The right size and resolution of screen depends mainly on the application. All general purpose CRT monitors will support an infinite variety of colours, so that the number that are displayable on a system will depend on the computer's output.

General Use

For general applications with Graphic User Interfaces (GUIs) such as Windows or Apple Mac, the most suitable size of monitor is usually between 15" and 19", nominal tube size.

Monitor sizes have traditionally been specified in terms of the size of the glass of the CRT used in the manufacture. Actual image sizes on CRT monitors are usually around 1" smaller, measured diagonally from corner to corner of the visible area — but actual image sizes vary from maker to maker. LCD sizes are normally quoted as the actual visible size.

Intensive Users

Resolutions are normally from 640 x 480 (VGA or Mac 13") up to 1600 x 1200. Microsoft these days recommends 1024 x 768 as the standard resolution for Windows.

Office Users

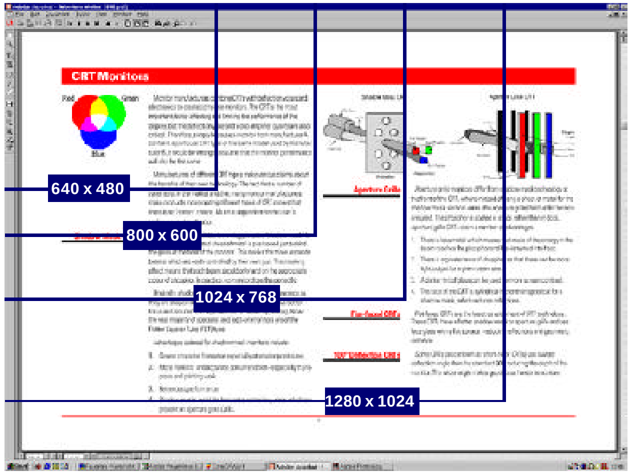
Users spending much of their time running office productivity applications such as Word Processors or Spreadsheets with large documents and many windows may want to have a resolution of up to 1280 x 1024 on a 17" or 19" monitor.

Specialists

For Specialist Users of Desk Top Publishing (DTP), Computer Aided Design (CAD) or applications that use Document Image Processing (DIP), a monitor in the size range from 17" to 24" is likely to be most suitable with resolutions up to 1920 x 1200.

The screen snapshot opposite shows a 1600 x 1200 display. The major advantage of higher resolution is the reduced need to zoom and pan - improving user productivity.

It is important to get the right resolution for a particular size of monitor. Too high a resolution on a small screen can be a problem



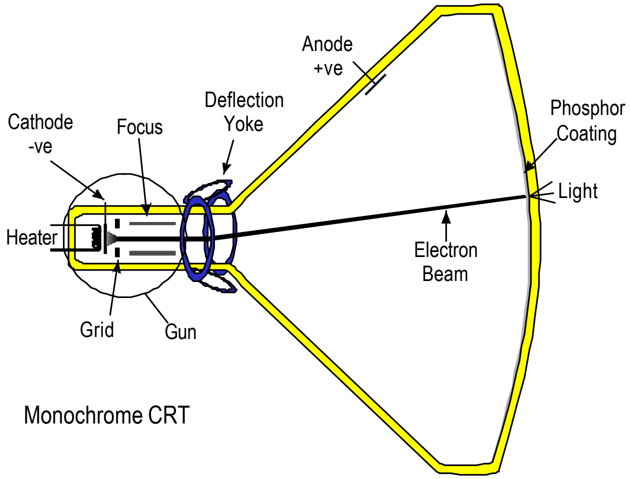
as many software packages use text that is limited to a fixed number of dots. If this software is used on a small screen with high resolution, the text may be too small for you to view comfortably. On the other hand, simply increasing the size of the monitor will not necessarily improve the image on the screen, unless the resolution is also increased. Sometimes a larger screen simply makes the characters and images more 'dotty'.

Unless you have the chance to see the monitor running the software that you plan to use, and are happy with the image, be cautious of screen sizes and resolutions outside those in the table. You may be happy with a resolution that is outside the ranges quoted (e.g. 14" at 1024 x 768), but most users would not, because of the small character sizes. It is unlikely that combinations outside this range would meet ISO 9241/3, the major international standard for monitor ergonomics. (These recommendations do not apply for CAD and other specialist applications). Small character sizes may also be in breach of the current safety legislation on screen use (see page 21).

Monitor Nominal Size (Diagonal)	Typical Image Size (Diagonal)	Minimum Resolution	Maximum Resolution	Monitor Horizontal Frequency Needed
15"	13.5" - 14"	640 x 480	1024 x 768	38kHz - 60kHz
17"	15.5" - 16"	800 x 600	1280 x 1024	47kHz - 80kHz
19"	17.5" - 18.1"	1024 x 768	1280 x 1024	60kHz - 80kHz
20" / 21"	19" - 20"	1024 x 768	1600 x 1200	60kHz - 95kHz
24"	21" - 22"	1600 x 1000	1920 x 1200	80kHz - 95kHz

CRT Monitors

Most monitors are based on CRT (Cathode Ray Tube) technology. The CRT is a mature technology and the most cost effective way of displaying high quality colour images on desktop computers.



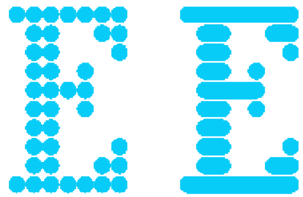
Monochrome CRT

A monochrome (e.g. amber, green or white) CRT is the simplest kind. In the diagram above, a monochrome CRT is shown. A heater is used to liberate electrons from a cathode. (This is why a monitor takes time to 'warm up'). These negatively charged electrons are attracted towards the positively charged anode which is near the front of the CRT. The stream of electrons is focused into a fine beam by extra elements near the cathode in an assembly known as the 'gun'. The number of electrons, and hence the brightness of the image is controlled by a voltage applied to the grid.

When the electrons get to the front of the CRT, they impact with a special coating of phosphor and this collision results in the release of light. The colour of this light depends on the formulation of phosphor used.

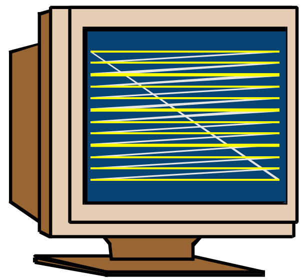
In order to make a picture, the beam scans from left to right and from top to bottom creating a grid or 'raster'. The image is formed by increasing or decreasing the brightness of the points on the raster. Where the beam brightness is switched on or off a dot is formed. This is called a pixel (short for picture element).

To make an upper case E on a standard resolution monitor, for example, this pattern of pixels would be used:-



When the beam gets to the right of the screen, it is switched off (blanking) and 'swept back' to the left. When it reaches the bottom it is blanked and swept back to the top. The number of times that the screen is drawn in a second is called the refresh rate.

The beam is made to scan by an assembly of coils which are wrapped around the neck of the CRT. This assembly is called the deflection yoke.

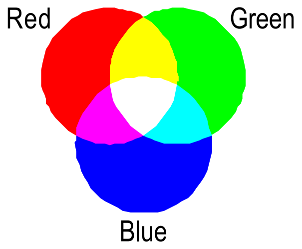


Colour Monitors

There are two major colour CRT technologies, Shadow Mask and Aperture Grille. They share some common features.

Because the eye reacts to Red, Green and Blue light, all visible colours can be made from mixing the three primary colours of Red, Green and Blue. Colour CRT technology is based on using small areas of phosphors that emit these basic colours, but making them small enough and close enough together, that the eye cannot see the individual colours or points. Three separate beams of electrons are used to make the respective phosphors glow.

CRT Monitors



Monitor manufacturers combine CRTs with deflection yokes and electronics to create complete monitors. The CRT is the most important factor affecting and limiting the performance of the display, but the deflection yoke and video amplifier quality are also critical. Therefore, simply because a monitor from manufacturer A contains a particular CRT type or the same model used by manufacturer B, it would be wrong to assume that the monitor performance will also be the same.

Manufacturers of different CRT types make various claims about the benefits of their own technology. The fact that a number of types exist in the market and that many monitor manufacturers make products incorporating different types of CRT shows that there is no 'correct' choice. Much is dependent on the user's preference and application.

Shadow Mask CRTs

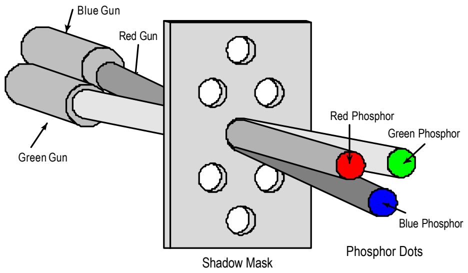
The most widely available technology is called 'shadow mask'. In these CRTs, a perforated sheet of metal is positioned just behind the glass at the front of the monitor. This masks the three separate beams which are each controlled by their own gun. The masking effect means that each beam should only land on the appropriate colour of phosphor. In practice, no monitor does this perfectly.

Originally, shadow mask CRTs had a very curved appearance as they are shaped like a section from a sphere. This allows better focus and reduced the negative effects caused by heating. Now, the vast majority of specialist and 'add-on' monitors are of the Flatter Squarer Tube (FST) type.

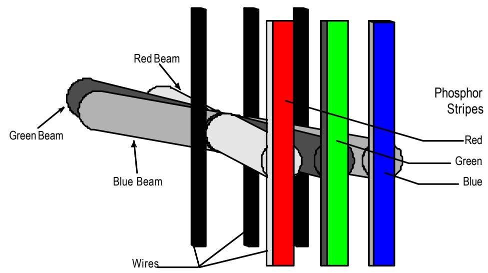
Advantages claimed for shadow mask monitors include:-

1. Clearer character formation especially at smaller point sizes.
2. More 'realistic' and accurate colour rendition - especially in pre-press and printing work.
3. Better cost/performance.
4. Shadow masks avoid the horizontal restraining wires which are present on aperture grille CRTs.

Shadow Mask CRT



Aperture Grille CRT



Aperture Grille

Aperture grille monitors differ from shadow mask technology at the front of the CRT, where instead of using a sheet of metal for the shadow mask, vertical wires (the aperture grille) held under tension are used. The phosphor is coated in strips rather than in dots. Aperture grille CRTs claim a number of advantages.

1. There is less metal which means that more of the energy in the beam reaches the phosphor and less is turned into heat.
2. There is a greater area of phosphor so that there can be more light output for a given beam size.
3. A darker tint of glass can be used for more screen contrast.
4. The face of the CRT is cylindrical rather than spherical for a shadow mask, which reduces reflections.

Flat-faced CRTs

Flat-faced CRTs are the latest development of CRT technology. These CRTs have a flatter shadow mask or aperture grille and use face glass with a flat surface - reducing reflections and geometric distortion.

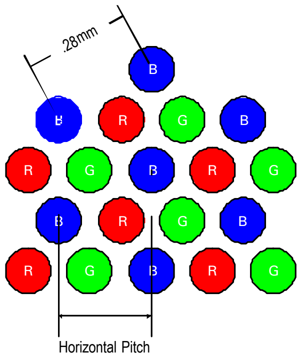
100° Deflection CRTs

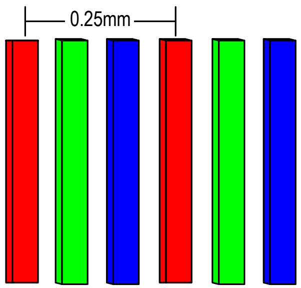
Some CRTs (also known as 'short-neck' CRTs) use a wider deflection angle than the standard 90°, reducing the depth of the monitor. The wider angle makes good focus harder to achieve.

There are many factors that affect the resolution of a monitor. A small number have the effect of limiting the maximum resolution and the most important of these is the dot pitch.

Dot Pitch

The dot pitch is the measurement between adjacent RGB phosphor dot groups (triads); therefore, the smaller the dot pitch, the more dots per inch and the higher the potential maximum resolution of the monitor. (On the other hand a smaller dot pitch may mean reduced brightness, so smaller is usually better, but not automatically). In the case of an aperture grille monitor, it is the distance between two adjacent sets of stripes of phosphor.





As you can see from the diagram, there is a difference in the way that pitch is measured between aperture grille and shadow mask CRTs and so the pitch measurement may not be directly comparable. Some makers quote the horizontal pitch which makes the figure sound smaller. Other makers quote the mask pitch, which is the distance between the holes in the shadow mask rather than the distance between the phosphor dots. The mask pitch is slightly smaller than the dot pitch, so, for example, a 0.27mm mask pitch will be the same as a 0.28mm dot pitch.

To further complicate matters, some makers have developed CRTs that change the traditional geometry of adjacent pixels, by changing the angle between pixels of the same colour. This has the effect of increasing the horizontal resolution, although it reduces the vertical resolution. For a more detailed explanation of the different methods of calculating pitch, see 'Dot Pitch Explained' at http://www.csf.org.uk

Dot pitch is sometimes used as a factor by periodicals when judging monitors. Be cautious of this. No serious buyer judges a car purely on its 0-60 mph time and price alone. So when looking at monitors, dot pitch should not be the only factor taken into account. Try to 'test drive' the monitor before purchase.

While the dot pitch is the ultimate limiting factor of the resolution of the monitor, there are many other factors which can limit the maximum resolution.

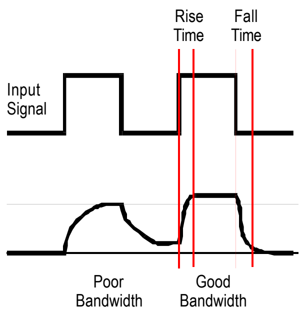
Bandwidth

The second factor affecting the resolution of a monitor is the bandwidth. The bandwidth represents the ability of the video circuitry in the monitor to turn a single pixel on or off.

The signals for the three beams must be passed through the video amplifiers in the monitor to the guns themselves. Even if the signal from the computer is perfectly formed (and it may not be with a poor video driver card or cable), there will be some deterioration of the signal. If the amplifiers are not good enough, then the signal will be degraded visibly.

Video cards differ significantly in the quality of the image that is displayed. Getting the best out of the monitor needs a card with a fast rise time.

The bandwidth needed for a display is proportional to the number of pixels per second, so the higher the resolution or refresh rate that you are running, the higher your bandwidth requirement.



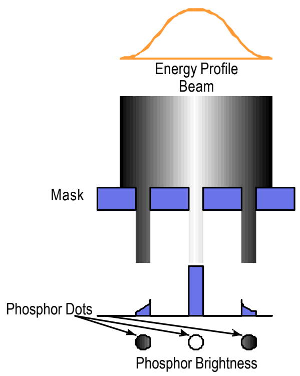
The effects of poor bandwidth are:

1. Thin vertical lines do not reach maximum darkness or brightness. Therefore there is a difference in brightness between horizontal and vertical lines. (A major potential problem for DTP and CAD applications).
2. The picture loses sharpness and seems to be horizontally smeared. Characters can be made very unclear and may cease to be legible. (Note that in the diagram on page 6, the vertical stroke in the character E is made two dots wide. Character sets need to be designed this way to minimise the problems of poor displays).

Resolution

Focus

The subjective sharpness of a display is strongly affected by the focus of the monitor. This is an extremely difficult factor to measure and there is no industry-wide agreement on a simple number that can be used to summarise the performance of a display. (Note that the focus of a monitor should not be judged until it has warmed up for 20/30 minutes - see page 14).

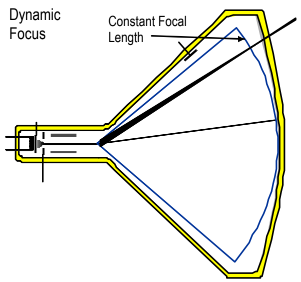


In the diagram on page 7, the beam is shown at the same size as the hole in the Shadow Mask. In practice, the beam will be wider than one shadow mask hole. In lower resolution monitors, the beam may be even wider still.

A beam that is too narrow can lead to difficult to read text and low brightness and may lead to increased problems with moiré (see page 12).

The beam is not cylindrical in shape, but conical and should come to a point and the three electron beams should come together (converge) as near as possible to the shadow mask. As CRT technologies lead to flatter displays, new techniques have been developed to improve sharpness.

Dynamic Focus

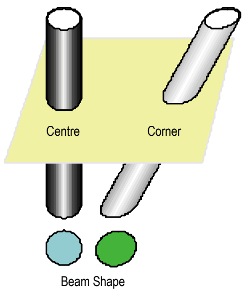


The optimum focal length for the beam varies as the beam scans from top to bottom and from side to side on the face of the CRT leading to a difference in focus between the centre and edges of the screen.

In some monitors, extra elements in the CRT gun continuously adjust the focal length of the beam and the convergence points of the three beams to ensure consistent performance. This technique is called dynamic focus.

When evaluating low cost monitors, you will often see a large variation in sharpness between the centre of the screen and the corners. Monitors with dynamic focus reduce this variation dramatically.

Dynamic Beam Forming



Another effect comes from this difference between the radii of focus and the CRT face. At the centre of the screen, the circular beam lands on the shadow mask at right angles, so that the spot formed is circular. At the corner of the screen, the beam lands at an angle so that a more elliptical shape is formed. This increases the spot size and reduces focus performance. To correct this, CRT manufacturers have developed special focusing lenses that change the shape of the beam as it scans into the corners.

If you are planning to buy a monitor of 17" or larger at a resolution of 1280 x 1024, you should look for this feature.

Convergence

The next factor to affect image sharpness is the convergence of the monitor. The full range of colours including white is only available when all three beams come together at the same point on the shadow mask.

In an ideal world, the Red, Green and Blue beams would be in perfect alignment. In practice they are never perfect because of the difficulties in deflecting the three beams through very slightly different angles using the same deflection coils. If the convergence is imperfect, the energy from one colour beam will go through a different shadow mask aperture than the others, leading to a distinct colour 'fringe'.

Careful attention to Deflection Yoke design and hand tuning with small magnets can improve performance and new digital technologies can correct convergence errors very accurately.

In monitors with digital convergence correction, the screen is divided into separate areas (e.g. 5 x 5 or 8 x 8) and the convergence is factory adjusted for each area. There can be a variation of convergence performance even within one production batch of monitors and performance can drift over time. Some monitors feature user adjustable convergence and this can be useful on high resolution monitors to correct long term drift.

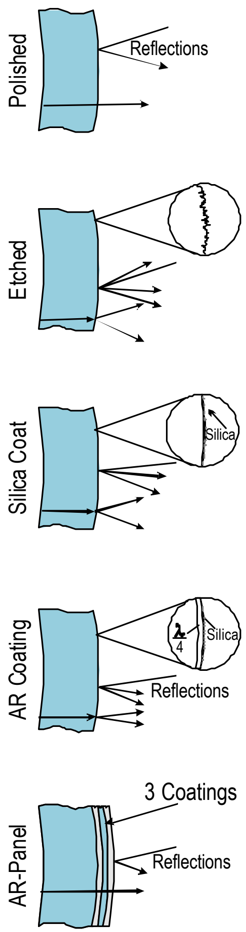
Resolution

Reflections

The surface treatment needed to reduce reflections and glare from the screen can affect the sharpness of the image. There are five current CRT surface treatments.

Polish

A polished screen looks sharp but would not be allowed under any ergonomic standards because of reflections.



Etch

With an etched screen, the surface of the CRT is treated with an acid to make it rough. This diffuses the light that hits the screen. It also diffuses the light passing through the glass, reducing the sharpness. Quality screens should not be etched.

Silica Coatings

A further step is to coat the screen with a very fine layer of silica. This improves the anti-reflective performance compared to etching and reduces the image diffusion. The low cost of this process has led to wide adoption as a replacement for etching.

Anti-Reflective (AR) Coatings

In this process, two very fine layers of silica with different refractive indices are coated onto the surface of the tube. With this process a substantial part of the benefits of the AR panel could be gained, but at a relatively low cost. It is worth looking for a monitor which has this feature.

AR Panels

The best way to stop reflections is to use three layer multicoated filters on a special glass panel bonded onto the face of the CRT. This eliminates almost all the visible reflected light, with no degradation of the image. Unfortunately it is expensive and so is only used on specialist monitors.

Clip-on Screens

Clip-on screens will not be as effective as a monitor with a bonded panel or good quality coating and may even add to reflection problems because of the extra surfaces. The best solution to glare problems is to minimise reflections by careful lighting and screen positioning.

Glare

Glare is the name given to the reflections from the surface of the phosphor on the inside of the glass faceplate. Glare reduces the contrast of the screen image and can also reduce legibility.

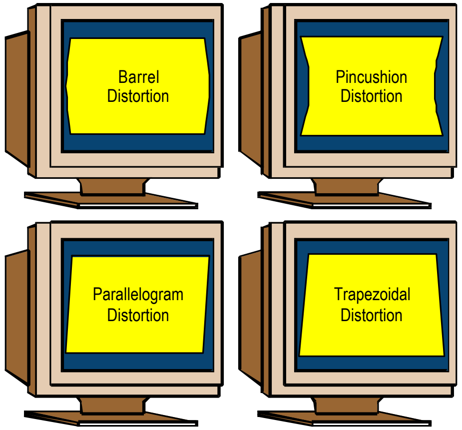
The main way of reducing glare is to use a tinted glass. The reflected light has to pass through the tinted glass twice, while the screen image only passes through once. This reduces the effect of glare. Typically screens will have a transmission rate of 50% or less, so reflected light is reduced by at least three quarters. You can get a good idea of the amount of tint by checking how dark the screen is when the monitor is switched off.

Some CRT makers use black masks around the phosphor dots to improve contrast. Other makers use colour filters on the phosphor that reduce reflections, allowing higher transmission glass to be used for higher brightness.

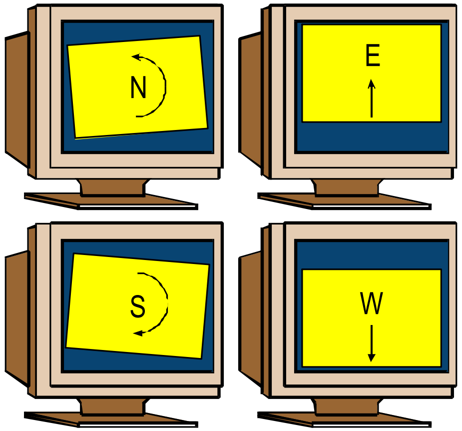
Geometry & Distortion

The CRT is uniquely good at supporting multiple image formats on the same monitor, but this means that it can be very difficult to ensure accurate and consistent screen geometry. Good geometry and linearity are very important in applications such as CAD, DTP and graphics. Some users find flat-faced monitors better in this kind of application.

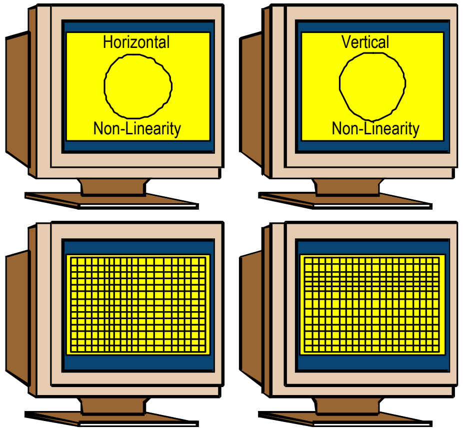
On static pictures, there can be a number of different kinds of geometry imperfections. The main ones are:



Because of their reliance on magnetism, screen images are affected by the direction that the monitor is facing (see page 13). As the monitor is rotated through the earth's magnetic field, changes in tilt can occur. Some monitors have user adjustments to compensate for this, while others have built in magnetometers and digital circuitry to eliminate the effect.



Distortion can occur if the beam sweep is not linear across the whole screen. The human eye is very sensitive to shape, so a circle is often a good way to see if there is non-linearity. On the other hand, a grid pattern is useful to see the degree of the problem.



Power Supply Regulation

While all these kinds of distortion can affect static images, some screens can suffer from problems caused by poor power supply regulation. When the screen, or a significant proportion of it, changes brightness level, the load on the monitor power supply changes. Because the scan coils depend on the power supply, the picture shape can change if the power supply is not well enough regulated. (In the same way that starting the engine can cause other electrical items on a car to stop working).

The effects on the user of these changes are not obvious, but can result in fatigue because the eye tries to keep focus on one part of the screen and has to do a lot of work if the screen image is moving, even slightly.

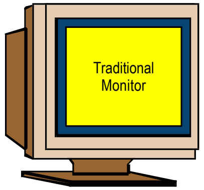
A good way to test for this on a monitor, if you do not have specific test software, is to display a spreadsheet on the screen. Select the whole of the sheet, then select one cell. This will usually mean a rapid change from dark to light. The sides of the screen and the position of the image should stay constant.

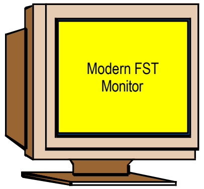
Resolution

Multimedia applications in particular rely on a stable power source, otherwise the rapid changes in a video window can cause the whole screen brightness to change.

No monitors avoid these distortions completely, but there is a big difference between the best and the worst. Suppliers should be able to quote a specification for the maximum size change.

Borders



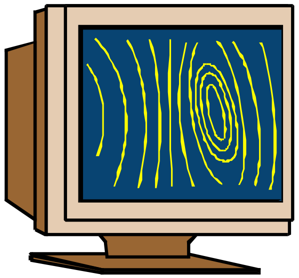


Because of the use of dynamic focus and dynamic beam forming, the corner performance of monitors has improved substantially over recent years. This means that there is really no reason to accept a monitor that has a large black border around the image. (This was necessary in the past to avoid serious mis-convergence and poor focus). There can be less than a 1" difference in screen image diagonal between a good modern 17" monitor and a 19" monitor of only 5 years ago. The improved corner shape of FST CRTs has also made a big improvement in usable screen area.

A wide black border is less ergonomically desirable because of the contrast for the eye between the dark area and the light image of a GUI like Windows.

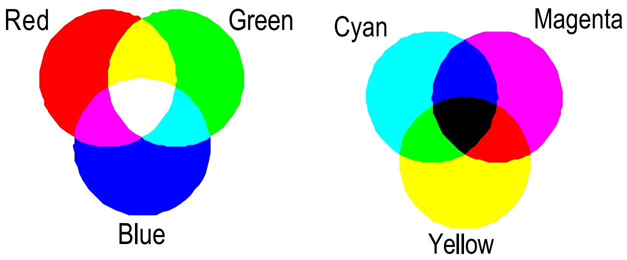
Moiré

An undesirable side effect of the improvement in focus of modern monitors is an increase in the appearance of moiré patterns. These are interference patterns caused by the interaction between the pattern of dots from the beam and the pattern of dots on the shadow mask. In some parts of the screen they line up exactly and a tiny area may be brighter. In other areas, they are darker. Moiré patterns are often most visible when a screen back-ground is set to a pattern of dots, for example a grey screen background consisting of alternate black and white dots.



In the past the only way to eliminate moiré effects was to defocus the beam, but now a number of monitor manufacturers have developed techniques to increase the beam size, without degrading the focus. For many users, moiré is merely an irritation which can be resolved by changing the screen background colour, but for specialist graphics users it can be a very real defect.

With the improvements in technology and the cost reductions of colour printers in recent years, many more users are now performing DTP and other colour critical work on desktop systems. For many of these users, the ability to easily match the colours from the screen to the printer would be invaluable.



Unfortunately, colour monitors and printers work on fundamentally different colour models. As has been described on page 7, colour monitors work by an additive method. Various proportions of the primary colours of Red, Green and Blue are added together to make all the colours from black to white. Printing systems work by the subtractive method. White light landing on the paper is filtered by different inks which do not reflect certain colours. These colours are Cyan, Magenta, Yellow and (because the inks do not blend to form a perfect black) Black. This is known as the CMYK model.

Because of the different colour systems, even the most advanced specialist systems have only a limited ability to match colours between the screen and the printer.

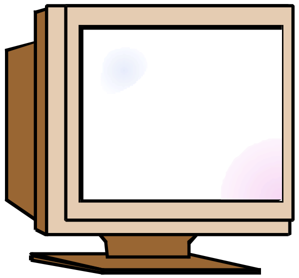
Colour Performance

In order to get the best colours on the screen, it is important to start with pure Red, Green and Blue. CRT manufacturers use different types and formulations of phosphor which can give monitors made with those CRTs a distinctive colour performance. Some monitor makers use phosphors that match the recommendations of the European Broadcasting Union, helping them to more accurately match the colours that may be seen on TVs. It is difficult to say one is better than another, so a subjective judgement must be made.

On the other hand there are a number of areas of colour performance which can reasonably be compared and the first of these is colour purity.

Colour Purity

In order to get consistent colour performance across the whole screen, each phosphor colour must be pure. Irregularities and 'patches' in screens of the primary colours of Red, Green and Blue or on a white screen may be a problem for graphics specialists. These patches are caused by slight misalignments of the beams as a result of magnetic irregularities. As with convergence, new digital techniques can reduce variations.



Occasionally colour patches are caused by the monitor having been moved after switching on.

Because monitors are so sensitive to tiny fluctuations in magnetism, each time a monitor is switched on a 'degauss' operation is performed; that is to say, a coil fitted around the front of the CRT is used to 'extract' any residual magnetism from the shadow mask. If the monitor is subsequently moved or rotated, the influence of the earth's magnetic field will be different and this may result in colour patches.

If this is the problem, the use of a manual degauss button (if fitted) or simply turning the monitor off and on may solve the problem. This may be a particularly useful feature if the monitor is not normally powered off, but is controlled by power-saving circuitry which may not operate the degauss coil.

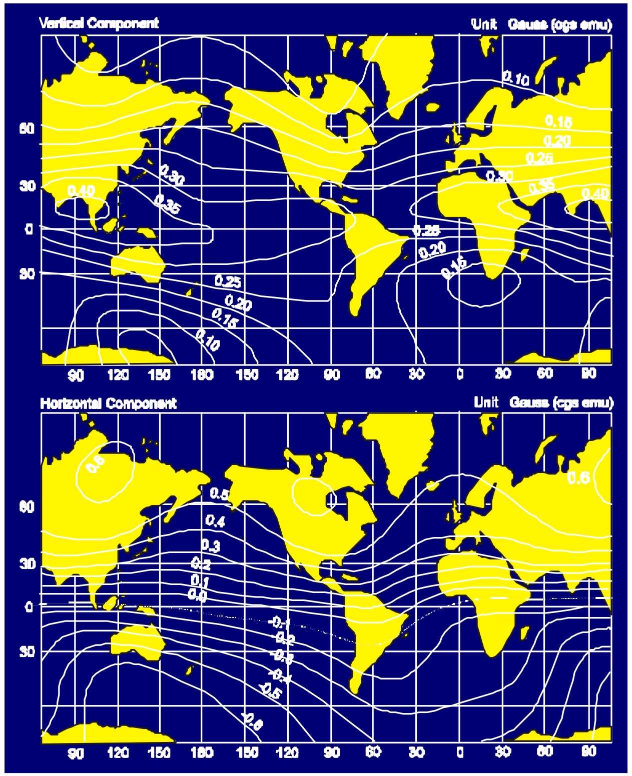
Colour patches caused by magnetisation of the shadow mask can be removed by a technician using a special degaussing coil.

Some vendors with digital circuitry are able to supply optional calibration kits to minimise colour variation.

Colour

Persistent colour patches may be improved upon by a skilled monitor technician using magnets fitted to the Deflection Yoke. On the other hand, the use of extra magnets will affect other aspects of the monitor's performance including convergence and distortion. Therefore, a better colour result may not be possible without some compromise on other parameters. In some cases, the difference in brightness may be because of variations in the phosphor coating and in this case no improvement is possible.

Colour patches are sometimes the result of monitors being used in a different part of the world than the area they were made for. High quality monitors may use a number of different magnetic settings depending on where in the world the monitor is to be sold. Even low quality units should be set differently for the Southern and Northern Hemispheres. It may be difficult to believe, but a monitor correctly adjusted for Australia will have very strong colour patches when used in Europe.

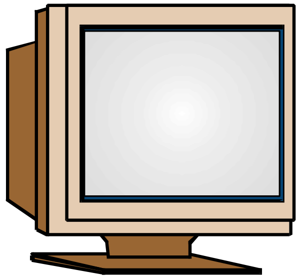


Such colour patches can be a problem if monitors are purchased overseas and then brought back to Europe. Fortunately within Europe, the differences are small enough that there should not be any need for adjustment.

Increasing use of digital correction can eliminate the effects of the earth's magnetic field.

As with focus, colour performance should not be judged until the monitor is at working temperature (20-30 mins use).

White Uniformity



Shadow mask monitors are likely to have different levels of white brightness on the screen. The centre may be noticeably brighter than the corners of the tube. This is less of a problem on monitors fitted with digital correction circuitry.

The performance of all monitors is affected by heat. As the beam lands on the shadow mask or aperture grille, some of the energy is absorbed and turned into heat. The shadow mask then expands. This is why it is very difficult to make a completely flat CRT and why an assessment should not be made of the quality of a monitor, nor focus or convergence adjustments made until the monitor is warmed up. In recent years CRT manufacturers have been able to use flatter CRTs by adopting Invar, an alloy, instead of iron for the shadow mask. Invar has a lower coefficient of expansion and so is less affected by heat.

Aperture grille monitors claim an advantage here because the wires used do not change shape as much as a shadow mask under the influence of heat.

Colour Controls & White Point

The advent of microprocessor controls into monitors meant that much more control could be taken of the colour amplifiers in the monitor. They can be very difficult to set up and may be of limited value, given the fundamental problems associated with colour matching discussed above. However, most monitors with colour control also include presets which adjust the 'white point' and this can be useful.

Presets which approximate to 'paper' white are useful when judging how a publication may look when printed. Some monitors have a preset for 'TV' white. This can be helpful if you are using a desktop system for video processing.

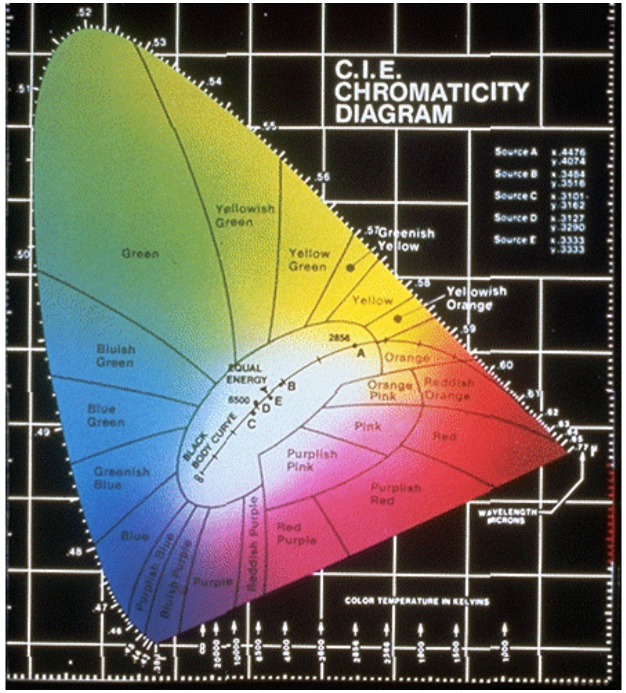
The white point is usually expressed as a colour temperature in degrees Kelvin (°K). Some typical presets you might find are:

Temperature	Source	Application
6500°K	Paper	DTP/Word Processing
9300°K	Computer Graphics	Multimedia/Video

Operating systems on desktop computers are becoming more sophisticated in their support of accurate colour and most monitors are now shipped with colour profiles that are in accordance with the formats defined by the International Colour Consortium (ICC). These profiles allow the monitor maker to give information to the computer system about the colour performance of the monitor and let the operating system compensate for differences between the monitor and other peripherals such as scanners and printers.

Some monitor makers supply software that allows an individual colour profile to be generated for the individual monitor being used, as a general profile cannot take into account the contrast and brightness settings for a particular monitor. These utilities will further reduce colour discrepancies between the monitor and other peripherals.

The complex nature of colour perception and the limitations inherent in current technologies mean you are strongly advised to find a knowledgeable specialist dealer for advice before purchasing a system if close and accurate control of screen colour is critical to your application.



Because of the amount of time that you may spend in front of a screen, the monitor has an important place in the ergonomics of the workplace.

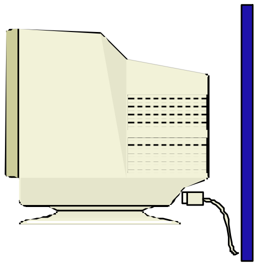
Tilt and Swivel

Most monitors are supplied with tilt and swivel stands. These should allow the monitor to be adjusted so that the work posture of the user is as comfortable and relaxed as possible. It is particularly important that the screen is positioned with a slightly upward tilt if possible so that the user is looking slightly down at the screen.

The monitor needs to be able to be swivelled to allow a comfortable working position and to minimise reflections on the screen from other light sources.

Special platforms are also available from a number of office equipment suppliers to allow the height of the screen to be adjusted. It is important when evaluating such systems to ensure that they are stable and strong.

Case Design



The case design should be visually simple to avoid any distraction to the eye. Strong and dark colours should be avoided. When evaluating monitors, the physical dimensions of the unit should be taken into account.

Current technology means that as monitor screen sizes get larger, the CRT gets deeper. Careful design, especially of cable outlets and controls can mean a shorter overall depth. This can be important where the back of a monitor is against a wall.

Flicker

As the image is redrawn on a monitor many times per second, the user may be aware of flickering. This is particularly common where a windowing operating system is being used with black characters on a white background. The peripheral vision is also more sensitive to flicker than the centre of the eye.

Individuals vary in their sensitivity to flicker, but in general, with standard phosphors and windowing software, a refresh rate of 72 - 75 frames per second (Hz) will seem flicker free to most users, although some users are sensitive until much higher rates. Unfortunately, a requirement for higher refresh rates will need better quality components, so reducing flicker may lead to increasing cost. Flicker is not usually an issue in applications which use small areas of colour on a dark background, for example in CAD work.

Recent research suggests that at refresh rates above 100Hz, there may be interference between the movements of the eye and the redrawing of the screen, which actually may reduce the efficiency of the display.

In the past, high resolutions at lower cost have been achieved using a technique called ‘interlacing’. Interlaced monitors use a system where alternate lines are refreshed on each frame. So on frame one the odd lines, 1, 3, 5 etc are illuminated, while on frame 2 the even lines, 2, 4, 6 etc are turned on. This technique is used in TVs. Interlacing can lead to flicker and although there are ways of reducing it, these tend to reduce other aspects of monitor performance. A monitor or graphics card can almost always display a higher resolution in interlaced modes than in non-interlaced or flicker-free resolutions, so be careful when checking specifications that if you need a particular resolution, that the system can do this with flicker-free performance.

The monitor is controlled by the computer’s graphics system, so that it will run at the rate set by the controller. Therefore, even if a monitor is purchased that can scan up to 100Hz, unless the controller is driving at that frequency there will be no benefit.

Non-Interference

As well as being sensitive to magnetic fields, monitors will also emit magnetic fields. Where CRT-based monitors are used close together, these magnetic fields may interact causing a variety of effects, from lines moving up or down the screen to slow changing distortion of the image, or even flicker in severe cases.

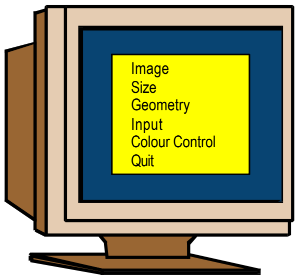
In recent years, monitor manufacturers have developed special coils, called Saddle/Saddle Deflection Yokes (S/S D/Y) which can reduce the output of these fields. Where two or more monitors of this type are used closely together, there should not be interference. Note that this technique will not significantly reduce the sensitivity of the monitor to external fields, so a monitor with one of these yokes placed next to a conventional monitor will react to the field emitted. The conventional monitor will show no effects because the other monitor has reduced fields.

This sensitivity to external magnetic fields can be a real problem if monitors need to be sited near large electrical installations (air conditioning plant etc), power circuits or large machines (even laser printers and photocopiers).

The only complete solution to this problem is to build special screens of a magnetically impervious material called mu (μ) metal. These are very expensive and generally have to be custom made.

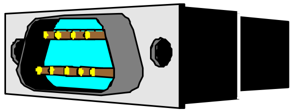
Controls

The inclusion of microprocessors into monitors has led to a dramatic increase in the number of controls that are available to the user. Monitor makers have developed on-screen displays (OSD), with menus showing all the options available and even with help screens on some models. Because of the number of the controls and because it is possible to make the screen display worse by bad setting, some manufacturers offer the facility to lock all but the most common brightness and contrast controls. A special sequence may be used to unlock the controls for service or support purposes.



Monitors are available that can communicate with a system unit and which can be adjusted by software running on the system. Some of these systems use proprietary or serial connections, while others can take advantage of USB or even send the contol signals using the standard video cable. The increased resources available to programmers in a Desktop Computer environment should lead to more user friendly controls. Some vendors have used the ability of the monitor to communicate with the system unit to allow monitors to be diagnosed and located across a network.

Connections



D-SUB Type

One of the factors to consider when selecting a monitor is the choice of input connections.

Many monitors now have the ability to accept more than one input and to switch between them with user controls. This can be very convenient if more than one system unit needs to be used by a single user.

You may also find that different kinds of connectors are used for the different inputs. Be sure to use a good quality cable - if possible the one supplied with the monitor - as a poor quality cable can cause a loss of bandwidth. (See Page 8)

Some monitors also have switchable termination or loop-through facilities. These options allow you to 'daisy-chain' a number of monitors together.

As this booklet went to press, a number of companies had announced 'Digital CRTs' designed to take advantage of the new Digital Video Interface (DVI). Using a digital interface can give a more consistent image without relying on the quality of the graphics card.

Multimedia

Recent developments in desktop computer design have led to new multimedia applications. All of these use graphics or video in one way or another and in general they add sound as well, so monitor makers have started to add extra functions.

Loudspeakers

The most common upgrade to monitors is the addition of loudspeakers. There are both advantages and disadvantages to putting the speaker in the monitor.

Because the relative position of the speakers is known very accurately, and the position of the listener is predictable, the stereo image can be very effective when the speakers are in the monitor. Some monitors even include '3D' effects in their speakers.

Monitors are also susceptible to magnetism, so the manufacturer can ensure proper magnetic screening by building the speakers in.

Because of the magnetic effect, speakers that may be used near monitors should always be designed specially for the purpose.

Because monitors are susceptible to vibrations, especially those with aperture grille CRTs, careful design is necessary to avoid resonance from the speakers. Low frequency sounds, which cause the largest vibrations are often best dealt with by a separate sub-woofer, which in some monitors is housed in the tilt/swivel base.

Microphones

Microphones are built into some monitors so that the monitor can be conveniently used for video conferencing or, in conjunction with a modem, as a loudspeaking telephone.

Cameras

For applications such as videoconferencing it can be convenient to house a camera in or on the monitor, so that the camera is as near the sight line of the user as possible. Because the camera can be an expensive component, and not required by all users, some monitors are available with attachment points for the camera to be fitted as an upgrade.

TV Display

TVs and monitors are designed for different purposes and using either for the other purpose is likely to involve some compromise.

Parameter	TV	Monitor
Key display attribute	Brightness & contrast	Fine detail and focus, accurate geometry
Gun optimised for	High current	Beam shape, focus and convergence
Frequency support	15.625kHz	30 - 115kHz
Refresh rates	50Hz interlaced	60 - 100Hz non-interlaced

Products designed to operate as both will tend to be better at one function than the other. On the other hand, a combined unit can offer a convenience that offsets some compromise on performance.

Blanking

If you use different video modes regularly – e.g. DOS full screen during a Windows session, OS/2 task switching, text to graphics mode switching etc. – then it would be worthwhile to check before buying whether the monitor that you are considering performs screen blanking. Some monitors with microprocessor control blank the screen when switching between two video modes and do not show the picture again until the image is synchronised.

This reduces fatigue in the user, as without such blanking, the eye tries to focus on the broken patterns that are on the screen as synchronisation occurs and, repeated regularly, this can be very tiring.

It is also worth checking how long the monitor takes to synch. Even good quality monitors can vary between ½ and 2 seconds depending on the graphics card and the modes being switched.

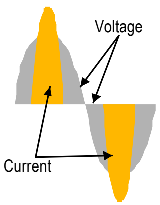
Power Saving & Consumption

Different monitors can vary quite significantly in their power consumption. Over the life of a monitor, increased power consumption can lead to higher costs and also to increased heat output. Where many screens are used together and where air-conditioning is installed it may be worthwhile to look at the costs of higher consumption.

Because monitors are considered to be one of the major growth areas in office energy consumption, monitor makers have invested a lot of effort in reducing power consumption and average power consumption is reducing on the best models. CRTs are being designed that reduce power requirements, for example using slim neck designs (mini-neck) to reduce the power needed for deflection.

Power Factor Correction

An increasingly common feature in new monitors is Power Factor Correction. Monitors, along with computers and other sophisticated electronic equipment, use switched mode power supplies which, unlike traditional power consuming devices such as heaters and lamps, do not absorb power evenly through the mains cycle. This can lead to power waste and problems in power generation, so legislation is likely to insist on power factor correction in the future.



Power Saving

There are a number of approvals for power saving. From the USA comes Energy Star and from Sweden, Nutek. These standards set the maximum levels of power that can used by the monitor in a power saving mode. The VESA DPMS system defines a mechanism for enabling power saving, but doesn't set standards for the levels of power to be used.

Energy Star/Nutek/TCO92

In the USA, the Environmental Protection Agency has promoted the Energy Star label. Systems that claim to be Energy Star compliant must have power saving modes which use less than 30W.

The Swedish Nutek specification requires that if the mouse or keyboard has not been used for between 5 minutes and an hour, the monitor is switched into a first level power saving mode from where it can be restored to full operation within 3 seconds. In this mode the power requirement must be less than 30W, with less than 15W desired. After a maximum of 70 minutes, the monitor must power down to less than 8W, with a desired level of less than 5W. There is no specified recovery time in the second mode. The TCO labour union has adopted Nutek's power saving levels as part of its TCO92 and TCO95 certification. TCO99 has made a requirement that recovery from the first level of power saving happens in less than three seconds.

VESA DPMS

The Video Extended Standards Association (VESA), an organisation of graphics card and monitor manufacturers have developed a standard (Display Power Management System - DPMS) which sets out how a Desktop Computer graphics card should signal to the monitor that a stand-by or low power mode is required. Most monitors which claim to be Energy Star compatible (i.e. have a low power mode) support the VESA DPMS signalling system. Some monitors also support additional mechanisms to switch to stand-by modes.

Plug & Play

VESA has worked with monitor and system suppliers to develop a standard for plug and play connection between a monitor and the host system to improve the ease of configuration.

The standard is called the Display Data Channel and there are three levels of implementation. The most widely available are DDC1 and DDC2B which allow the monitor to inform the system unit of its capabilities so that the user can be presented only with the configuration options - such as maximum resolution and refresh rate - that are supported by the host and also by the monitor. The third level, DDC2/AB (ACCESS.bus) has not been widely adopted by system vendors but allows control of the monitor from the computer.

Some system vendors use the ability of the monitor to identify itself using DDC to help with networked asset management.

Details of VESA standards are available on the World Wide Web at http://www.vesa.org

VESA Generalised Timing Format

Most resolutions for monitors are based on standardised signal timings produced by VESA to ensure compatibility between monitors and graphics controllers. To avoid the need for the VESA committee to define every possible graphics resolution, a new standard, the Generalised Timing Formula or GTF, has been published. This allows the graphics card and monitor to 'negotiate' a timing based on the individual capabilities of each.

Monitors with support for GTF should be able to automatically set the correct size and position for any GTF-compliant timing and some graphics card vendors are exploiting this capability to allow users to select a very flexible range of different resolutions.

Universal Serial Bus

Universal Serial Bus (USB) is a new interface designed for PCs that is intended to make interfacing simpler and to use less wires. Many of the devices that are likely to use USB, such as keyboards and mice are used on the desktop close to the user. Because the monitor is usually near to the user and because the monitor already has a mains power supply, it has been seen as a natural place to put a USB hub.

With a USB hub in the monitor, the keyboard, mouse and other peripherals such as modems can be connected back to the PC with a single cable through the monitor acting as a hub.

USB is fast enough to support stereo audio, so monitor makers are looking at putting the circuitry to convert the digital audio to analogue within the monitor. It could also support low resolution compressed video, allowing complete video-conferencing monitors to be developed.

A small number of monitors use USB to allow monitor control to be performed over the bus from the system unit.

Products from reputable manufacturers should comply with a number of standards for Electrical Safety, Ergonomics, Radio Frequency Interference (RFI) and Emissions.

Electrical Safety

The European standard for the electrical safety of IT Equipment is EN60950:1992 (IEC950). This includes specific provisions for CRT monitors. All products from reputable manufacturers should conform to this standard already. From 1/1/96 monitors carrying the CE mark must conform to the EC Electromagnetic Compatibility Directive. From the 1/1/97, monitors carrying the CE mark must in addition conform to the EC Low Voltage Directive (1989/336), which, in the case of monitors, will normally mean testing to EN60950.

Products marked TÜV/GS will have been tested for the German market. TÜV is a German testing organisation and the GS safety mark is an important part of the purchasing decision of German companies.

Ergonomics

The international standard for monitor ergonomics is ISO 9241 Part 3 (EN29241-3). ISO 9241/3 specifies a number of requirements for display screens. Testing to this standard is the best evidence of compliance with the display visual ergonomic requirements of the EC Display Equipment directive. In the UK, the Health and Safety Executive (HSE) says that compliance with the standard would meet the requirements of the directive.

Many monitors carry the TÜV/EG mark. This mark is issued by the German TÜV testing organisation and means that the monitor has been tested to EN60950:1992 (IEC950) for safety, basic ergonomics according to German law, MPR II for emissions and EN29241 parts 3 and 8 for visual ergonomics.

EC Directive

The EC Directive (90/270/EEC) on Working with Display Equipment, covers a number of areas of the working environment for screen users including the screen and keyboard, desk and chair, space, lighting, heat, noise and software. The enforcement of the directive is the responsibility of individual countries and in the UK, the Health and Safety Executive is the nominated body. The HSE publishes Guidance on the Regulations.

Their original publication "Display screen equipment at work - Guidance on Regulations" has been supplemented by a new publication "VDUs: an easy guide to the Regulations". Both of these publications are available from :-

HSE Books, PO Box 1999, Sudbury, Suffolk CO10 6FS
Telephone 01787-881165 Fax 01787-313995.

All new equipment used since the 1st of January 1993 must comply with the regulations and since the 1st of January 1997, all equipment, of whatever age, must meet the minimum requirements. At the very least, employers must ensure that equipment purchased before 1993 is audited for compliance.

Testing to ISO9241-3 is the best evidence of compliance with the visual ergonomic requirements of the EC directive. Be aware that simply assembling components that have individually been tested to the standard does not ensure compliance. For example, ISO 9241/3 specifies a minimum acceptable character size but this can be influenced by the choice of operating system, application and user settings. To meet their legal obligations, employers need to ensure that workstations are properly assessed.

A number of suppliers of business forms can supply packs of pre-printed assessment and audit forms and record cards to help employers ensure that they meet their legal obligations.

Emissions & Environment

Monitors are the source of a number of different types of radiation and emissions.

Ionising Radiation

The CRT is a potential source of X-Rays, but the levels are extremely low because of absorption of the rays by the glass at the front of the CRT and are governed by safety regulations such as the German X-Ray decree. No health problems have ever been identified with X Rays from computer screens.

All monitors that comply with safety regulations are fitted with a special circuit to protect the user in the event of malfunction. If the voltage on the anode became too high, then the level of X-Rays would increase. Therefore monitors are fitted with spark-gap devices which ensure that if the voltage becomes excessive, the power will drain to earth. Occasionally, especially in humid conditions, this circuit will operate and will make a noise. Momentarily the picture will 'collapse' and then come back. You should not be alarmed by this phenomenon, but if the condition recurs regularly, discuss the problem with your supplier.

Non-Ionising Radiation

As has been described on page 6, monitors generate magnetic fields from the deflection coils and electric fields from the high-voltage components.

Most monitors now comply with the MPR II recommendations of Swedac, the Swedish testing authority or the more stringent recommendations of the Swedish Confederation of Professional Employees (TCO). Although there has been controversy over the effects of fields, it is generally agreed that if such effects exist, the use of a screen with MPR II will mean that the monitor will become a relatively small source of these fields, compared to fields generated by other items of electrical and office equipment.

The TCO has updated its recommendations as TCO 95 and TCO 99. The emission levels recommended by TCO95 and TCO 99 are the same as those recommended in TCO92, although the test methods have changed.

At the time of writing there is an attempt being made to establish MPR3 as an international standard to consolidate MPR2 and TCO. Level A of MPR3 is the equivalent of TCO and Level B is the equivalent of MPR2.

Static Electricity

In the past, the static electricity that was generated on the front surface of CRTs has been alleged to be a factor in a number of health risks. Research has not shown evidence to support this.

Screens conforming to MPR II or TCO will be treated with conductive coatings which reduce the static charge on the monitor and eliminate any possible discomfort from static. The coatings will also help to avoid the build up of dust on the screen and will help to maintain the visual performance of the screen.

Further Information

The CSF has published an FAQ about monitor safety issues and this is available from the web site at http://www.csf.org.uk

RFI/EMC & The CE Mark

Radio Frequency Interference (RFI) and Electromagnetic Compatibility are not considered to be a primary issue of ergonomics, but can cause serious problems if there is interference between different items of electronic equipment.

Products carrying the CE mark will meet, among others, EN55022 for radio frequency emissions and EN50081-1 and EN50082-1 for immunity to interference. From 1st January 1996, all electrical and electronic products sold in the EU must carry the CE mark. Products marked with the CE mark have been certified by the manufacturer as being compliant with the EU electro-magnetic compatibility regulations.

Environmental Marks

To reflect increasing concern over the environmental effect of technology, a number of marking schemes have been developed that are intended to show the manufacturer's concern for environmental issues.

Emissions & Environment

TCO95

The TCO labour union issued new guidelines for the manufacture of more environmentally friendly computers and monitors in 1995. These added additional design requirements for recycling, limits on the use of certain chemicals and visual ergonomic requirements to the emission levels and power saving already established in TCO92.

TCO99

TCO again revised their guidelines in 1999 as TCO99. The main changes from an environmental point of view were in procedures. There were minor changes to the ergonomic requirements, power saving and emission measurement methods.

Blue Angel

The Blue Angel mark has been promoted by the German government for a number of years to help consumers to identify 'Environmentally Friendly' products. The Blue Angel mark on a monitor requires Power saving to Energy Star requirements, modular construction for upgrade and repair, the control of chemicals, MPR2 emission levels and design for re-cycling. The manufacturer must also be prepared to accept a product at the end of its life for appropriate disposal or re-cycling.

TÜV ECO mark

TÜV, the commercial German testing organisation has produced an ECO mark that covers similar areas to the Blue Angel.

The TCO and TÜV marks require testing to be granted, while the Blue Angel mark relies on certification by the manufacturer. Some aspects of the TCO and TÜV marks are also self-certified.

Warranty

Good quality monitors represent a significant investment. Therefore it is important to check the warranty available from the manufacturer as well as that from your supplier.

Manufacturers Warranty

A number of manufacturers are now offering warranty periods longer than one year either on a chargeable or no-cost basis. Ensure that if there is a registration qualification, the appropriate warranty registration form is completed and sent back to the manufacturer.

On-Site Warranties

To avoid any damage that could arise from transporting monitors, a number of manufacturers offer on-site warranties as well as return to base facilities. If an on-site warranty is an important feature for you, it is important to check at the time of purchase whether an extended on-site warranty is available and if so at what cost.

CRT Life

Some monitor makers will exclude the CRT from extended warranties. All CRTs start to slowly decline in performance from their new condition. This is because of reduced efficiency from the Cathode assembly. The reduction in beam strength leads to a gradual loss of brightness and focus. CRT manufacturers generally quote an average expected life of 20,000 hours for the CRT to drop to 50% emission.

20,000 hours represents 10 years of normal office use, but demanding users may find that the quality is unacceptable before this time.

Care should be taken to avoid displaying fixed patterns on the screen - especially at high brightness. This can lead to 'phosphor burn', reducing the life of the CRT. 'Screen savers' which blank the screen or change the pattern when the system is not in use can be helpful in reducing this effect. Screen savers used in conjunction with monitors equipped with Power Management (Energy Star or TCO) can also reduce the cost and increase the life of the monitor.

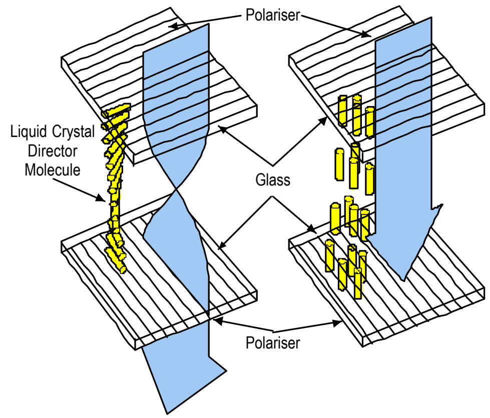
CRT monitor design is a mature technology that brings unique properties of economy, flexible format and excellent visual performance. However, a drawback of CRTs is that they are bulky. Furthermore as the image size increases, the depth of the CRT increases, making the CRT impractical for some applications. The race has been on to develop monitor technologies that can replace bulky CRTs.

The key technology that's likely to be used in the near future is Liquid Crystal Display (LCD) technology, which will already be familiar from its use in notebook displays. One or two makers also expect colour Plasma Display Panels (PDPs) to be popular in the 21" to 25" size range.

Liquid Crystal Displays

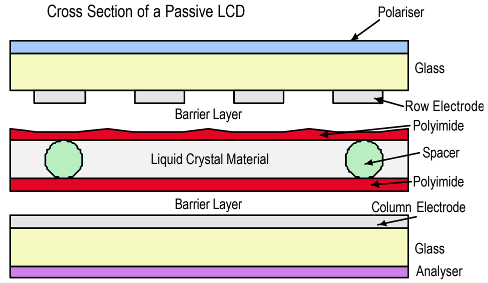
LCDs rely on the special properties of a group of chemicals called Liquid Crystals that are transparent and whose molecules are twisted. The twist of the molecules changes the polarisation of transmitted light. The angle of the change can be controlled by subjecting the crystal to an electric field. These properties have been used to develop displays that use the crystals to control the amount of light that is passed through the display.

Light is produced by a backlight and is passed through a polarising filter. When no field is applied to the LCD, the polarisation of the light is changed as it passes through the LC material (90° in a TN display, up to 270° in an STN system). The light then meets a second polarising filter that is at right angles to the first and the light is transmitted. If a field is applied to the crystal, the angle of twist changes and only a proportion of light is transmitted. In this way the brightness level is controlled, giving the grey scale necessary for high quality images.



The screen is divided up into picture elements (pixels). The image is built up using these pixels. In a colour LCD, each pixel is fitted with either a Red, Green or Blue filter.

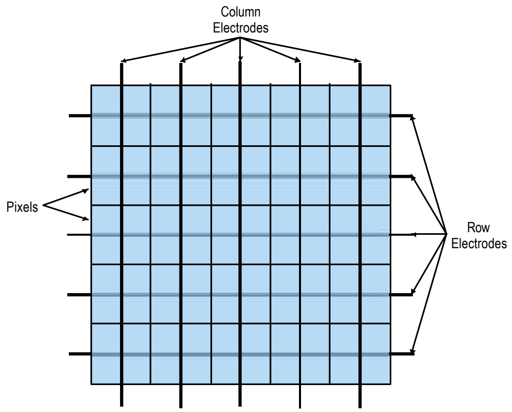
The image is made up of a matrix of pixels and the way that the brightness is controlled in each individual pixel, and known as the addressing, is a key difference between two types of LCD.



Passive Matrix LCDs

The simplest and therefore lowest cost form of LCD addressing is passive matrix addressing. In this scheme, transparent conductive lines for the rows and columns are applied to the glass above and below the Liquid Crystal (LC) material.

When a voltage is applied between the two points, the crystal re-aligns, changing the light transmission. In order to set different brightness levels for individual pixels, rows are set sequentially.



Passive Addressing

When a row is selected, the appropriate voltages are fed to individual column driver circuits. Current flows through the column lines to the selected row and the LC materials align accordingly. The drive circuits then move to the next row and repeat the operation. When the scanned row reaches the bottom of the display, it starts again at the top of the display.

This kind of scheme could cause a lot of flicker, so LC material is used that has a slow response time - that is, after the crystal is aligned by the field, it takes quite a long time to return to its unaligned state. The slow response means that fast moving objects can be difficult to see and can smear, making single scanned passive matrix displays unsuitable for fast changing graphics or motion video.

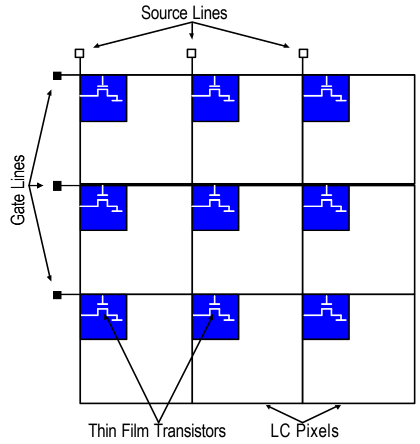
A further drawback of passive addressing is that there is some influence on other pixels in the same column and row as the pixel that is being set. The effect of this influence is called crosstalk and the visual result is that especially light or dark blocks of pixels on the screen can affect adjacent areas by making them lighter or darker respectively.

To reduce the crosstalk effect, makers divide the screen horizontally into an upper and lower half and refresh each separately. This kind of display is called a Dual Scan Twisted Nematic (DSTN) display and is by far the most common form of passive display used in notebook computers, although some low cost computers do still use single scanned displays.

To further improve performance and reduce crosstalk and smearing, a number of makers have introduced a technique called multi-line addressing that addresses two lines at a time. The best of these can almost eliminate crosstalk effects.

Active Matrix LCDs

Active Matrix LCDs (AM LCDs) use an electronic switch at every pixel position so that once a pixel is switched on, the field can be maintained by the switch. This allows fast LC material to be used, so that smearing is no longer a problem. The switch, which is usually a Thin Film Transistor (TFT) also isolates the pixel from the influence of adjacent pixels and eliminates crosstalk.



The main disadvantage of TFT LCDs is the extra complication of manufacturing, as the glass substrate that the transistors are built on is effectively a single chip - but with a 10" to 20" diagonal. As multiple LCDs are normally made on a single substrate to keep costs down, the level of care needed in manufacturing becomes very high. As an example, a substrate that has four 800 x 600 resolution panels on it has 5.76 million transistors - more than an Intel Pentium CPU.

TFT LCDs can offer very high levels of performance for motion video or other applications.

Defects

Because of the high number of components, it is impossible for manufacturers to make perfect TFT displays. Small defects will show as some pixels that are permanently light or dark. Each manufacturer of displays will have a standard for the number of defective pixels that is considered as acceptable for the product that they supply and this level will normally be agreed with the maker of the monitor or notebook computer - a factor that will affect the cost of the pane to the computer maker.

(CRTs often have these small imperfections, but these are usually less obvious than on LCDs where each pixel is more precisely defined)

Individuals vary in their sensitivity to these small defects. If you are choosing a display and are concerned about possible defects, it is important to either check with the maker the level of defects that are considered acceptable, or to ensure that you receive a demonstration of the actual unit that you plan to buy. (In a recent magazine review, makers quoted levels from 1 to 25 as the number of defects that would make them consider an LCD faulty and eligible for repair or replacement under warranty). Check for defects on a completely blank screen with a white background and also with a black background. Look for light, dark or coloured dots that stand out from the rest of the screen.

LCD Performance

Although LCDs avoid a number of the disadvantages of CRTs, they also lose some of the advantages.

Brightness

A key feature of LCDs is that they are transmissive, that is to say that the image forming aspects of the display are separate from the light generation parts. This means that, within a wide range, the brightness of the display can generally be increased without affecting picture quality, simply by increasing the backlight output.

Typical notebook LCDs are limited to around 70 cd/m^2, to minimise power consumption while LCDs designed for desktop use may have brightness from 120 to 250 cd/m^2.

Geometry & Formats

LCDs are of a fixed pixel format with the geometry precisely set in manufacture. Therefore LCDs do not suffer from imperfections in linearity and geometry.

On the other hand, the fixed format means that LCDs are highly optimised for a particular resolution, for example 800 x 600 or 1024 x 768. To display images of a higher or lower resolution, either only part of the screen, or some form of scaling technology is used. The scaling technologies vary a lot in their quality, so it's important to check the performance if you plan to use an LCD for multiple resolutions.

In practical terms, where a large number of users are given the same display system, some may use lower resolutions to give larger character sizes. This is not a problem where CRTs are used, because of the inherent multi-format capabilities of CRTs, but could cause difficulties with LCDs.

CRT displays have traditionally been rectangular with a width to height ratio of 4:3 as this is the most economic shape to make. LCDs do not have such an optimum aspect ratio, so we are likely to see a wider range of shapes in the future. The lack of any magnetic effects means that LCDs can be developed that are suitable for use in applications where it may be useful to be able to rotate the screen to landscape or portrait orientation.

Colours

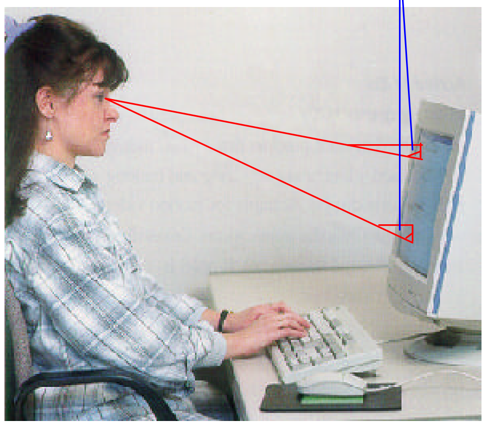
Most LCDs use digital circuitry internally and typical monitors support 262,000 (18 bit - 256K) colour, whereas CRT monitors support an infinite range of colours within their overall range, or gamut of colours. For motion video applications, the range of colours should be at least 262,000. Some LCDs support a much more limited range of colours and are not suitable for multimedia applications.

The gamut, or range, of colours available from LCDs is different than that available for monitors. The gamut is set by the performance of the backlight and the specification of the filters. This means that the performance of LCDs is less adjustable than for CRTs and makes them less suitable for colour critical applications.

Viewing Angles

Light emitted from the backlight and transmitted through the rear polariser doesn't only pass through the LC material at right angles to the polarisers. Light also passes obliquely through the LC material and filters which have a different optical effect at these angles. The result is that the optical performance can vary quite dramatically with viewing angle, in extreme cases and angles, leading to contrast inversion, where the dark part of the screen becomes light and vice versa. Typically the viewing angle is wider horizontally, but lower vertically on LCDs that have no special technology for viewing angle improvement.

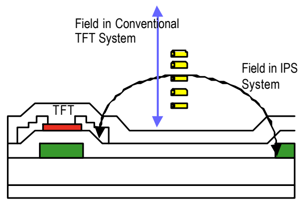
Viewing angles are different between the top and bottom of the screen



Restricted viewing angle is a limited problem with small displays on notebook computers where the position of the user is fairly accurately known. (In fact, some makers claim this as an advantage, giving greater confidentiality on aircraft!) In desktop applications the user - or more than one user - may need to see the display from a range of different angles.

A variety of strategies are used to improve the viewing angles on LCDs which are designed for desktop monitors. Some of these technologies lead to reduced optical efficiency which would make the techniques unacceptable on notebook applications because of the increased power consumption for the same level of brightness. This is less of an issue where the panel is for desktop use, as the consumption is still less than an equivalent CRT.

- In-Plane switching
  In this technique, the liquid crystals are arranged to be parallel to the glass substrate, rather than at right angles to it.



- Compensation Film
  Compensation film is used to compensate for the retardation effects of light travelling through the crystal at an oblique angle to the front face.
- Multi-domain Pixels
  In this method, each pixel is sub-divided and liquid crystals are aligned differently in each sub-pixel. The different alignments compensate for each other.

- Vertical Alignment
  Vertical alignment uses different LC material which aligns with the substrates when under power, like the LC material in an in-plane switching system.
- Reduced Cell Gap
  By reducing the gap between the panes of glass and the thickness of the LC material, reduced distortions from off-axis viewing can be achieved.

Increasingly, LCD manufacturers are using combinations of these techniques to achieve the optimum performance.

Pixellation

Because of the shape of the CRT beam, the edges of individual pixels are less clearly defined on CRTs than they are on LCDs (see page 9). Where the dots (pixels) that make up the image are very clearly individually defined, the display is said to be 'pixellated' i.e. each pixel can be clearly seen. Images such as photographs or motion video look much better with a 'seamless' quality where the pixels run together, as they do on a CRT. LCDs may be less suitable for applications such as viewing scanned documents.

On the other hand, some recent work in human vision suggests that images with more sharply defined edges to the pixel may cause less eye strain. (For more information on this, see the world wide web at http://www.prio.com)

Ergonomics

The ergonomic issues of LCDs are the same as for CRT monitors and employers have the same obligations. However, for cost reasons, it may be tempting to use smaller displays than would have been used with a CRT. This may result in character sizes that are too small to be legal. Furthermore, because LCDs are lighter and easier to position, it may be tempting to position the display away from the user, but the same care to avoid muscular/skeletal problems must be taken. LCDs must be mounted in ways that allow the user to tilt and swivel the display as appropriate.

Reflections

Just as with CRTs, there are potential reflection problems on LCDs and products from different makers perform differently according to the technology used (see page 10). Because of their higher cost you should expect any LCD display to have at least an anti-reflective coating.

Flicker

Flicker is not such a problem on LCDs, as a pixel that's transmitting stays in that state constantly. The type of backlight used on an LCD typically is a cold cathode fluorescent lamp that can operate at frequencies of 70KHz or more, 1000 times faster than a CRT, so flicker from the lamp is unlikely to be a problem!

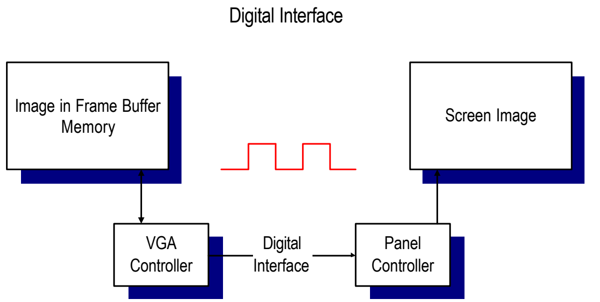
Interfaces

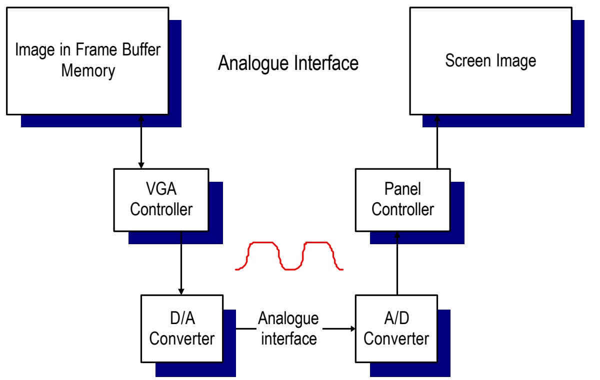
Because most LCDs use digital drive circuitry internally, the optimum performance of most LCDs can usually be achieved using a digital interface. To reduce compatibility problems, a number of different standards and recommendations have been produced in recent years. VESA developed a standard called Plug and Display (P & D), but it wasn't widely adopted. A further connection system called the Digital Flat Panel (DFP) interface was developed by vendors and later adopted by VESA. Finally, a group of PC companies cooperated to develop the Digital Video Interface connection (DVI). The DVI interface has been endorsed by many leading hardware companies and seems likely to be the standard for the future. Monitors and systems using DFP or P&D can support DVI, subject to appropriate connector adaptors being used.

Some digital displays may use proprietary digital interfaces with graphics cards specifically engineered for particular makers' panels. If you are considering a digital interface with a proprietary interface, it's important to check the supplier's commitment to supplying and maintaining software drivers for the operating systems and applications that you plan to use.

The alternative to a proprietary digital interface is the use of an analogue to digital converter in the monitor. These add cost, but ensure 'Plug and Play' operation with existing graphics controllers.

Unfortunately, some quality may be lost in the conversion from digital to analogue in the host computer and from analogue back to digital in the monitor, especially if there is some loss of bandwidth in the output stage of the graphics card.



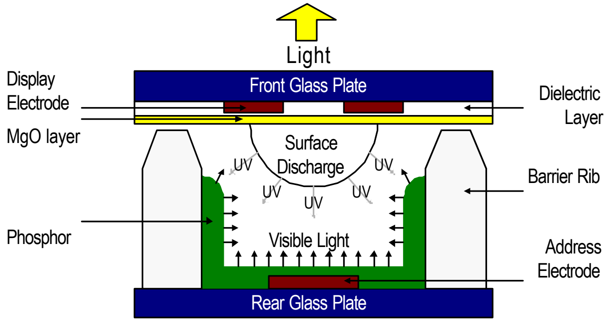


Warranties

LCDs are expensive components and with the rapid pace of development, product life cycles can be short. Repair is also the province of highly specialised facilities. Therefore it's very important to establish early in the purchase decision what the warranty on an LCD monitor is and if any components, such as the backlight, are excluded. You should also check what extended warranty is available and the cost of out of warranty repairs.

Backlight Life

The source of light in most LCDs is one or more cold cathode fluorescent lamps. Like a CRT, LCD backlights will gradually deteriorate over time, but should be replaceable. Some monitors are designed for the replacement to be performed by the user, while others may need to be returned to the maker. Charges for new backlights can vary from maker to maker.



Plasma Display Pixel

One advantage of an LCD is that replacement of the backlight will bring performance back to the new level, as there is no widespread evidence of gradual failure of other components over time, although some polarising filters have been shown to deteriorate when exposed to bright sunlight over long periods.

Plasma Display Panels

Plasma Display Panels (PDPs) are another type of flat panel technology that is just starting volume production. In a PDP, each pixel is like a miniature fluorescent lamp that glows red, green or blue. Like CRT monitors, PDPs produce light by causing phosphor to glow, so have wide viewing angles and good colour and motion video performance.

There are some very difficult technical issues involved in making small pixel sizes on PDPs, so most products are likely to be intended for TV and public information applications, although at the time of writing, one or two companies are claiming to be able to make 21" diagonal PDPs with a resolution of 1280 x 1024, bringing them into the workstation application area.

Further Information

If you have further questions or need more information, please call the CSF Monitor Hotline on 01905 727610. (Please note that we cannot offer purchase advice on the choice of specific models or brands).

Web Site

The CSF has a World Wide Web site which has an electronic version of this publication available for downloading at http://www.csf.org.uk

Monitor Test Software

You can also download our 'CheckScreen' monitor test software for PCs to run on computers with the Microsoft Windows operating system from the CSF Website
http://www.csf.org.uk

High Resolution Graphics Display Systems, J Peddie, McGraw Hill
ISBN 0-8306-4291-9

Screen Facts - TCO - PO Box 5252, S-102 45 Stockholm Sweden
Tel 00-46-8-782-9100

VDU's — an Easy Guide to the Regulations - HSE ISBN 0-7176-0735-6,
HSE Books Tel 01787-881165

EC Screen Directive no 90/270/EEC 29th May 1990

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