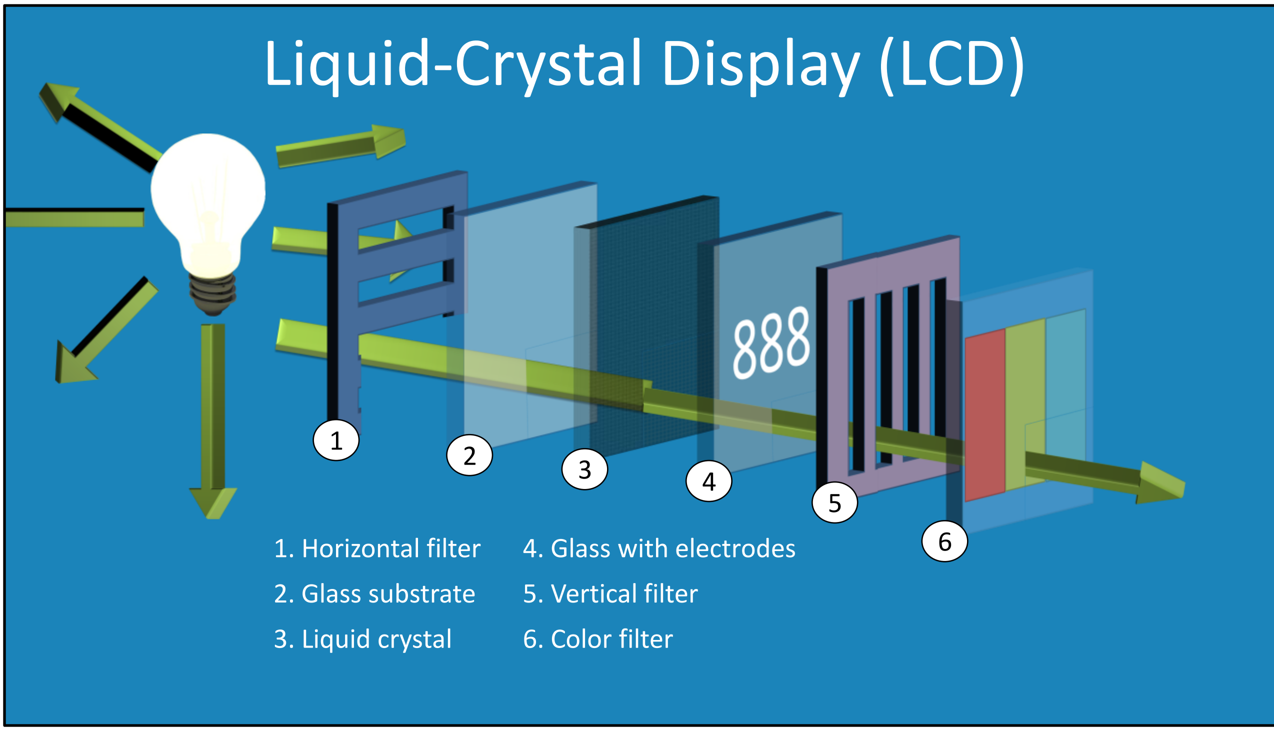
In this video from ITFreeTraining I will look at monitors. Monitors essentially display a picture that allows you to know what is going on inside the computer. There are three basic types of monitors, flat-panel monitors, projectors and virtual reality headsets. This video will look at flat-panel monitors and I will leave the rest for another video.

Cathode-Ray Tube (CRT)

- Has toxic waste so dispose of correctly

0:23 Before I start looking at flat-panel monitors, I will first have a very quick look at CRT monitors. I say quickly because for the CompTIA exam you really only need to know that CRT monitors contain toxic waste and thus need to be disposed of correctly. This means disposing of a CRT monitor in an e-waste facility, not just sending it to land fill.

CRTs are big and bulky compared with flat-screen monitors and thus less preferable. In 2008 flat-panel displays exceeded CRT sales. The last CRT was manufactured in 2015. If you do come across one in the workplace, you will most likely be asked to dispose of it. Now to the main topic of the video.



1:07 The liquid crystal display, or LCD, has become the most used and sold monitor on the market. There are a few different types, but before I start looking into that I will first look into how they work. You don't need to know too much about how LCDs work for the CompTIA exam, but having a basic understanding of LCDs will help you understand what you can expect to achieve out of them and their limitations.

An LCD screen essentially starts with a light source. There are a few different ways this can be done, but for the present let us just consider this is at the back of the monitor creating light. The light goes off in every direction. When the light is distributed in different directions it is also distributed in different wave forms.

I will spare you a big physics lesson, but essentially what happens is a filter is placed in front of the light source. This filter blocks some of the waves but not all. Essentially, what is going through the filter is light of all the same wavelength. The filter is placed so it is horizontal. To understand why, I will skip ahead a little bit.

Towards the end of the process, there is a second filter. This filter is essentially the same as the first however it is rotated 90 degrees. Since the filter is rotated, this means it will block any light allowed through by the first one.

You may be wondering why you would have two filters that block all the light that travels through; however, it will start making more sense soon. In the middle of the process there is a layer of liquid crystal, and this is where its name comes from. When light passes through it, it will travel through but will not be altered. However, if electricity is applied to it the liquid crystals this will change the wavelength of the light traveling through it. Depending on what wavelength is when it hits the second filter it will either be allowed or blocked.

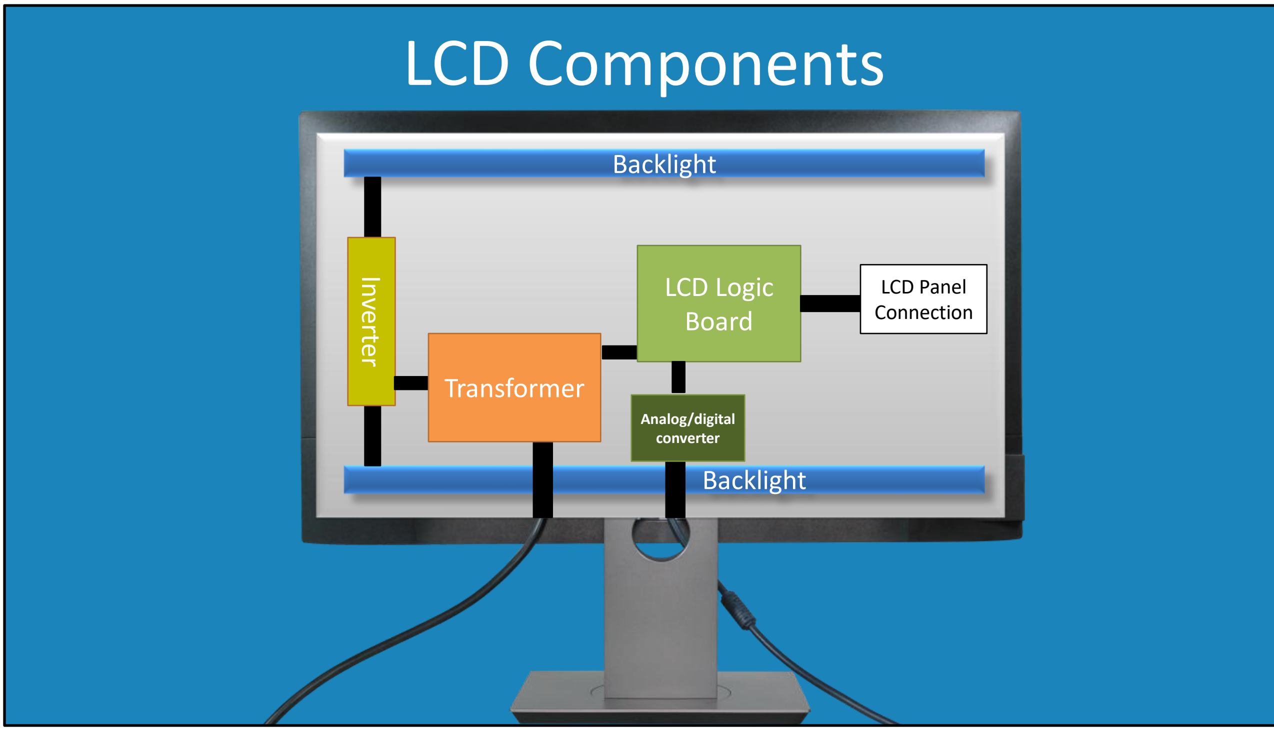
This may seem like a complex process but let us consider what we have managed to do so far. Essentially, we have got a light source. We have filtered the light to allow only light of a certain wavelength. A second filter will block this light; however, we now have a way of changing the wavelength, so it is allowed through. So, what you have in a nutshell is a method to control what light goes through and what light gets blocked. This is starting to look like something we can use to display an image, but we still need a few more things.

As we are using liquid crystal, you need a way of holding it in place. To do this, a glass layer is used. This layer is designed so it will not block or scatter the light that goes through it.

The next part that we need is a way of controlling what light goes through down to the level of a pixel. To do this, another glass layer is added which has electrodes in it. This layer allows electricity to be applied to small parts of the liquid crystal layer. This essentially controls how much or how little of the light is allowed to be transferred through it.

So, we now have a way of controlling what light goes through on a very small scale, however it will only be white light and does not have any color. In order to get color, a final layer is used which is tinted in three different colors.

This is the fundamental method used to display pixels on an LCD screen. Different LCD screens will use different methods to control the process. Later in the video I will look at some of the different methods that different LCD monitors use. Next, I will look at the different components that make up an LCD screen.



4:43 Although different LCDs can differ in design, they are fundamentally made up of the same components. If I consider a typical LCD screen: All LCD monitors will have the screen itself. Next you need to have some way to light the screen. Different processes have been developed to do this which I will look at later in the video. One of the earliest approaches was to use a backlight. A backlight essentially shines a light on the back of the LCD screen lighting it up, thus the name backlight.

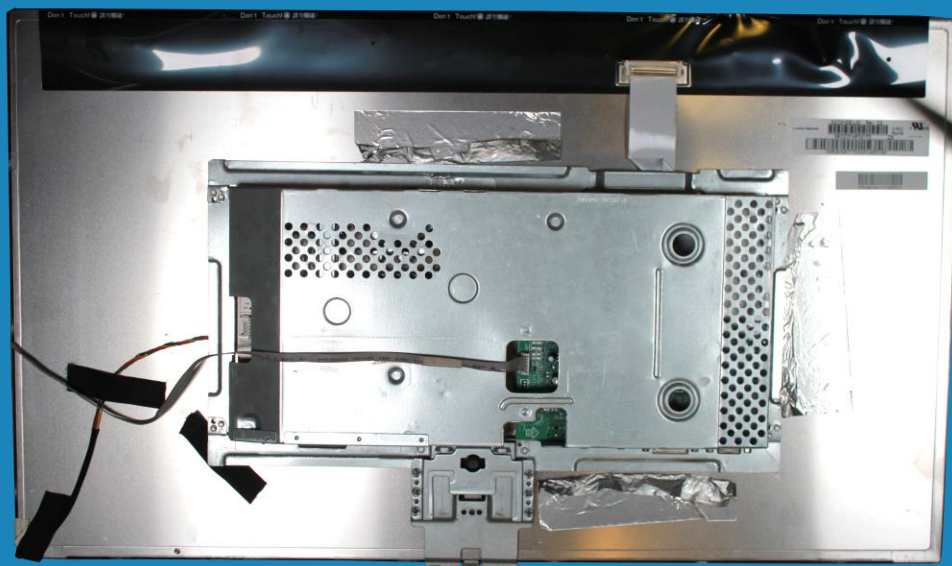
Some LCD screens have a backlight at the top and the bottom, however there were also cases in large early TV screens that there were a number of backlights all down the back of the screen. These backlights are often built in the screen itself, so you won't be able to access them easily. Usually you will need to dismount the metal casing around the screen itself to get to them.

In the older LCD screens, these backlights were powered by an inverter. An inverter provides alternating power to the backlight which essentially makes it flicker at a high rate. The inverter is powered by a transformer which is connected directly to the power cable.

In order to control what is displayed on the screen, there is an LCD logic board. This logic board will takes the instructions from the computer and transfer them to the LCD panel via a connection, which generally will be a ribbon cable attached to the screen.

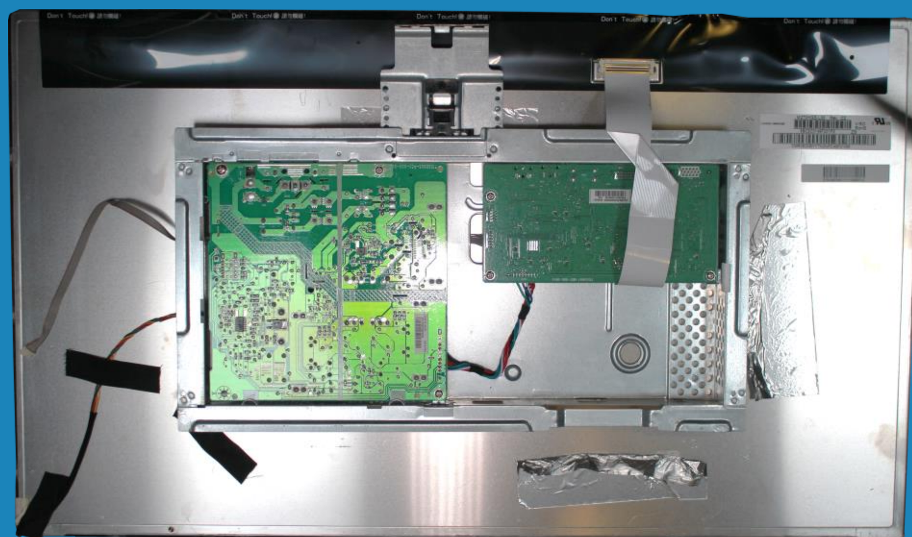
Lastly, to get the instructions from the computer, the LCD logic board may be connected to an analog/digital converter in which the connections from the computer are plugged into. I said maybe, because this may be part of the LCD logic board itself. Different monitors will differ in design, but they all follow a similar overall pattern. Let's have a look inside one to get a better understanding. If you decide to do something like this, remember the inside of an electronic device can hold power and cause an electric shock. You should not take apart something like this unless you are trained to do so. ITFreeTraining cannot take any responsibility if you disassemble an LCD screen.

Inside LCD screen



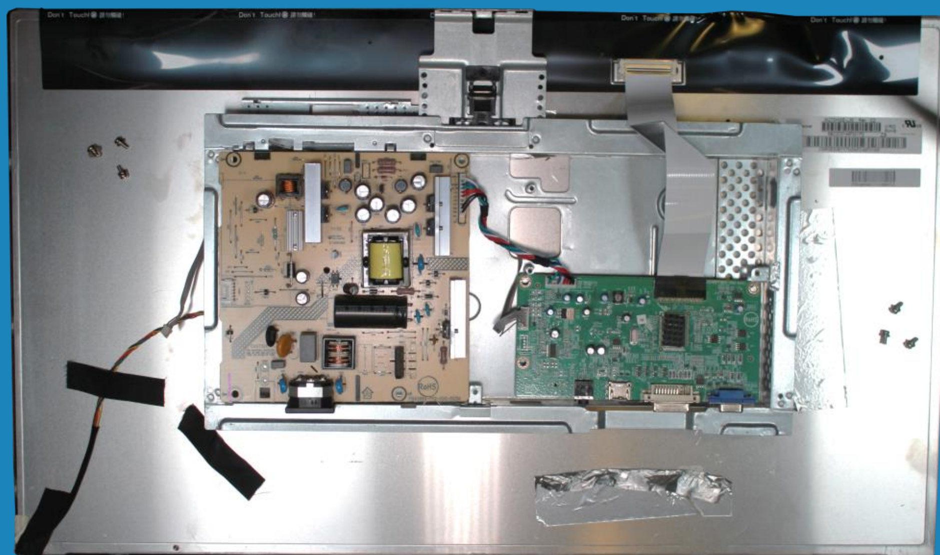
6:52 Although the design can differ, once you take the back off the monitor, the components will often be found behind a metal casing. Once you remove this metal casing, you will be able to see the components inside.

Inside LCD Casing



7:04 The next step is to flip the casing over to see the components inside. We can only see the back of the components, so we cannot see much about them. So, I will unscrew the components and flip them over.

LCD Components



7:16 In this LCD monitor you can see that the components are divided up into two boards. The left board is the power transformer and powers the backlight. The right board is the logic board which would also contain the analog to digital converter. So essentially if you want to break it down, for this monitor, there are three basic parts. The screen, the logic board and the power board. All these are connected to each other by cables.

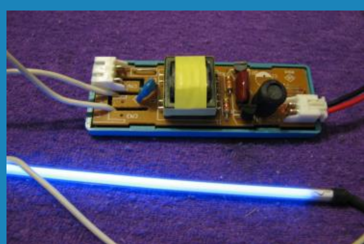
So, something to think about, if you had two broken monitors could you replace parts from one with parts from the other. The answer is yes you could. If a part is faulty, you could replace one with a working part. You could also order replacement parts if you knew which part was faulty.

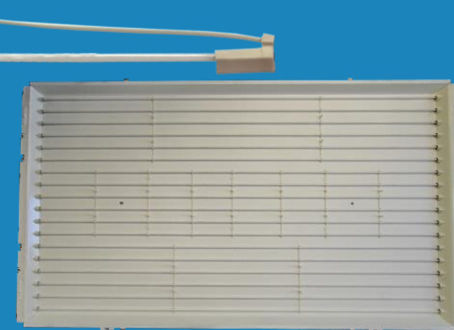
Depending on who you work for will determine how much effort you will go to in fixing an LCD monitor. Since LCD monitors are cheap, most companies will just replace the monitor. If they really want it fixed, they may send it away to get repaired. If it is your home monitor, well you may want to spend the time to fix it. When looking at the components in the monitor, look for things like damaged capacitors or scorched electronics. If you see either of these, the board probably needs to be replaced. A damaged LCD screen is easy to see because you see distorted patterns all over the screen. If the screen is dim or not lit correctly it could be the backlight or possibly the power to the backlight.

Now that we understand how the basics of LCD monitors work, I will now have a look at how the components have improved, starting with the backlight.

CCFL Backlight

- Uses AC power so requires an inverter
- Gives off heat (Can’t put too close to screen)
- Difficult to light evenly (Particularly larger screens)





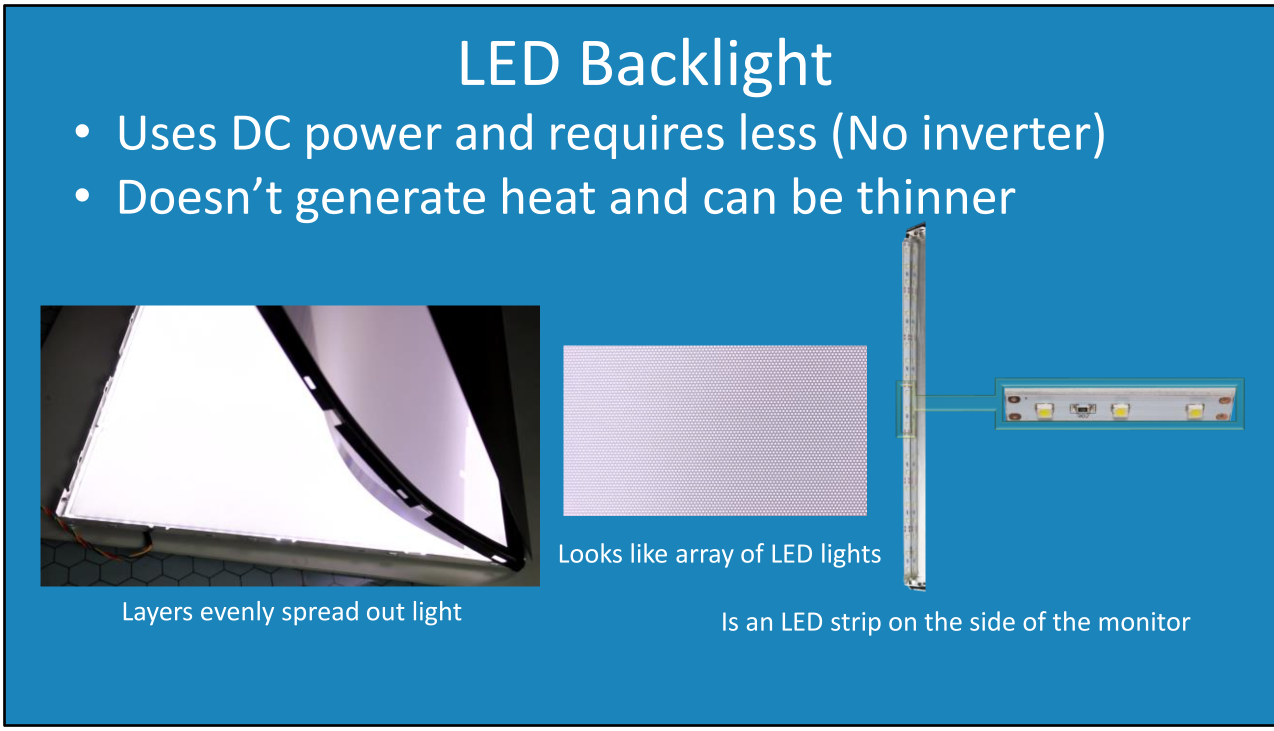
8:53 CCFL backlighting was the main way to light LCD screens until LED lighting took over, which I will look at next. Don’t worry too much about the term CCFL as this method is no longer used. If you have a monitor using this and it breaks, you should consider replacing it.

This kind of backlight used a tube or multiple tubes to light the screen. This worked, however was not without its problems. Firstly, the tubes required AC power so required an inverter. This may not seem a lot, but any extra components that are added to an electronic device increases its cost and is another thing that can break.

The next problem with this kind of backlighting is that the tubes generate heat. This means that you can’t put the tubes too close to the screen otherwise they could damage it. Also, when using tubes, there was the problem that it was difficult to evenly light the screen. This particularly became a problem with larger screens. To get around this, a number of tubes were deployed behind the screen to provide more light.

It is difficult to see, as the case is white in this example, but this is a picture of a 42-inch TV set which has 18 tubes running along the back of it. This many tubes were required to make sure the back of the screen was evenly lit.

Some screens will have a top and bottom tube to light the back of the screen. The problem however is that the middle of the screen may not receive as much light as the rest of the screen. Having a top and bottom light did not work for screens that were over a certain size. So, let us have a look at how these issues were dealt with as the technology improved.

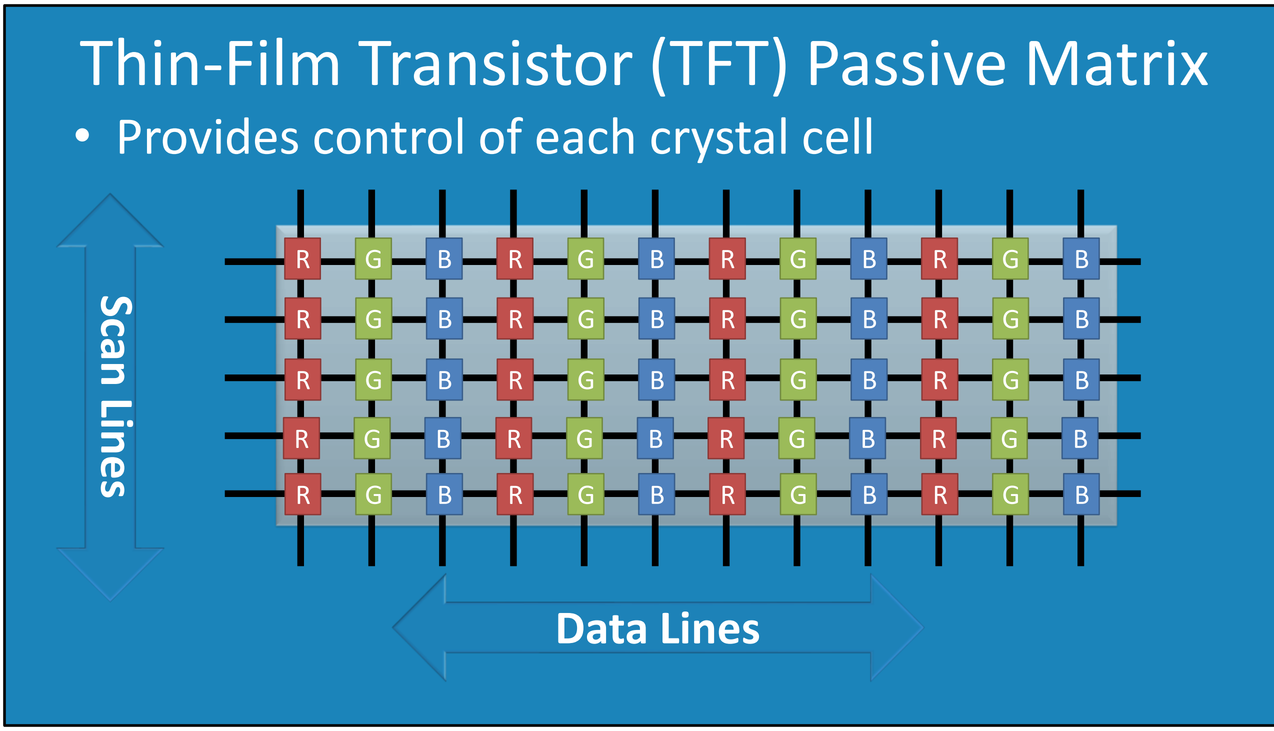


10:31 To improve the way screens are lit, LED backlighting was developed. This differed in that it used DC power rather than AC, meaning there was no need for an inverter. LED backlights generate less heat and thus can be placed closer to the screen.

Shown here I have a screen that uses an LCD backlight. You will notice that there are a number of layers. These layers include layers for diffusing and reflecting the light forward. Do not confuse these with the polarizing layers which are part of the screen itself. These layers are designed simply to help spread out the backlight evenly.

Once I get to the LED screen and have a closer look, you will notice that it looks like an array of essentially LED lights. However, in fact it is not. In order to provide a backlight, there is a LED light strip on the side of the screen. This LED strip provides the light. The other layers spread the light out evenly and reflect it forward. With improvements in monitor manufacturing, the manufacturers have become very good at this process. However, when you pull the monitor apart it does initially look like an array of LED lights behind the screen, however this is not the case.

Now that we have had a look at how at an LCD monitor is lit, let's now have a look at how we control what we see on the LCD.



11:56 To control what is displayed on the screen, a special layer in the monitor called a Thin-film Transistor layer is used, otherwise known as TFT. It is why you will sometimes hear LCD monitors referred to as TFT monitors.

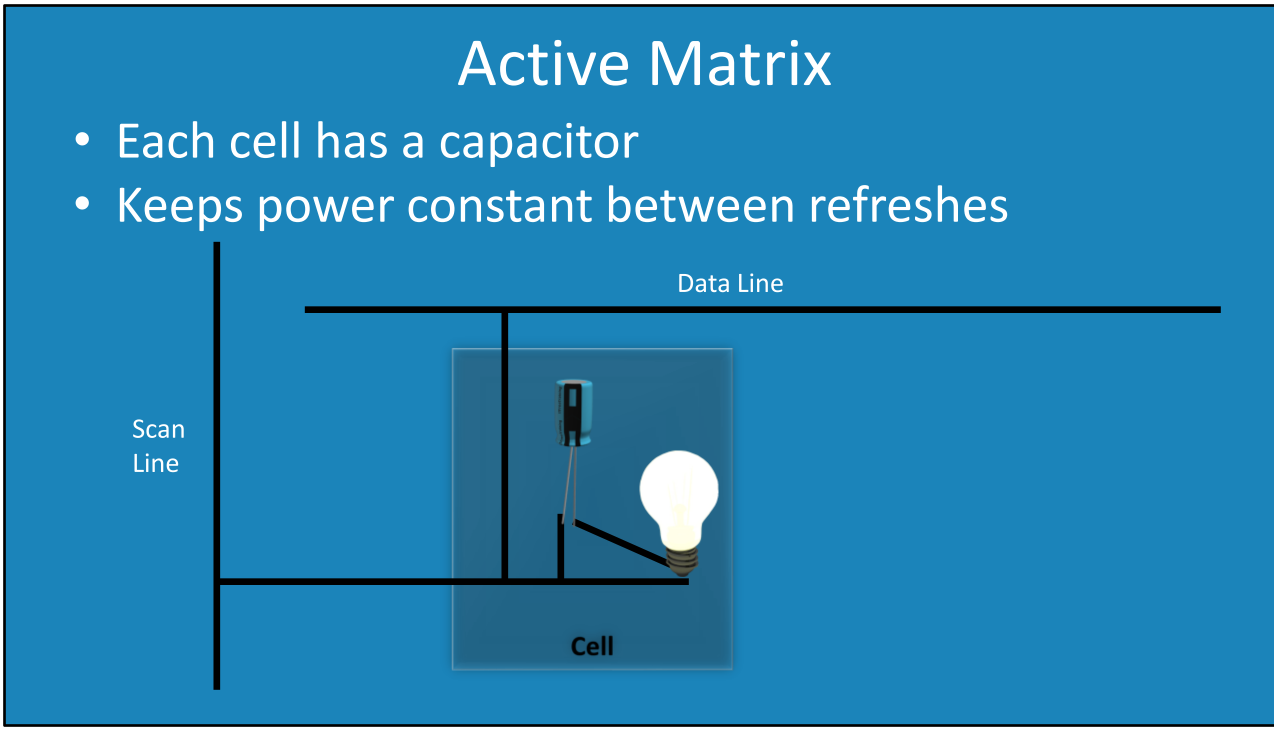
If you consider that there is a layer that controls what is displayed on the screen, to be able to supply voltages to different parts of the screen you need some wires. The vertical wires are the scan lines. To create the picture, the monitor will run through these scan lines starting from the top going down to the bottom. The process is than repeated.

This controls each line; to control each pixel a data line is added horizontally. As the monitor activates the scan lines, the required data lines are activated allowing control of each cell. To create a pixel you require three colors, so each pixel requires three cells.

There you have it, a TFT essentially provides control of each crystal cell. How much power the cell receives will determine how much light is allowed to pass through it. This allows the monitor to control what is shown.

A simple design like this is called a passive matrix. Passive matrix was used in the first LCD displays for devices like laptops. The display did not update very quickly so when you did something like move the mouse, you may have seen a ghosting effect where it appears the mouse is leaving a trail when it is moving.

Passive matrix was used in LCDs until about 2010. They may still be used for less demanding displays like the control panel for an electronic device. However, LCD displays changed to another method in order to improve their performance.



13:39 To improve performance, active matrix was developed. The difference is that active matrix uses a capacitor in each cell. A capacitor is an electronic component that holds a small amount of electric charge for a small amount of time.

One of the big problems with passive matrix is that it only powers the cell during a refresh. By adding a capacitor to each cell, the cell power is kept constant between refreshes. This improves the picture quality of the display.

To understand this better, let’s consider a single cell. The cell’s main job is to either allow or block light. I will represent the light coming through with a light bulb. As before, you need to control if the light is allowed through or blocked and this is done, as before, with the data lines and scan lines.

Using a passive matrix, you can only essentially have the cell light up during the refresh cycle. This caused some problems. With a passive matrix it is difficult to control how long the light will stay on for. You can start to see why you get a ghosting effect on monitors. Also, it is very difficult to control how bright the light is. For example, having the light on a quarter brightness. Generally, computers will use a byte to control color. That is, the value of the light can be 0 to 255. Ideally you want to control the light, so its brightness is on the same scale, that is brightness is between 0 and 255. With passive matrix you cannot achieve this, but with active matrix you can.

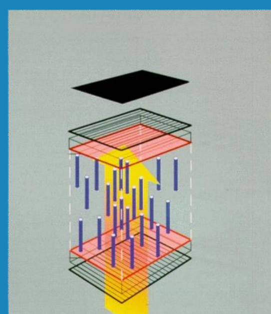
This is a very simplified version of the electronics that is used in an active matrix monitor, but essentially a capacitor is added to the circuit. The capacitor will store a charge and keep the light on so to speak between refreshes. Using this method also allows you to keep the light on at different levels. So, you can start to set the light on a scale between 0 and 255. This gives you much better control over the colors that can be seen on the screen. In contrast, passive matrix is like switching the light on and off really fast to try and get the result you want.

Nowadays all LCD monitors are using active matrix. The only place you may see passive matrix used is in low performance devices, for example a calculator or a device that does not require good color or good performance.

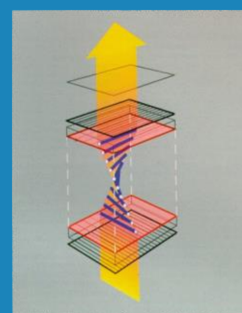
Active matrix gives us a way to control the cells on the screen; next I will have a look at the technology that controls what each cell on the screen shows.

Twisted Nematic (TN)

- Cheap to make/Fast refresh rates
- Poor color reproduction
- Poor viewing angles



Off



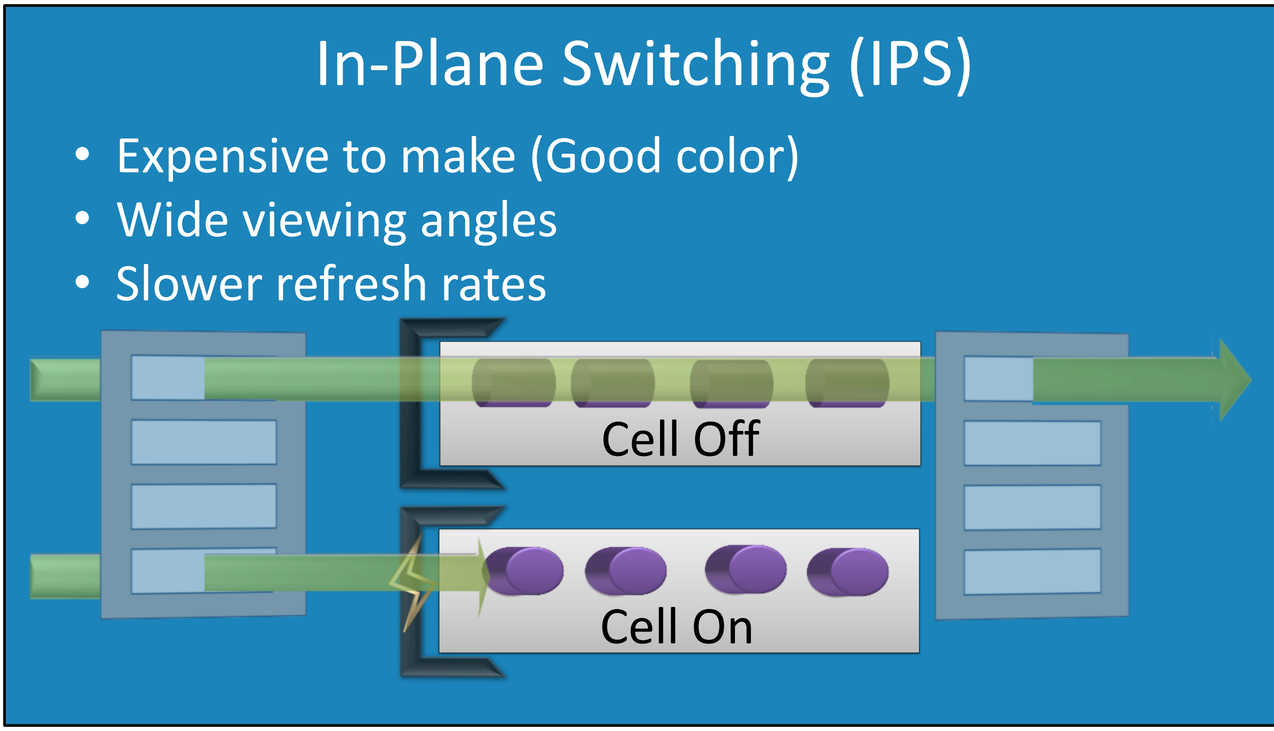
On

16:15 There are a few different methods, however in this video I will cover the three most common ones. The first one is Twisted Nematic otherwise known as TN. In the off position, that is there is no electricity traveling through, but light is allowed to travel straight through.

If you recall at the start of the video, the first filter in the process will block light except for a particular wavelength. When in the off position, this wavelength will be allowed to travel through unaltered. When the light hits the second filter it will be blocked.

In order to allow the light to travel through the second filter electricity is applied which causes the liquid crystal to twist the light as it travels through it. The electricity is applied through the cell from top to bottom. This twisting causes the wavelength to change as it goes through. Since the wavelength has changed it is now allowed to pass through the second filter.

The advantages of Twisted Nematic are that it is cheap to manufacture and has fast refresh rates. The disadvantage is that it does not offer the greatest color reproduction. Twisted Nematic also has poor viewing angles. If you step too much to the left or right of the monitor it will decrease the brightness of the image. You will also find this effect will occur faster if you look at the monitor from above or below it. Generally a person sits in front of a monitor, so this is not too much of a problem, however this may be more of a concern if you are mounting the monitor on a wall and it will be viewed from different angles.



17:48 To overcome some of these problems, In-Plane Switching or IPS was developed. In contrast to TN, IPS is expensive to make but has better color reproduction. It also has wider viewing angles to TN, however the downside is its refresh rates are slower.

IPS works a little differently to TN. To understand how it works, let's consider two cells, one is off and one is on. While the cell is off, that is no electricity is passing through it, but light is allowed to pass through it. This is the opposite to how TN works. Notice, the second filter is oriented the same way as the first filter whereas with TN the second filter is rotated 90 degrees to the first.

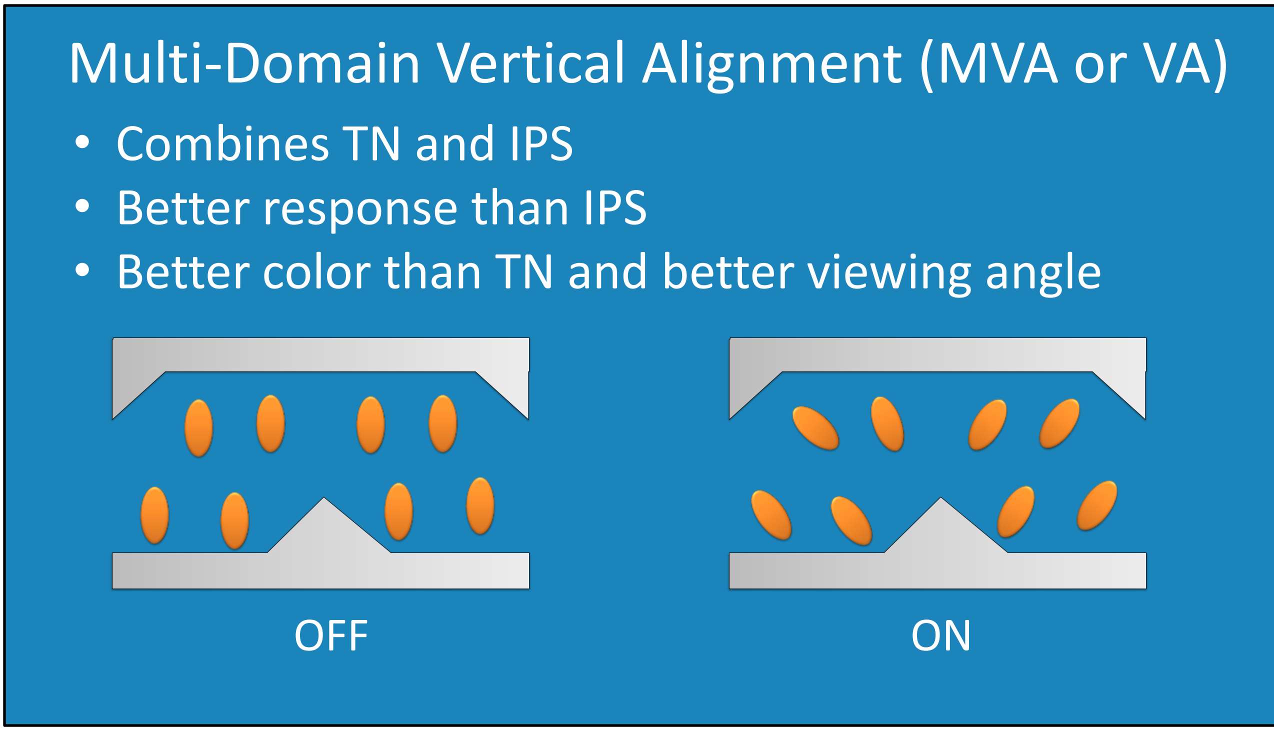
It should come as no surprise that in the 'on' state, light is blocked from traveling through the cell. In the case of TN, the liquid crystal is twisted, while in the case of IPS, the liquid crystal is rotated 90 degrees. With TN the electricity was applied to the cell from top to bottom. This is not the case with IPS. With IPS the electricity is applied to the cell from one side only.

Essentially IPS the electrodes are on either side of the cell, while TN the electrodes are on the top and the bottom. Electricity travels between the two which causing the turning effect changing the amount of light that goes through the cell. It is harder to manufacturer electrodes on either side of the cell rather than at the top and bottom of the cell, thus making IPS monitors cost more.

It may not seem like a big deal where the components are placed other than increasing the cost, but remember that there is a backlight behind the screen. This needs to shine through these electronics to get through. The placement of the electronics has an effect on the light travelling through. IPS the backlight needs to be brighter. To understand this better, consider that you have a light bulb and you mark it with a black spot. The more black spots you put on the light bulb the less light is going to get through. In order to get the same amount of brightness the light needs to be brighter. Therefore, the backlight on an IPS monitor needs to be about 15% brighter than with a TN monitor to get the same level of brightness. Brighter also means more power usage, so IPS is less energy efficient. In the case of the TN, since electrodes are at the top and bottom, when you are in front of the monitor the electronics line up with each other. Thus, no reduction of light, but as to move away from the center they end up getting out of alignment blocking more light. You can understand why TN does not have good viewing angles like IPS does.

This video only covers the basics of IPS. There have been a few different variations of the basic IPS design like super IPS and advanced IPS, however they all work in a very similar way to the basic version. The later designs produce better results. Most of these will be marketed as IPS. Later in the video I will look at how to compare different monitor specifications.

Let’s now have a look at the next specification which attempts to improve on some of the limitations of TN and IPS.



59:59 To overcome some of these problems, Multi-domain Vertical Alignment or MVA was developed, which combined TN and IPS together to produce a better result. MVA may also be referred to as just Vertical Alignment or VA. For the purposes of this video I will refer to it as MVA.

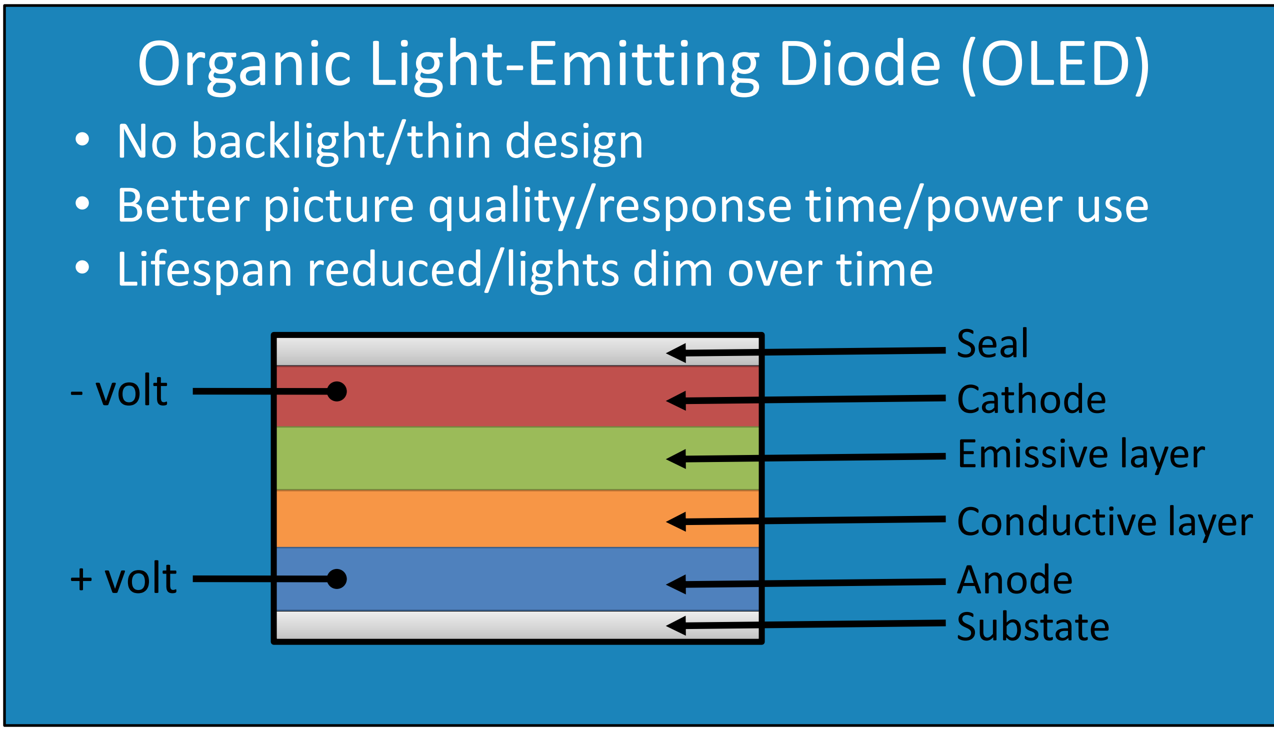
MVA offers better response time than IPS. MVA also has better color than TN and better viewing angles, so let's have a look why.

The cells of MVA are designed differently to IPS and TN. That is, they are designed so that there are a number of protrusions in each cell. That is, there are a number of pyramid like structures that stick out. If I consider a cell in the off state, the liquid crystals are all facing the same direction, that is 90 degrees to the glass that is holding the liquid crystal in place.

Now, let's consider the cell in the on state. In the on state, electricity just like with TN, travels from one side to the other. However, unlike TN, rather than a twisting patten the pyramid protrusions cause the liquid crystal to turn and face different angles. The result of this is, rather than the light leaving in one direction the light leaves at multiple angles. This is what gives MVA a wide viewing angle.

Of course, creating these little protrusions is difficult and thus costs more money to manufacture. This is why MVA monitors generally cost more. You generally see MVA used for the more expensive monitors. Remember MVA is a trade-off between the other two types, so it is not necessarily better in all ways compared to the other two but aims to improve on some of their weaker areas.

This covers the main ways that monitors control what is being seen on the screen. Next, I will look at a new design which removes the need for the monitor to have a backlight.



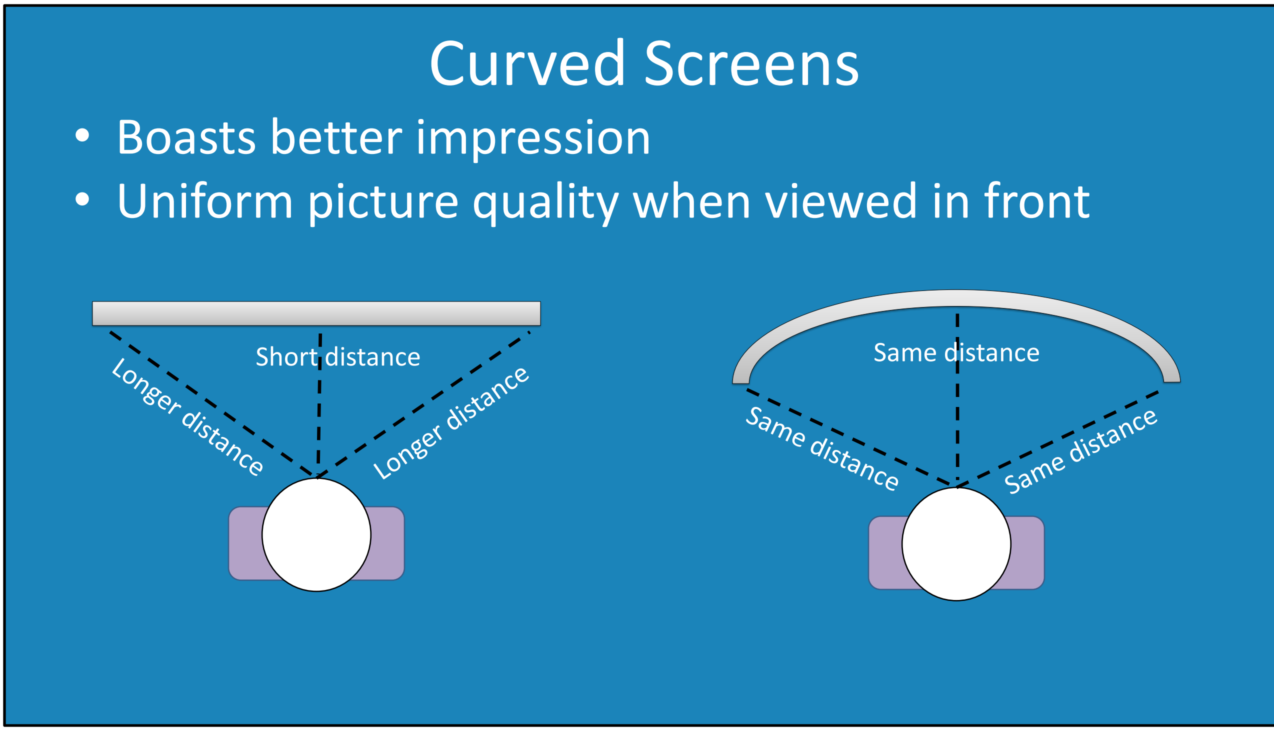
22:36 One of the newer designs in monitors is Organic Light-emitting Diode or OLED. This design uses a light-emitting diode or LED for each cell on the screen. Since a LED is used to generate the light, there is no need for a backlight, thus OLED screens are lighter in weight and of a thinner design than monitors that require a backlight. OLED also offers better picture quality, response time and power use. Since there is no backlight, OLEDs are also better at showing a true black. Using other technology this is not easy to achieve, since it involves trying to block the backlight which can often involve some light getting through, thus making black a little lit up rather than being fully black.

The downside with OLED is they have a limited lifespan compared with other designs. Since the design works with LEDs, the LEDs can also wear out over time. This means that the longer the LED is on the weaker they get. If your monitor is displaying the same thing all the time, for example the company logo in the same place, this can reduce the strength of the LEDs. If you remember old CRT monitors, they could suffer from an effect call screen burn in. This is when an image after being displayed for too long is effectively burnt into the screen, so a faded image is seen all the time.

On OLED monitors, you don't have screen burn in like CRTs, but LEDs will still wear out at different rates. For example, a company logo that is always present on the same part of the screen may be seen as a weakened area on the screen when it is not displayed, like a ghost image.

A cell in an OLED monitor has a number of different layers as shown. Voltages are applied on either side. The main two layers are the conductive layer, which as the name suggests conducts electricity, and the emissive layer which displays the light.

OLEDs currently cost more than the other types of monitors. It is possible that with improvements in the manufacturing process that the price will come down and they will replace the other monitor types. However, only time will tell if this is the case. OLEDs are often used in smartphones due to reduced power consumption and being thinner makes them a good choice. We are however starting to see them used more in monitors and TVs. OLED also allows for the screen to be easily made into different shapes which brings us to the next topic.



25:09 There are a number of monitors on the market that are made in a curved shape. These monitors boast better emersion when using them. Whether they do or not I will leave up to you!

Curved screens are designed to give a uniform picture quality when viewed from the front. To understand why, consider that you have a regular flat monitor with the user directly in front of the monitor. As you move out to either side the distance from the user to monitor gets longer with the shortest distance being in the middle.

The viewing angle of monitors has improved a lot, however when you start getting larger and larger screens, this can start to have an effect where the corners of the screen appear to be darker than the rest of the screen.

In an attempt to reduce this effect, curved monitors were developed. The idea behind this is the distance to each part of the monitor is about the same. This, in theory, should give a better experience, but I personally think this is up to the person who uses the monitor.

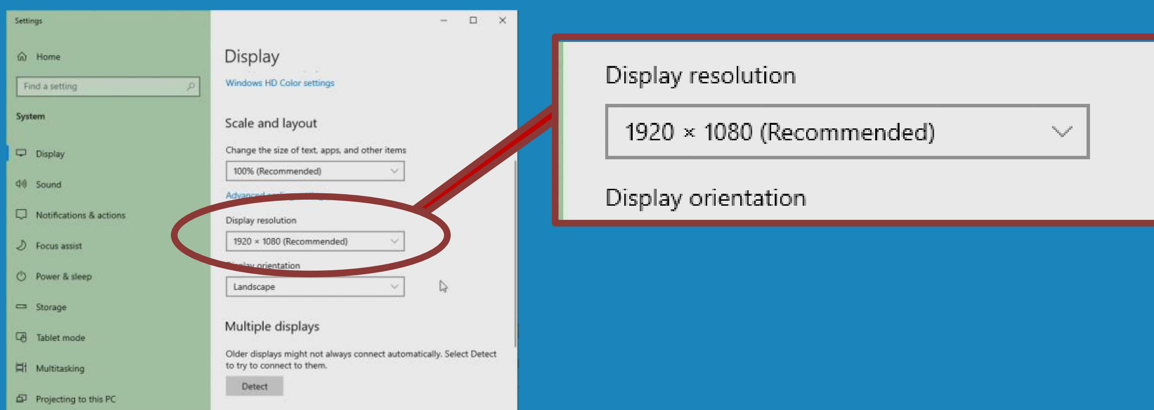
If you are planning to purchase a curved monitor, consider what effect this may have if you decide to use more than two screens later on. I personally find it better to use multiple screens when they are all flat screens, however this is my own personal preference.

There are a lot of technologies that are used to create monitors. What makes it harder to compare monitors is that, as time goes on, manufacturing processes get better. So, a new IPS monitor may have a better response rate than an old TN monitor simply because the manufacturing process has improved.

One way to compare monitors is the technology that they use, so let’s look at some other ways to compare monitors to get a better understanding of what you are buying.

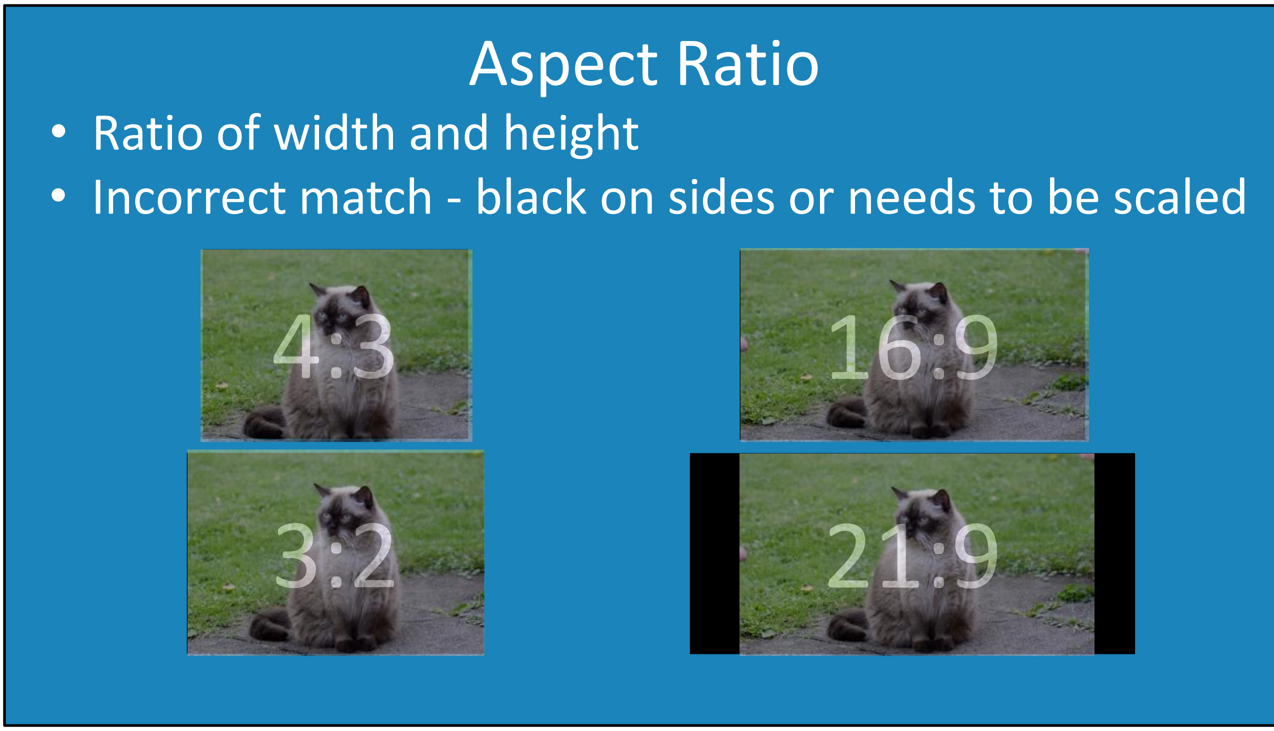
Resolution

- Number of pixels in the display (E.g. 1920x1080)
- LCD designed to run at native resolution



26:50 One of the first things to look at when purchasing a monitor is the resolution that the monitor runs at. The resolution is essentially the number of pixels in the display. LCD monitors are designed to run at a particular resolution. You can see in Windows when I set the resolution, that the native resolution of the monitor is listed as recommended.

The monitor will not display a resolution higher than this. If you attempt to display a resolution lower than this, the monitor will use a process called interpolation to display the image. Essentially, interpolation means scaling the image to match the monitor's native resolution. This can result in a loss of quality in the image. This will be particularly noticeable on jagged corners. Essentially, when you purchase an LCD monitor you want to run it at the native resolution. Many LCD screens, if they are run at a different resolution than the native resolution will display a message telling you to change the resolution.



27:52 The next point to consider is the aspect ratio of the monitor. This is essentially the ratio between the width of the monitor and the height. Shown here are some common aspect ratios used for monitors. In the old days many CRT monitors were 4 by 3; however, they tend to be 16 by 9 nowadays. Many smartphones use 16 by 9 and wider, however devices like iPads tend to be 4 by 3.

It is up to you to decide which aspect ratio meets your needs. Some people prefer wider monitors. When showing a video on a screen, if the size of the video is different to the screen resolution than black will be shown on the sides or it will need to be scaled to fit. In this case, a 16 by 9 video is being shown. On the left-hand side the video has been cropped to fit the screen. This means generally the sides of the video will be cut off. On the right-hand side you can see the 21 by 9 screen there is black on the side. The video essentially does not fill up this area, so it has been left black.

When Hollywood movies are converted from the big screen to other media, you can see that it is someone's job to work out if they should scale the video in order to get it to fit or cut off the sides. The video could also be scaled to remove the black area, however doing this potentially distorts the video.

When purchasing a monitor or TV, consider what you are going to use it for, and this will help you determine what aspect ratio you want. The aspect ratio tells you what the shape of the screen will be, but will not give you an indication of how many pixels the screen has.

Pixels Per Inch (PPI)

- Number of pixels per inch (Width/Height/Diagonal)
  - Can be in centimeters/millimeters (ppcm/ppmm)

$$PPI = \frac{d_p}{d_i} \qquad d_p = \sqrt{w_p^2 + h_p^2}$$

d_i is diagonal size in inches

d_p is diagonal resolution in pixels

w_p is width resolution in pixels

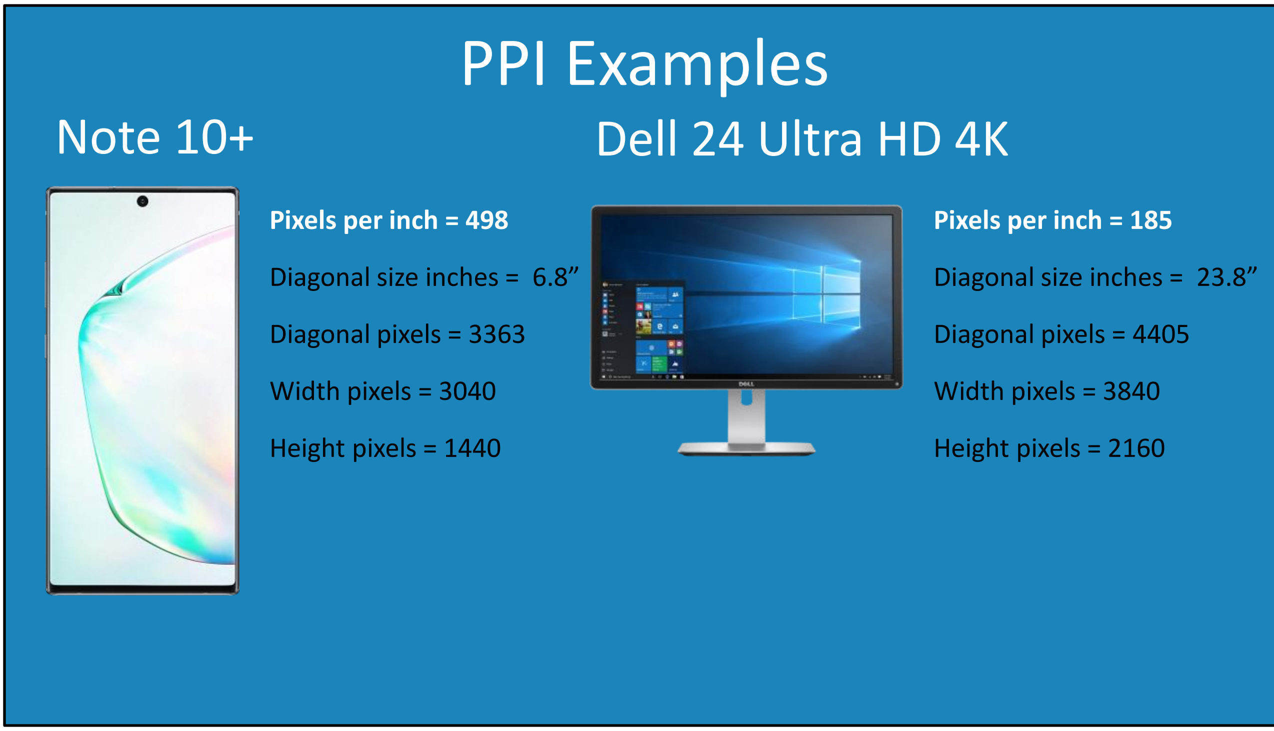
h_p is height resolution in pixels

29:34 The resolution of the screen will tell you how many pixels there are, however, it will not tell you how dense the pixels on the screen are. Having an idea of how dense the pixels are is another measure you can use to compare screens. This is often done using pixels per inch. This is essentially the number of pixels per inch on the screen. The measurement can be performed either by width, height or the diagonal. Sometimes you will see width and height listed, sometimes just the diagonal. This can be also be measured in metric depending on where in the world you are.

To calculate width and height in inches is pretty simple, it is just a matter of working out how many pixels are horizontal in an inch or vertical in an inch, so I won't look at the maths involved – diagonally is a little harder, so I will look at that instead.

To calculate diagonal pixels per inch, the following formula is used. The bottom part of the formula is the size of the monitor in inches. This can be done by measuring the length of the screen from one corner to the opposite corner. Usually the manufacturer will provide this information.

The top value is the diagonal resolution in pixels. This needs to be worked out using the following formula. This formula is the Pythagoras Theorem which calculates the diagonal resolution in pixels given the width in pixels and the height in pixels. Using this formula you can calculate the pixels per inch.



31:03 Let’s consider two examples, the first is the Samsung Note 10 Plus and the second is a Dell 24-inch Ultra HD 4k monitor. The Note Plus has a lower resolution than the Dell monitor, however, notice that it has 498 pixels per inch while the Dell monitor has 185. The Note Plus pixels are much more dense, but the Dell monitor supports a higher resolution. This is why when you have two monitors of different sizes but the same resolution, the larger monitor will look more grainy. This is also why modern smartphones look so good, even though the resolution may not be as high as a desktop monitor, the number of pixels it has per inch is so high that they look visually stunning.

With pixels per inch, higher values are better, but there is also a value you may come across when comparing pixels where lower is better.

Dot/Pixel Pitch

- Distance between pixels
- Usually measured in mm (Smaller is better)

Pixel Pitch = 0.05135mm

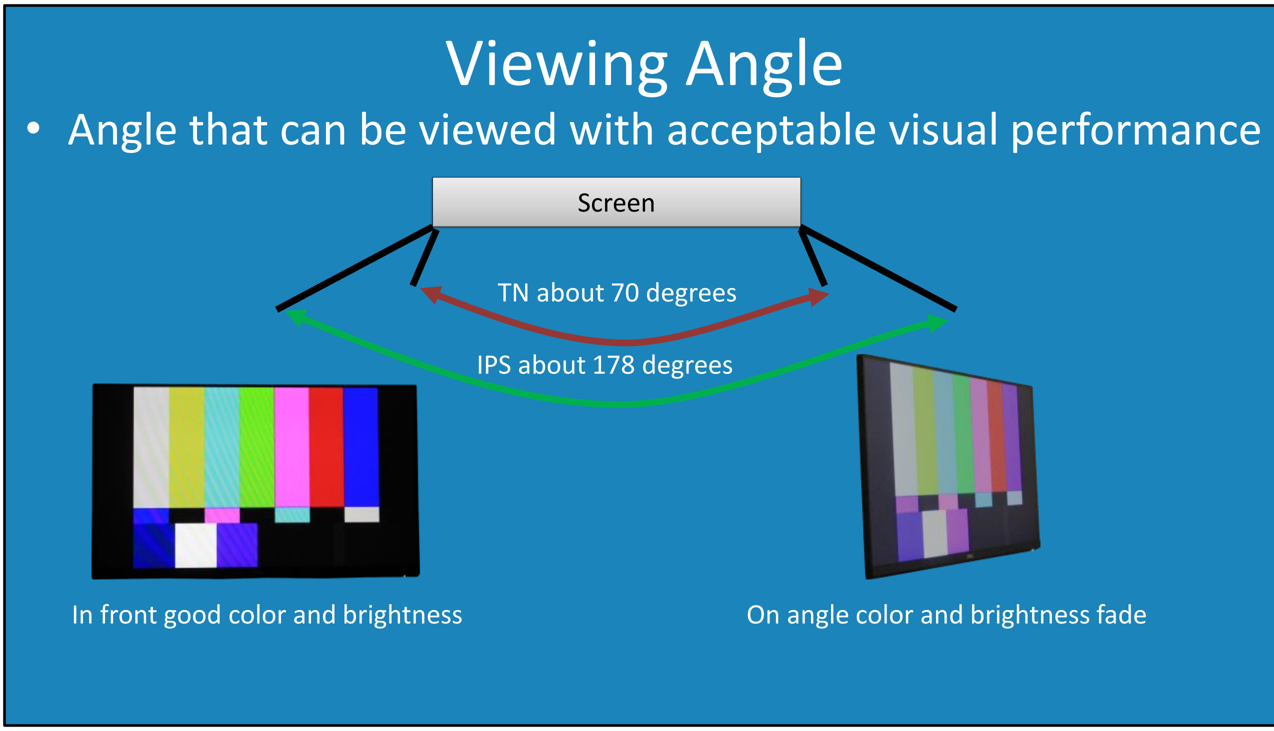
Pixel Pitch = 0.13725mm

32:01 This measurement is dot pitch or pixel pitch. This essentially is the distance between each pixel. This is usually measured in millimeters. Remember also that pixels are made up of three different colors. There are many different ways this could be measured: From the red of one pixel to the red of the next pixel or the center of one pixel to the center of another pixel. As long as the same point on each pixel is chosen, it does not matter where it is measured from.

In our previous example, you will notice the pixel pitch of the Note 10 Plus is much smaller than the Dell monitor. This is what you would expect. Remember that smaller is better when it comes to pixel pitch.

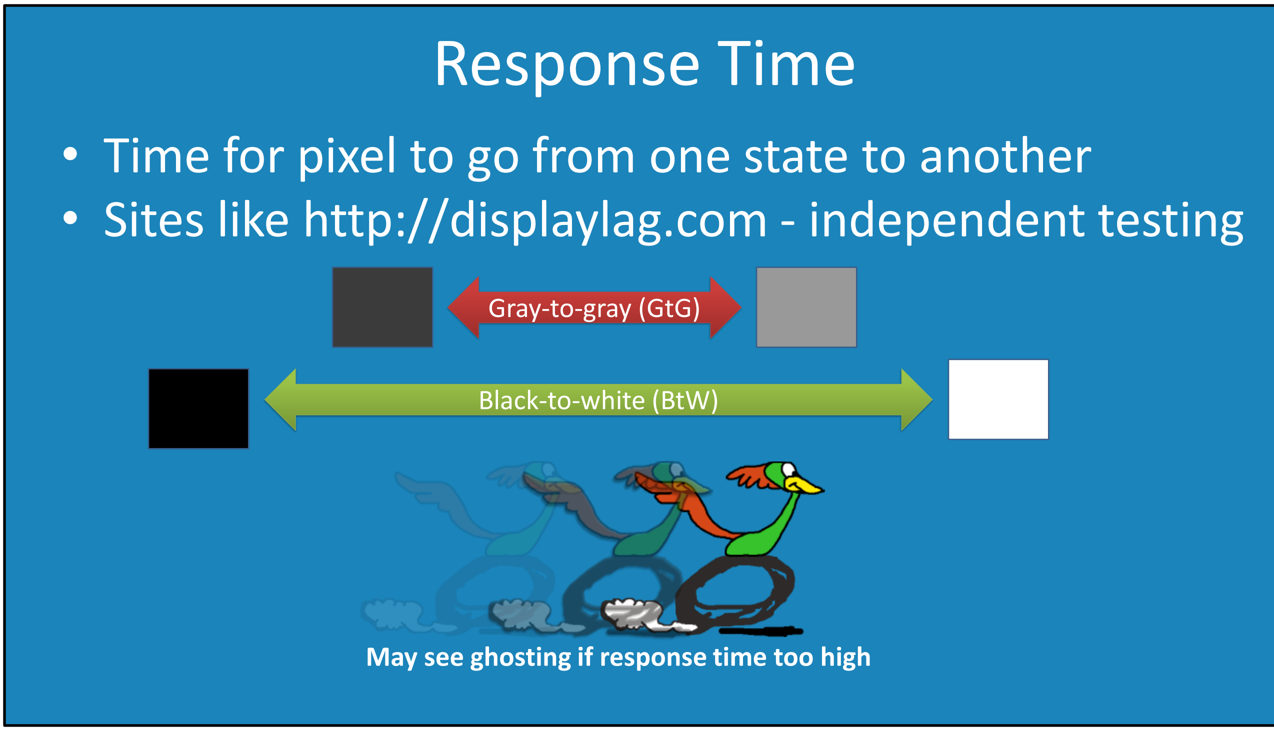
32:45 The next characteristic of monitors that I will look at is brightness. Brightness is essentially how bright the screen looks. Brightness is measured in 'nits'. A nit equals one candela per square meter. A candela is equal to one candle. Note that, high brightness is good for outdoors. Generally, computer monitors will be around 200-300 nits, however they can range from 100 to 1000 nits. Some of the newer mobile devices are up about the 600 nit range and higher.

Desktop monitors are generally not used outside, so they don't need to be that bright. Increasing the brightness can cause some issues which I will look at shortly, however generally brighter is better but this will use more power. You can see that having a brighter screen for a mobile device really helps when using it outside. Without the extra brightness, you will need to cover the screen or you won't be able to use it in brightly lit areas.



33:46 The next characteristic I will look at is the viewing angle. The viewing angle is essentially the angle the LCD can be viewed at with acceptable visual performance. When you view any LCD from directly in front of it, you will notice the colors are good and the brightness is good. You will find that if you move enough to the side, when you move past a certain point, the image will become darker and the brightness will be reduced.

This is something you can try next time you go to a TV store. Look directly at the middle of the screen and see how far you can go either side before the image starts reducing in quality. You should notice on most LCD screens this will happen more quickly if you go up and down rather than from side to side. Different LCD screens will differ in their viewing angle – TN screens will be about 70 degrees while IPS screens are about 178 degrees. If the monitor is for use in an office, the viewing angle probably does not matter that much. If the LCD screen is being used to display information to customers, the angle will matter more since the customer may be standing at a variety of different angles when looking at the screen.



34:57 The next characteristic I will look at is response time. Response time is the time in milliseconds to go from one state to another. Most LCD manufacturers will give you the 'gray-to-gray' time. This is the time it takes to go from one shade of gray to a different shade of gray. The problem with this is there is no industry standard of what colors to use or how to conduct the tests. For this reason, the figures the manufacturers release should be taken as an estimate of response time.

There is a different way of testing response time called 'black-to-white'. This gives a more accurate response time measure since black is fully off and white is fully on. Using black-to-white, manufacturers cannot just choose a different shade of gray to get their response times down a bit. Unfortunately, since black-to-white is always longer than gray-to-gray, manufacturers will typically not release the black-to-white response times since it looks better from a marketing perspective to release the lower time.

Using the response time from different manufacturers of gray-to-gray you can't reliably compare the response times, however there are independent sites like displaylag.com that test monitors for you using the same tests. These sites should give you a better figure to compare different monitors.

If the response time is too high, you may experience a ghosting like effect when something moves quickly across the screen. In older displays with response times over 20ms you may notice this. With most monitors nowadays you should not have any problems with ghosting. If you are a competitive gamer, you may want to get a monitor with the fastest response time that you can get.

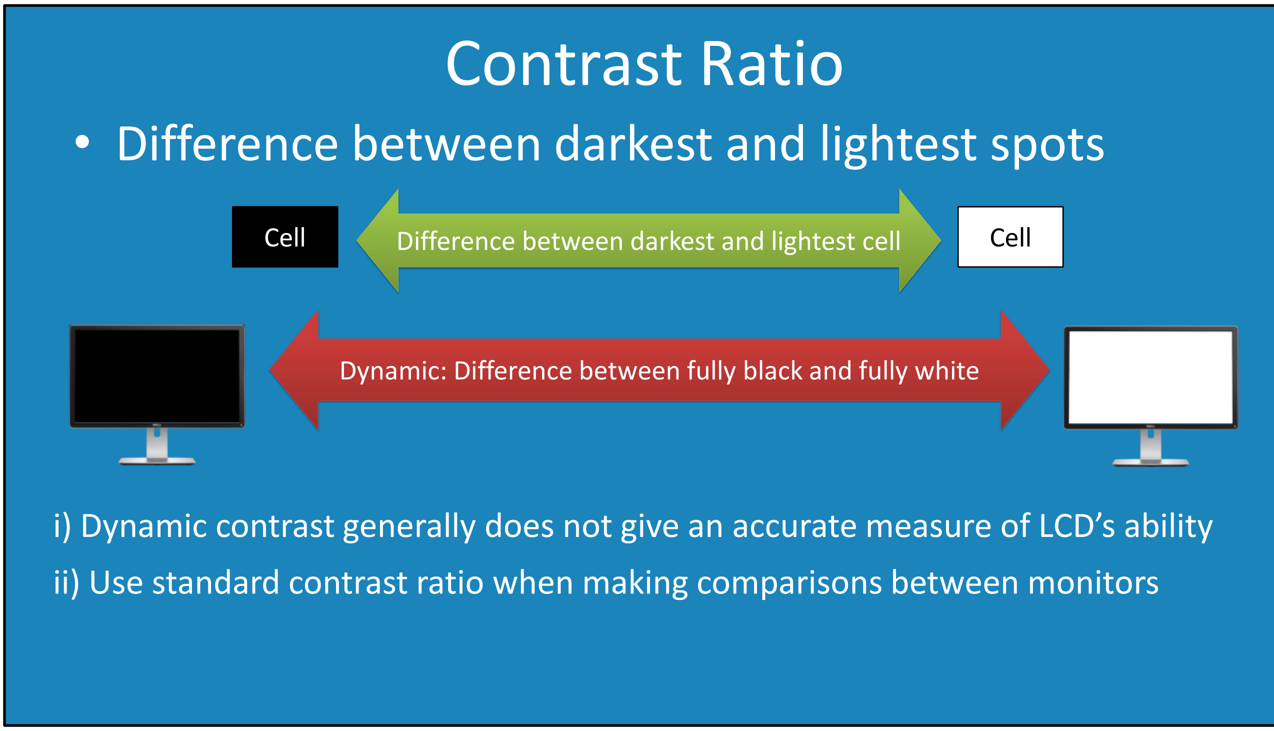
Refresh Rate

- How often LCD screen can update per second
- Rates vary from 30Hz to 240Hz (60Hz very common)

36:42 The next characteristic that I will look at is the refresh rate. This is how often the LCD screen will update per second. Refresh rates from monitors can vary, all the way from 30Hz up to 240Hz can all be found in the marketplace. 60Hz is very common and what I would consider the starting point.

You can see that in the video shown, when the refresh rate is low the video is choppy. As the refresh rate increases the video becomes a lot smoother. An office user running basic applications could potentially get away with 30Hz, however if you have ever played any modern computer games, you want to start at 60Hz. If you try to play a fast computer game at 30Hz, the low refresh rate will increase the time it takes for you to see changes in the game and thus affects your response time to those changes.

After 60Hz, the changes become less and less noticeable. Also remember, for the computer to take advantage of the high refresh rate it will need to update the frames at the same refresh rate or at least get close to it. In the case of 3D monitors, you will often find the refresh rate they support will be much higher. This makes sense because with 3D you need twice as many frames. So, for a 3D monitor to get the same results as a standard 60Hz monitor, it would need to run at twice the speed, so it would need to run at 120Hz.



38:09 Next, I will look at the contrast ratio. This is the difference between the darkest and lightest spots on the monitor. This will give us a ratio, for example 1000:1. This means the darkest and lightest spots are 1000 times different in intensity. Larger is better, so 250:1 would not be as good. But like response time, it is not that simple.

There are two different ways of measuring contrast ratios. The first way, which is just referred to as the contrast ratio, is a measure of the difference between the darkest and lightest cells the monitor can display. This is the best way to compare different monitors. This will also give you a lower contrast ratio.

You may also see dynamic contrast ratios. This is the difference between the LCD screen being fully black and being fully white. Given that when the screen is fully black, you can do tricky things like switch off the backlight, this can give an unrealistic indication of what contrast ratio the monitor can achieve. If the backlight is off, the monitor will look very black, however you cannot switch the backlight off when displaying images.

In some LCD displays, the display can control how bright the backlight is. This is called active backlight. This does not give the best result as the backlight effects all the cells on the screen. However, adjusting the backlight can make the whole screen darker or brighter. Thus, dynamic contrast can cheat a little bit more giving you a contrast ratio that is darker and lighter depending on what is being displayed. This is not a measurement of differences between cells, it is a measure of the whole screen. This can change what can be achieved under very specific conditions, not what would normally be achieved.

For these reasons, dynamic contrast generally does not give an accurate measure of an LCD's screen abilities. When comparing LCD screens, you should use the standard contrast ratio as this will give you the best understanding of how the LCD monitor will actually perform under normal operations, whereas dynamic contrast ratio will only give you an indication of how the LCD monitor will operate under certain conditions. Conditions such as how the LCD monitor will work when fully black and fully white do not give you any idea of how the monitor will work under normal usage.

Color Depth

- Number of bits used to indicate color of a pixel
- Most monitors use 8-bits per channel (3x8bit RGB)
- More expensive monitors use 10-bits

8-bit 16,777,216

10-bit 1,073,741,842

* 10-bit good for photo/video editing and color grading

40:38 The last characteristic of monitors that I will look at is color depth. Color depth is the number of bits used to indicate the color of a single pixel on the screen. Most monitors on the market should be using at least 8 bits per channel. Nowadays it would be hard to find a monitor that did not. In the old days, some old TN monitors used to have 6 bits per channel. The number of bits determines how many different shades of color the monitor can display, and a higher number of bits means more colors.

There are three channels, red, green and blue, thus with 8 bits three times eight would give you 24. This is why you often hear it referred to as 24-bit color. The more expensive monitors on the market use 10 bits for each color, making them effectively 30-bit color.

8-bit color effectively gives us 16 million colors that can be shown. It is estimated that the human eye can distinguish about 10 million colors, so this is more than we need. It is not a bad thing to have a little bit more of something than too little.

In the case of 10-bit color, there are over 1 billion shades of color that can be represented. This is well and truly more than our eyes can distinguish. So, the question is, why do we need so many? For the average user, well you don't. Movies and other media are generally encoded to use 24-bit color. So, what is the advantage of having more bits?

To understand this, consider that you have two colors in 8 bits. For this example, the colors are right next to each other in their shades. That is, the difference between the two pixels' green channel is one. In reality, I am showing you two greens that are much more than one value apart and are essentially very different shades of each other. I have done this so you can understand the concept; if I made the shades right next to each other you would have difficulty telling them apart and unless you have a 30-bit monitor, you would not be able to see the color difference I am about to show you. Essentially, you will need to use your imagination that the two pixels are one shade different from each other.

If I now consider 10-bit color, this gives us more shades between the two 8-bit pixels – 64 shades to be precise. If you are doing video editing or color grading these extra shades come in handy. Consider that in video editing you are combining videos together. When you combine two videos together you are essentially using mathematical functions to combine them. So, what does 10-bit color give you? It gives you more precision when performing these mathematical functions. If you are using 8-bits, you have less precision, thus when dealing with 8-bit color there will be more rounding. This translates in video editing terms to being able to see a better result since less rounding is occurring.

This kind of extra precision is useful in photo editing, video editing and color grading. When doing these functions, sometimes you may want to do things like have a smooth gradient. That is, the color changes slowly from one color to another. A sunset is a good example of this. With 8-bit color you may see parts of the image where it appears to jump from one shade to another rather than making a smooth transition. This becomes more of a problem when you start combining images and doing things like applying effects. When this process is complete, normally it will be outputted so it uses 24-bits, that is, 8 bits for each color. You can see why in most cases the average user only needs 24-bit color, because essentially the end result of graphic productions will generally be in 24-bits. It only becomes useful if you are editing images or videos before you produce an end result.

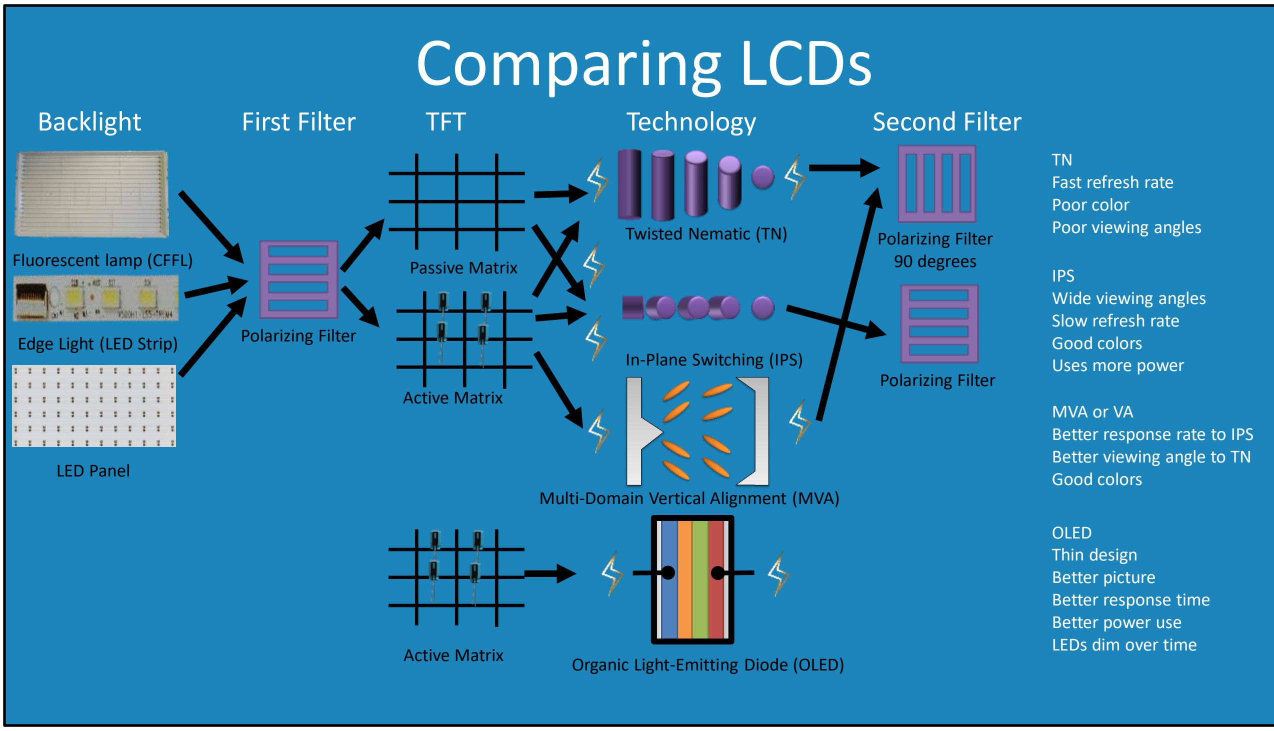
Color Depth Terms

- 24-bit color (8 bits per color. RGBx8 = 24bit)
- 30-bit color (10 bits per color. RGBx10 = 30bit)
- 32-bit color
  - Red, green, blue making 24-bits
  - Plus 8-bits for transparency

44:37 Before I move on, I will have a quick look at some of the color depth terms you may come across to make sure there is no confusion. 24-bit color is essentially when 8 bits are used for each of the red, green and blue channels.

30-bit color is when 10-bits are used per color. Since there are three channels this makes a total of 30 bits.

The last color depth that I will look at is 32-bit color. When you see this, generally this is referring to 24-bits being used for red, green and blue. The last 8 bits are used for transparency. For example, Windows uses 32-bit color so that it can use transparency effects. Windows uses this mainly on title bars. When you look at a title bar on Windows you will partially see what is behind it. Thus, this extra channel will generally be used for transparency. The monitor does not require the transparency channel so you will only see it in some file storage formats or referenced in some device drivers. Even if transparency is not being used, CPUs work better when data is divided into 32-bit chunks rather than 24-bit chunks. So, you may see 24-bit color being stored in the computer as 32 bits to improve the speed the computer can process it.



45:58 There has been a lot covered in this video, so what I will do is summarize all the information to give you a better understanding of what to look for when purchasing a monitor and what technology you can expect the monitor to have.

Most LED monitors will have some sort of backlight. The backlight is either blocked or allowed through the screen. The first of these backlights were fluorescent lamps. These took up more room at the back of the screen making it bigger in size. Large screens required multiple lights in order to create a bright enough backlight.

As technology improved the fluorescent lamps were replaced by LED lights, so you won't see florescent lamps unless you are working on an old monitor. For small screens, they may only be using edge lights. Edge lights are LED strips that are usually found on the top and maybe the bottom of the monitor. These are a cheap way to light a screen, but can only be used on small screens and thus generally found in laptops.

For larger screens an LED panel may be used. This essentially is a panel behind the screen that is made of only LEDs. This will either be multiple LED strips or a grid of small LEDs. Due to improvements in technology, even a large screen may still only use a one or two LED strips as a back light. So, don't jump to the conclusion because it is a large screen that it has to have an LED panel.

The next layer is a polarizing filter. This filter is the same filter that is found in sunglasses. It essentially takes the light that comes into it, blocks certain wavelengths and allows others to go through. The overall effect is a dimming effect; however, it also means only certain wavelengths are allowed through. End result, we filter out the light we don't want and keep other light that allows us to block or allow the remaining light later on.

The next part of the process is the Thin-Film Transistor or TFT. This is essentially the electronics that allows the cell on the monitor to be controlled. The first ones were passive matrix. These were essentially a wired grid that allowed each cell to be individually controlled. The problem with this approach is, it is like pressing an on/off switch. Since the monitor works using scan lines, once you press the switch you have to wait until the next scan light cycles through to press the switch again. This did not give very good control over the screen.

To give better control, active matrix is used. Active matrix adds a capacitor to the electronics. The capacitor allows the cell to have power between refreshes. This gives much better control over the screen. Old monitors used passive matrix; however, you should find that all new monitors now use active matrix.

The next part of the LCD screen is the technology that is used in the screen itself. This is what is used to control the actual cells on the screen. The older technology is Twisted Nematic. This works by applying electricity from one side of the cell to the other. When this occurs, it causes the liquid crystal to twist. This twisting effect also changes the light's wavelength which becomes important in the next step.

As technology improved, In-Plane Switching was developed to address some of the limitations of TN. IPS applies electricity from the same side rather than from both sides of the cell. Unlike TN, the liquid crystal is not twisted, rather it is turned 90 degrees.

To attempt to overcome some of the limitations of TN and IPS, Multi-domain Vertical Alignment or MVA was created. This differs in that the liquid crystal is divided up into essentially pyramids, so each cell is divided into little domains, thus the name. Electricity is applied from either side of the cell. Since liquid crystal is at different angles, this means that, as light passes through it leaves at different angles increasing the viewing angle of the monitor. Since MVA is the newest of these technologies, it is unlikely that you would find a monitor of this type using passive matrix.

The next layer of the monitor is a second filter. In the case of TN and IPS, this filter is turned 90 degrees. Turning the filter means that light will be blocked by default, unless the cell changes the light as it passes through it.

In the case of IPS, the filter is the same direction as the first filter. This means the light will be allowed through unless the cell changes it.

There are some variations of these designs which may have different names, however they all work on the same basic principles except for Organic Light-emitting Diode or OLED. This design is where the cell is essentially a LED. The LED creates the light and thus there is no need for a backlight or filters. Each LED is powered through the cell.

You can see as the technology has improved, things like fluorescent lamps and passive matrix are no longer used. However, even though TN is the oldest monitor type, you can still purchase them. Why? Because every monitor has their advantages and disadvantages.

In the case of TN monitors, the refresh rate is good, but the color not so good. They also have poor viewing angles compared with other monitors. Due to the fast refresh rate, you may see these monitors marketed as gaming monitors. So, you may see a TN monitor as the cheapest and also as the most expensive monitors on the market. The more expensive TN monitors are designed for gamers.

IPS monitors offer wider viewing angles than TN. However, the refresh rate is not as high. Keep in mind that an expensive IPS monitor probably has a better response rate than a cheap TN. IPS monitors also offer better color reproduction. If you intend to buy an expensive TN monitor, you may just want to see if the color is any good before you buy it.

In order to improve on some of the disadvantages of TN and IPS, Multi-domain Vertical Alignment or MVA was developed. This may also be referred to as Vertical Alignment or VA. This offers better response rates than IPS and better viewing angles than TN. It also has better color reproduction. It is a trade-off between the two, so the response time although better than IPS is not as good as TN. The viewing angle is better than TN but not as good as IPS. These monitors are also harder to make and thus cost more.

The last type of monitor is OLED. Due to them not having a backlight and other filters, these monitors have a thin design. They also have a better picture, better response time and better power use. The only thing that they don’t do better is lifespan due to the LED lights wearing out over time. There is a good chance that OLED will replace the other monitor designs as manufacturing gets better and cheaper. At present they are mainly used in mobile devices.

You can see there is a lot of technology that makes monitors work. Looking at the technology by itself may not always give you the best idea of how the monitor will perform, particularly if you are comparing monitors that are using the same technology.

LCD Characteristics

- Size of the monitor
- Max resolution the monitor will run at (Native)
  - Resolution monitor should run at
- Response rate (< 20ms)
- Refresh rate (60Hz min)
- Viewing angle if important

53:03 To get a better understanding of which monitor to purchase, looking at monitor characteristics may help you make up your mind. I won't look at all of them, but I will look at the more important ones. I have not listed price, but of course this is generally the most important one. First there is the size of the monitor. You generally don't want a 70-inch screen for an office computer, however for an electronic notice board you want something big. Depending on the price of the monitor, you may consider purchasing two monitors and running them next to each other. I once worked for a company which gave the users a choice of a large monitor or two smaller ones. Which is better is ultimately a personal choice of the person using the computer.

The max resolution is the next thing I will look at. This will be referred to as the native resolution and the resolution you should run the monitor at. If you are running the monitor at a different resolution the monitor will need to do some scaling to the image. Keep this in mind, if you purchase a monitor that is capable of higher resolutions then what will be used, you are effectively paying more than you need to, however you are also purchasing some future proofing if your needs change.

When purchasing I would also consider the response rate. This is how quickly the monitor essentially can update each cell on the screen after changes occur. In an office environment this is not to important, but if you're a gamer or doing multimedia production this is more important. Personally, I would not purchase any monitor that did not have a response rate under 20 milliseconds. Pretty much every monitor on the market nowadays should have a response rate lower than this.

The next thing to consider is the refresh rate. Nowadays I would consider 60Hertz a minimum, however depending on what you are using the monitor for you may be able to get away with less. All monitors on the market should do at least 60 Hertz, however be aware that on some monitors the refresh rate may reduce when the resolution increases. For example, some of the first 4K monitors would only be able to run at 30 Hertz for 4k, however for any other resolution they could run at 60 Hertz. Make sure you check before you buy that the monitor will run the resolution and refresh rate that you want.

Lastly, if the viewing angle is important consider what viewing angle the monitor supports. If you are sitting directly in front of the screen this is not that important, but if you are viewing it from multiple angles this becomes more important, for example if the monitor is being used as an advertisement or electronic notice board.

This has been quite a long video, but if you have gotten this far I hope you have found this video informative and I hope to see you in other videos from us. Until the next video, I would like to thank you for watching.

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