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Abstract

The aim of this bachelor thesis is to provide a brief description of the development of display technology from the first displays to the latest technologies and the technologies that will be used in the near future. This thesis describes the characteristics of the different types of displays, an operating principle of used technologies and specifies their advantages and disadvantages.

Keywords

Development, display, technology, CRT, LCD, LED, OLED, Plasma, Hologram.

Abstrakt

Cílem této bakalářské práce je poskytnoust stručný popis vývoje zobrazovacích zařízení od prvních displejů až po nejmodernější technologie a technologie, které budou používány v blízké budoucnosti. Tato práce popisuje vlastnosti jednotlivých typů displejů, princip fungování použitých technologií a specifikuje výhody a nevýhody jejich použití.

Klíčová slova

Vývoj, zobrazovací, zařízení, CRT, LCD, LED, OLED, Plasma, Hologram.

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(podpis autora)

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Introduction

The term *Display Technology* refers to every device which we use to display all kinds of information. For example, monitors, televisions, parts of notebooks, mobile phones and so on. The development of this technology meant really great progress in the consumer, automotive, industrial, office automation, telecommunication, military and avionic fields and the development of equipment such as analytical instruments, radios, clocks, blood pressure indicators, heart monitoring devices, calculators, cameras, multi-meters, electronic billboards, hand-held terminals, household appliances, photocopy machines, oscilloscopes and much more.

Inventing and developing Display Technology has a truly great impact on everyday life. This is shown by the manner in which young people or children spend their free time. If we ask older generations what their childhood was like and we compare it with the way children spend their time now we would get totally different results. Imagine how many activities you can perform with the help of Display Technology; you can play games, read electronic books and work at a computer with office applications. All activities that have brought more possibilities to our everyday life. There is a question whether these things can improve our lives. My own response is that I think that if we use them in balance with "living a normal way of life", which older generations know, it is certainly a great leap toward.

Display Technology has been evolving from the "big boxes" with simple functions to "thin panels" with complex functions and enhanced capabilities. Those "big boxes" which I mentioned refer to CRT Technology which is described first in this work. Although the development of Display Technology began in the 1930's with the launch of the first televisions, the main progress has been achieved during the past twenty years. Between the introduction of CRT and most modern technologies is a really long journey, where changes in used components and principles take place. During the past few years technologies such as LCD (resulting in the usage of TN, xVA or IPS panels), LED, OLED, Plasma and Holography have been created. All of these technologies, their functions and principles on which they work are included in this work.

The final part of this Bachelor Thesis is dedicated to the attitudes of people toward Display Technology, what is their knowledge and experiences. The development of Display Technology influences our lives more than we can ever imagine. If progress continues in the same exponential manner, we have really much to look forward to.

The main reason why I chose the development of Display Technology as a topic for my bachelor thesis is that I am very interested in this kind of technical industry. My interest in this topic started at high school where we had a subject called Hardware. I took the graduation exam on this subject. We had to allocate one number to a question. This was a surprise for me, because I was examined about displays, my favourite question.

1 History

1.1 The Cathode Ray Tube

Display Technology was first used for the purpose of displaying information in the form of a Cathode Ray Tube, commonly referred to as CRT. For many users of televisions or monitors CRT Technology is something in the past. Although there were great efforts to improve CRT Technology, people today prefer flat panel televisions which can easily be fixed to a wall or ceiling. Because of the fact that CRT screens are very wide, they are no longer used to the same extent. Regardless of being cheaper or having a more effective method of working than the narrow ones, people prefer the narrow screens.

The principle of the Cathode Ray Tube was discovered in the 19th century by Sir William Crookes who observed cathode rays in a tube that he constructed in London. However, the inventor of the Cathode Ray Tube model of Display Technology is considered to be Karl Ferdinand Braun. He used Crookes' idea to create a tube which he made of deflection and fluorescent materials in 1897. He made an addition by alternating voltages to the equipment to facilitate it to transmit controlled streams of electrons from one end of the tube to the other.

Although the first attempts to create a screen took place at the end of the19th century, the first successful televisions built on the Cathode Ray Tube principle were in the late 1940's. Actually the first usage of CRT Technology might have been during the First World War as part of a ships radar system. The exact date is not known because there was no interest in divulging secret information about experiments conducted at that time.

The next leap forward in CRT Technology is considered to be the “first television” developed in 1927 by 21 year old Philo T. Farnsworth. By this time it was becoming obvious that CRT Technology had a big potential concerning the development of displays. The Radio Corporation of America (RCA), with its origins in 1919, made a great effort to raise interest in television which in the future would be able to display information from remote regions and could be commercialized.

Transmitting of sound radio was in full flow, so that it was only a matter of time before pictures would also be displayed. RCA estimated that the cost of development of television and its preparation for commercial use would be in the region of about USD 100,000. However, the actual cost exceeded this prognosis by more than 500 times. The first public announcement of television occurred in April 1939 at the New York World’s Fair which was the second most extensive American World’s Fair of all time. After this great event, the sale of the first television sets began and television broadcasting was under way. Because of the really high price of these sets, an estimated USD 625 a unit, not many of these sets were initially sold. Only a few hundred units.

Two years later in April 1941, unlimited commercial broadcasting of a 525 line system was authorized. After Second World War, during which there was very little production of any televisions, widespread manufacturing of black and white sets began. After selling less than 7,000 of these black and white sets, colour television came into existence. That happened in June 1951 and led to vast developments in the technique of colour televisions during the 1950’s and 1960’s.

During the late sixties the Sony Corporation came up with a new colour CRT tube that had better image quality and greatly improved the development of televisions. This was achieved by the use of a “Trinitron” tube with a single electron gun which manufacturers have been using for decades since then.

The big event for creators of Display Technology was the invention and subsequent manufacturing of computers and electronic devices, one example being oscilloscopes. This has greatly increased demand for these products.

1.2 The Liquid Crystal Display

I mentioned previously the requirements of people today. People want to have a television or monitor in the form of a flat panel which can easily be fixed to any surface that they want and wherever they want. That was one of the reasons for the development of new technologies which would fulfil these conditions.

There were attempts to create thin panels of this CRT technology, but what really caught on was Liquid Crystal Display (LCD) Technology.

The first liquid crystals were discovered in cholesterol extracted from carrots by Friedrich Reinitzer in 1888. In 1962, RCA researcher Richard Williams was successful in the generation of stripe patterns in a thin layer of a liquid crystal element by the appliance of a voltage.

According to the IEEE, the world's largest professional organization dedicated to advancing technological innovation and excellence for the benefit of humanity:

> Between 1964 and 1968, at the RCA David Sarnoff Research Centre in Princeton, New Jersey, a team of engineers and scientists led by George Heilmeier with Louis Zanoni and Lucian Barton, devised a method for electronic control of light reflected from liquid crystals and demonstrated the first liquid crystal display. Their work launched a global industry that now produces millions of LCDs. [1]

This statement tells us how great an impact that the LCD has had on our lives today, even if this technology was invented a long time ago.

During the 1960's research of liquid crystal was also performed in the Soviet Union and England. At that time when LCD Technology started to be developed, it would take them two long decades before the first LCD television would be produced. Until that time, CRT televisions were the number one seller. The first products that used the LCD principle of working were wrist watches and portable calculators. The discovery of the twisted-nematic (TN) effect by James L. Ferguson in 1969 meant big progress and compact LCD calculators and wrist watches began to be part of everyday life. In 1973 the British scientist George Gray found a way to make liquid crystals stable under normal temperature and pressure conditions.

The first personal computer with an LCD monitor was introduced by the NEC company in 1986 and was so called “passive” (DSTN). Huge delays of passive displays with a delay in the order of 100ms was not resolved until an “active” Thin Film Transistor (TFT) display was introduced. TFT principle erased most of the major mistakes of older technology.

Countries, which were most productive and successful concerning LCD Technology were the United States, Japan, and the Swiss in Europe who also started to expand into this kind of industry. This technology became integrated into everyday life and parts would be used in such products as television screens, computer displays, vehicle dashboards, air plane cockpit displays, telephones, gaming consoles, monitoring systems, electronic indicators and many, many other products.

LCD Technology was revolutionary in the way that the image of display (in the meaning of how something looks like) absolutely changed. There was no need for a wide screen, you did not have to have more space when you wanted to put in on a table and what is more, with the invention of this screen, there opened new ways for enhancing portable devices.

1.3 The Light Emitting Diode

Light Emitting Display (LED) Technology was developing mainly during the 1960’s. The main cause of this was the need to make a method of outdoor advertising exist. Advertising in the form of hanging posters was already part of everyday life, so lighted billboards with short videos brought great improvement into the everyday world of media and advertising.

The first attempts to use point source of light were light bulbs. This gave rise to the first large screen, but ran into a lot of technical problems. The slow response of bulbs, overheating of fibre, and slow cooling did not provide a smooth motion and so monochromatic areas with static imaging and minimal dynamics began to exist. Fortunately, the development of semiconductor devices was progressing quickly and light emitting diodes were soon created.

One of the first attempts to create light emitting diodes was in 1962, when several companies (Bell Laboratories, Hewlett-Packard, Monsanto Chemical Company) used a principle based on Gallium Arsenide Phosphide P-N junctions. Later in 1966 Gallium Phosphide was added to Nitrogen which led to the better performance of light emitting diodes. The first LED device was introduced in 1968 by the Hewlett-Packard and Monsanto Chemical Companies.

Digital measuring devices such as portable multi-meters were ideal for usage of these displays. The low operating voltage and high brightness of display was the reason for choosing this technology. During the 1970's there occurred a great shift concerning the performance improvements of devices, and at the same time radical reduction of the prices which at first had been really high.

One of the most popular products using LED Technology were watches. One scene from a James Bond film where LED watches had been shown was a great advertisement for them. From that moment on it became a very popular device. However, its popularity did not have a long duration. Because of its high power consumption, the battery did not have a long lifetime and what is more, it was extremely difficult, almost impossible, to read the time in sunlight, so LED watches disappeared from the market and were replaced by their competitors LCD watches.

The Colourfulness of LED devices depends on a wide colour spectrum visible to the human eye. Therefore, the first LED colour was red, followed by orange, yellow, green and finally blue. The blue colour had long been unattainable, as well as the colour white. These colours are not dependent on all three ingredients being present, i.e. a combination of red, green and blue. Today we can recognize the quality of a white diode depending on whether or not it has a bluish tint.

At first there were only LED devices of one colour. After period of time bi-coloured devices were developed. They were mainly a combination of a red and green colour. Also Tri-colour devices were produced, based on the principle of bi-coloured devices, but with the possibility of only certain combinations of certain colours.

With the development of the control electronics there began to appear full colour LED display screens. Since the shortage of blue LED diodes, which by now manufacturers had started developing, prices of LED diodes usually ranged in multiples of red or green ones. The intensity of radiation of blue points was solved by adding one extra red LED diode. Colour point thus consisted of one blue, one green and two red LED diodes.

The intensity of LED radiation increased by this time. The main problem was sunlight and in the case of indoor applications, artificial lighting. It was necessary to solve the interference of surrounding light sources.

1.4 The Organic Light Emitting Diode

The Organic Light Emitting Diode (OLED) Display Technology is based on the electro-luminescence of organic materials. This electro-luminescence was first observed by André Bernanose in 1950 at the Nancy Université in France. The first demonstration of illuminating polymers *(“A polymer is a large molecule, or macromolecule, composed of many repeated sub-units.”* [2]) was in 1966 performed by CDD (Centre for Doctoral Training). The first full colour television with OLED Technology and active matrix (*“Active matrix is a type of addressing scheme used in flat panel displays.”* [3]) was released in 1998 by Kodak. Since the year 2001, when Sony introduced at that time the world largest 13" full colour OLED television, OLED Technology improvement has made rapid growth.

The first mobile phone with OLED display was developed in 2006 by Nokia. Mobile phones mostly use displays called AMOLED (Active-Matrix Organic Light-Emitting Diode). According to ©Statista 2016 [4], AMOLED display shipments worldwide more than doubled in 2016 compared with 2014. Akio Takimota from CEA Japan Display company, which is a display producer for Apple smart phones, proclaimed: *“We will take advantage of our advanced Thin-Film Transistor Technology in developing OLED screens.”* [5] when talking about development of the display for Apple. After Apple will start using OLED Technology for their devices, the number of shipments is expected to be many times higher.

So far, all that I have mentioned has been about the “box” type of solid mobile phones. However, the possibilities of OLED Technology are far from that. With the usage of OLED it is possible to create displays which look like thin plastic sheets, which can be bent, rotated and folded. That means that in the near future there is going to happen a real revolution in mobile phone technology, because mobile phones might no longer resemble the phones we know today.

1.5 The Plasma Display Panel

When we talk about Plasma Technology, most of us can imagine the Plasma Globe. According to Wikipedia: *“A plasma globe or plasma lamp (also called plasma ball, dome, sphere, tube or orb, depending on shape) is (usually) a clear glass sphere filled with a mixture of various noble gases with a high voltage electrode in the centre of the sphere.”* [6]. The first globe was invented by Nikola Tesla, and modern versions were formed by Bill Parker. The principle of working is based on interaction of an inserted inner gas and alternating current energy, similarly as in the case of plasma displays.

Plasma Display Panels (PDP) are also very often called Gas Discharge Displays. Their development began after the year 1915, when a neon lamp was invented by Georges Claude in France. The first attempts to demonstrate PDP principle of working was in 1927, however, real progression took place during the 1960's. The first PDP display is supposed to have been developed in 1964 at the University of Illinois, although it was only an AC driven memory display.

During the 1970's PDP displays used newly invented Self Scan Technology, produced by the Burroughs Corporations. Its main advantage was reduction of the number of circuit drivers.

According to CNN Money in 2014: *"The world is running out of plasma TVs."* [7]. The last producer of PDD in the United States of America announced the end of the production in November of 2014. Nowadays we cannot find any PDP display on the market, other Display Technologies have replaced them.

1.6 Holography

The term "Hologram" is a compound of two Greek words – "*holo*", which means "whole" and "*gram*", with the meaning "message". Its name talks for itself; *Hologram:* to enable to show a picture in absolute real form. It is something absolutely different from other types of displaying information. In the case of a Hologram, a picture becomes almost real and unrecognisable from the original.

A Hologram is a photographic emulsion with information displayed in three dimensional form. When it is illuminated properly, the presented object seems to be so real that people put their hands where the scene apparently lies to find out that there is nothing solid. I have recently seen a video, where there were a lot of students sitting in a gymnasium and suddenly a huge whale jumped up from the floor with plenty of water. It not only seemed to be very realistic, but children were even sidestepping because of the fear of the whale.

The first mention of Holography happened in 1947 when a British scientist Dennis Gabor created the Theory of Holography while working on improvements to an electric microscope. Dennis Gabour was awarded the Nobel Prize for this great invention in 1971. In 1960 a problem with light sources, which in earlier times were not coherent (monochromatic), was overcame by the Russian scientists Nicolay Bassov, Alexander Prokhorov and the American scientist Charles Towns, who came up with the Laser. The Laser, with its clear beam of light, was appropriate for creating Holograms. Doctor Theodore Harold Maiman developed in 1960 a pulsed-ruby Laser, which provided a very powerful source of light which endures for a few nanoseconds and enables the creation of Holograms of high speed events.

The year 1962 was a very important time in the development of Hologram Technology, when Emmett Leith and Juris Upatnieks of the University of Michigan discovered that a Hologram could be used as a 3D visual medium using an off-axis technique. In the same year a White Light Reflection Hologram was created by Dr. Yuri N. Denisyuk from Russia.

The remaining important events of the Hologram Technology development are: 1968, when White Light Transmission Holography was invented by Dr. Stephen Benton and 1972, when the Integral Hologram was designed as the result of combination of the White Light Transmission Technology and conventional cinematography.

2 The Working Principle

The next part of this Bachelor Thesis is dedicated to a brief description of how the different methods work and what is their basis of functioning. I primarily focused on the main characteristics, which are typical for each of the mentioned Technologies, but without engaging too deeply on the subject. I also included mentioning interesting properties of these technologies.

2.1 The Cathode Ray Tube

The Cathode Ray Tube Technology was the dominant type of Display Technology, but nowadays its usage is in sharp decline. However, the advantage was a high contrast ratio, which the LCD panels achieve just barely, fast response, true colour representation and excellent viewing angles.

The main components of colour monitors, which are based on the Cathode Ray Tube Principle, are three Electron Guns comprising hot cathodes, which are designed to emit the electron beams. For each of the three colour components (red, green, blue: RGB) is assigned one Electron Gun which emits light to the phosphor layer. These beams go through the shadow mask, which uses a metal plate with tiny holes, in order that electron beams only illuminate the correct phosphors on the face of the tube. These three colours when mixed together can create all the colours that can be seen on a screen. The beams are moved by a deflection system which can be either electrostatic or magnetic. The advantage of magnetic over electrostatic is the possibility of larger deflection angles at low voltages.

Figure 1. *(upper section) Triad-dot shadow-mask colour CRT. (lower section) Vertical stripe, slotted shadow-mask colour CRT. [8]*

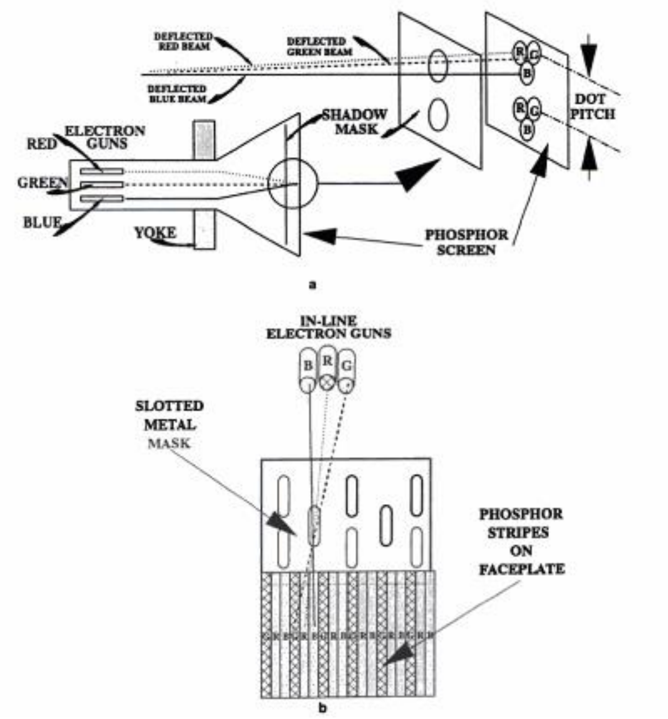


Figure 1 illustrates a demonstration of the principle on which CRT displays work. Three beams from three electron guns pass through a hole in the shadow mask and hit on the phosphor screen at a specific location. The phosphor layer is composed of triads of dots and each one is assigned one colour which is either red, green, or blue. With the use of a standard type of shadow mask, misalignment of beams can occur, which would cause the loss of the purity of colours and a reduction in luminescence. The attempts to solve these problems resulted in the development of a Trinitron mask. This has better features and uses vertical stripes and horizontal beams and resulted in the development of the Trinitron-In-Line Gun.

The emission of certain coloured light by Luminophore takes place only for a brief period of time. The image is therefore necessary to be rendered several times per second. The image is rendered from the upper left corner in rows downward and then the beam returns to the left upper corner. An Electron Gun still has to emit the beams to all the dots of the phosphor layer in every row and that has to be repeated. In the case of CRT, there is never displayed the entire image at any one moment. Instead, it is rendered row by row in such quick time that the human eye sees only the whole image.

2.2 The Liquid Crystal Display

Liquid Crystal Displays are based on the light-modulating of liquid crystals. Liquid crystals are anisotropic materials, which means, that they have different properties in different directions. As the result of this, they have the advantage of behaving differently when they are in contact with an electric field.

All the LCD screens are built from several different layers. The first is a back-light – the source of light, which are either LED diodes or Cold Cathode Fluorescent Lamps (CCFL). CCFL are used less and less, because of their high power consumption, low efficiency, shorter lifetime and decreasing brightness in time. LED diodes used as a back-light are more power efficient, have a longer life, but do produce more heat. Then there is a layer with a Liquid Crystal polarizing agent and a matrix of thin-film transistors, which are placed between two polarizing filters. The second polarizing filter is rotated 90 degrees to the first one, which prevents light from getting through. The application of an external electric field causes the transistors to selectively re-orientate the polarizing agent. This results in changes of the direction of rotation of molecules in that way, which means that all the molecules have the same rotation phase and can pass through the filter. The amount of polarized light, which pass through the filter is controlled by the rotation of Liquid Crystals. The insertion of an RGB filter provides the creation of a colourful image, where, for each pixel, there is a red, green and blue component. Although all LCD screens work in this manner, there are many different ways of manufacturing and reorientating the polarizing agent. This has resulted in several types of LCD Panel.

There exist more types of LCD screens and they differ in the usage of different kinds of Panel Technology. The Panel Technologies are TN, MVA, PVA, IPS, S-IPS, PLS and AHVA. I researched on the internet to find out whether the information about types of panels used in LCD displays are included. I found that not all of the items had a description containing this feature. However, in most cases this information was included. Most people have heard about LCD, LED, Plasma Technology, but they may not have heard about different types of panels, even though there are big differences between, for example, LCD with the TN panel and LCD with the IPS panel. The Technology of the Panel determines the properties of the screen, such as contrast, viewing angles or the behaviour of dead pixels.

The next part of this description of LCD Technology is dedicated to a brief narration of particular types of the LCD panels.

2.2.1 The Twisted Nematic

The first panel used for LCD screens was a Twisted Nematic (TN), which provided the worst screen parameters. However, it is at the same time the type of panel that was most used. The reason for that was its low cost.

In an LCD screen with TN panels you can find a layer made up of Twisted Nematic Crystals that control the flow of molecules. Its main advantage is a very fast response. The crystals can be quickly rotated in the desired direction, which result in and maintain moving images to look smoother.

TN panels offers 6-bit colour depth, which means that they can have only 262,000 types of colour. However, manufacturers often state, that their LCD display with TN panel have 16.2 million or even 16.7 million types of colour. If there is a given number of 16.7, the display is still 6-bit, but using dithering. Dithering works on the principle of optical illusion, when the required colour is usually achieved by the composition of colours in the 2 x 2 pixel. For example, when you want to show some degree of shade you put the black and white pixels next to each other and when you take a look from a sufficient distance, you see the desired colour. The colour image resolution is thus only half. If there is a given number of 16.7 the display should be 8-bit, however this information is not in most cases described. The main disadvantage of TN are probably its viewing angles.

2.2.2 The Vertical Alignment

Another type of LCD Panel Technology is Vertical Alignment (VA). Its name indicates that these Technologies are based on the idea of orienting the Liquid Crystal molecules vertically. This feature enables it to provide deeper blacks, higher contrast, better viewing angles and colour reproduction compared to TN Panel Technology. There exists two types of VA Panel Technology and it is denoted as Multi-Domain Vertical Alignment (MVA) by the Samsung Company and Patterned Vertical Alignment (PVA) by the Fujitsu Company. Each sub pixel is usually divided into four domains. When a pixel (or sub pixel) is in the off state, it does not produce light, thus possible damage of a pixel will cause it to only display a black colour. This is significantly less intrusive and as a result of such a pixel (respectively sub pixel) any drawbacks are not noticeable. The main disadvantage of xVA (x indicates both M and P) is their slower response time which can lead to blurring during fast motion of the displayed pictures.

2.2.3 The In-plane Panel Switching

The most efficient Panel Technology is In-plane Panel Switching (IPS). The Liquid Crystal molecules of these panels are in the idle state parallel to the base plane. After applying voltage, the liquid crystal is rotated by 90 degrees, allowing light to pass through.

There are again more types of this kind of panel; Super In-plane Switching (S-IPS), Plane to Line Switching (PLS) and Advanced Hyper-Viewing Angle Panel (AHVA), but actually at their core they are very similar. The major difference between them is, that IPS, S-IPS were developed by LG Display, PLS by Samsung and AHVA by UAO. All of them are often called "IPS Panels".

IPS Panels have the best results concerning viewing angles, colour accuracy and image quality in comparison with other types of panels. The only drawback, which is its biggest problem, is its price. That is the reason why TN Panels, even though they provide the worst quality, were for a long time the best selling Panel Technology. In my opinion, the trend of buying IPS types of panel is going to rise sharply and it will not take a long time before the IPS Technology will become the number one best seller of screens with this type of panel (actually, it may already be the number one). The reason, why I make this assumption is that on the website Heureka.cz the first three best-selling LCD monitors have IPS type of panel [9]. That also holds true for computer screens. In the case of television, LCD Technology is mostly replaced by LED or OLED Technology.

The parameters of this and also other panels are shown in Table 1 on the next page, where it is obvious which of the panels has the best chance to be of the best quality.

Table 1. *Parameters of different Panels.*

The Panel Technology	*Contrast*	*Viewing angles (H = horizontal V = vertical)*	*Response time*	*Colour reproduction*
TN	1000:1	176 H, 170 V	1ms	6-bit
VA	2000:1 – 5000:1	178 H, 178 V	4ms	8-bit
IPS	10000:1	178 H, 178 V	4ms	8-bit

Response time is a measure of how quickly a pixel can change its colour from white to black or from one shade of grey to another. The lower the response times are, then the better it is. Even though the response time of TN Panels seems to be better than that of IPS Panels, practical tests show that a 3ms TN Panel is as fast as a 6ms S-IPS one. Measuring of viewing angles is also not simple. While LCD manufacturers claim that viewing angles of their screens reach values around 160 horizontally and vertically, in reality this number is much lower. The values shown above are thus only tentative figures.

2.3 The Light Emitting Diode

Light Emitting Diode Technology provides better control of light in comparison to LCD. Basically, it can be said that LED Technology is actually LCD only with the use of LED diodes for back-lighting. One of the first manufacturers, who focused on the use of the LED back-lighting of LCD Panels was Samsung, doing a massive promotion of its televisions. The company also created the misleading term "LED TV". LED diode is an Electronic Semiconductor Device comprising a P-N junction. Once the transition current flows through the junction, the LED starts to emit light.

In the case of LCD with CCFL tubes back-light, there is no possibility of switching these tubes on or off. The only possibility is to arrange them in vertical or horizontal lines. As a result of this drawback, the displayed pictures have a poorer quality. Because the back-light is never switched off, there is a problem with displaying dark scenes as some places appear to be brighter than they should be.

The advantage of LED back-light is, that LED diodes can be easily switched on or off. That leads to better controlling of the back-light. They are also more energy efficient, enable production of thin panels and a wider colour Gamut. According to Wikipedia, Gamut is the *"certain complete subset of colours"* [10]. There are more types of LED back-light. They differ in the way how the LED diodes are arranged.

2.3.1 The Edge LED

The first type of LED diode back-light is Edge LED. TVs with this technology are less difficult and expensive to manufacture in comparison with the Direct LED models. White LEDs are placed on the edges of the entire LCD panel, and the light from this is directed to the centre. Subsequently it is reflected to the screen in the direction of the viewer by using the so-called Light Guide Plate. This is a large thin layer covered by bulging bumps formed of reflective material that is able to repulse the incoming light towards the screen. As the centre of screen gets less light, the bumps are larger as they get closer to the centre. As the result of this method, light is equally distributed across the LCD panel. The advantage of this technology is the use of a smaller number of LEDs and thus reduced production costs and hence the reduction of prices of TVs with this kind of panel. With the use of this back-light a thinner display can also be created. Last, but not least, they have the lowest power consumption.

2.3.2 The Direct LED

The second type of LED diode back-light is Direct LED. Direct LED is technology which has LED diodes placed over the entire panel directly behind the LCD panel, similar to CCFL tubes. Above this LED diode array is located a distribution layer, providing a uniform back-light intensity of the screen. An arrangement of each layer in this way offers additional potential for improving the image quality. This can be achieved with the help of a technique called "Local Dimming", which allows the dimming of individual LED diodes or small groups of LED diodes. The displayed picture is therefore more contrasted and sharper, because black and dark grey colours are darker and more realistic, while the lighter parts of the image remain the same. Most of the manufacturers use white LED diodes for back-lighting. They are actually composed of three RGB elements together, resulting in a white shade.

2.3.3 The RGB LED

Sony, however, for some of its LED televisions uses single colour LED diodes for red, green and blue. They are divided into groups of four and in each group there are two green, one red and one blue diodes, which when combined, form a white colour. The technology, which Sony uses, is called Triluminos and it is the last type of LED back-light; RGB LED diode back-light. This solution offers a colour spectrum almost twice as high than in the case of common CCFL LCD televisions. Combined light output of red, green and blue LED diodes produces a brighter white light than that from a single white light from a tube. They have relatively high power consumption, often even higher than the CCFL back-light.

Nowadays, there is rising popularity in the so called QLED TV’s (Quantum dot LED). They are basically LCD LED devices which use an enhanced colour filter system (quantum dot) that is part of the LCD panel. The result of this filter is that they are able to display more colours in order to give a much more realistic picture than ordinary LCD LED TV’s.

2.4 The Organic Light Emitting Diode

Although its name OLED is very similar to LED back-light Technology, the technology is very different. It is based on electro-luminescence of organic materials. I mentioned previously that LED diodes are used for back-lighting. In the case of Organic Light Emitting Diode (OLED) Technology, there is no need of backlight, because the diode is made of organic material which emits light of a certain colour when a DC voltage is applied. This is achieved thanks to a multilayer OLED cells from which the panel is made up from. The OLED cells consist of several layers, between which is a so called emissive layer (EML). That is composed of organic polymeric materials that are capable of emitting light of a certain desired colour upon excitation.

OLED displays provide many advantages. The main is almost unlimited contrast and wide colour Gamut. A black shade is truly black, since the OLED itself is the source of the back-light and the pixels can be switched off.

There are two basic types of OLED displays; the Passive Matrix Display (PMOLED; Passive Matrix Organic Light Emitting Diode) and the Active Matrix Display (AMOLED; Active Matrix Organic Light Emitting Diode).

2.4.1 The Passive Matrix Organic Light Emitting Diode

PMOLED are simpler and they are used especially when we want to display only text. Individual pixels are controlled passively by a grid matrix of crossed wires. In place of a crossing, the wires are connected to the electrodes (cathodes or anodes) of OLED structures and therefore individual pixels are created. By using grids of wires and multiplexed switches there are selected points where an electrical voltage is applied on the anodes and cathodes which forces the organic substance to emit light. Signals are generally delivered in columns and synchronized with the cyclic connecting of rows. The optical output is thus formed by sequential folding of rows, which occurs 60 times per second. The higher current that on impulse is applied, the brighter the pixel emits. Due to higher power consumption and display properties that are not so good, PMOLED displays are particularly suitable for smaller screen diagonals and displaying mostly static and text information (MP3 players, mobile phones, information displays in cars, etc.).

2.4.2 The Active Matrix Organic Light Emitting Diode

AMOLED are suitable for graphically demanding applications with high resolution displaying video and graphics. The switching of each pixel is performed by its own transistor (in fact two; one controls the charging and discharging of the capacitor and the other is a stabilizer in order to ensure a constant amount of current), resulting in the prevention of flickering of the pixels, which should emit light during several consecutive cycles. Simultaneously, the current flow is increased and the response time is reduced. Among the advantages of AMOLED over PMOLED are higher frequency imaging, rendering sharper images and lower power consumption. The biggest disadvantage is complicated structure of the display and therefore a higher price.

Although OLED displays have a lot of advantages (resistance, operating temperature, subtlety, viewing angles, sensitivity, resolution and production costs), there are also some disadvantages. The most important one is life span that is not the same for all the RGB colours. The blue colour begins to lose intensity as early as after 1000 hours, the green is about the life of 10,000 hours and red approximately of 30,000 hours.

2.5 The Plasma Display Panel

The first Plasma Screens used two groups of conductors which were vertical and horizontal. These two types of conductors are arranged at very close distance to each other, but they are not touching each other. The intersection between a vertical conductor and horizontal one enables the creation of dots of light on the screen. One pair of conductors is chosen by the screen control circuitry, which creates an electric voltage between them. The Plasma is ionized gas using Electrons and Protons which are taken out of Atoms. The Plasma Displays use the Neon Glow Discharge Principle. When the voltage is high enough – characterised as threshold voltage V_{th} – a sealed glass envelope containing Neon gas, or a similar Noble gas in the screen will ionize. The ionization of the gas causes a visible glow which has usually an orange or red colour. Glowing takes place until the voltage decreases to an amount referred to as an extinguish voltage (V_{ex}). Each pixel of the Plasma screen is composed of three sub-pixels (RGB; red, green, blue), and each of them is filled with Plasma (usually using the rare gas Argon). Every sub-pixel is connected to the electrode. The voltage in the electrodes is maintained to be very close to the threshold voltage and ionization then occurs just by a very low increase in the voltage in the electrode.

Modern screens use the same principle but with some changes that considerably improve the picture quality. First of all, these conductors are transparent. Also, instead of using a gas that emits visible light, the gas emits U.V. light, that humans cannot see. The U.V. light is shined on to a Scintillator. The Scintillator is made of phosphoric material, which after the influence of U.V. light emits the visible light. Each Scintillator is filled with a different gas mixture. Therefore, when the UV radiation reaches the Scintillator, it produces light of a different wavelength and thus a different colour. It is 510 nm for green, 610 nm for red and 450 nm for a blue colour.

Colour Plasma Screens employ three phosphoric materials. The first emits red, the second green and the last a blue light. The combination of these basic colours at different intensities is what allows us to see all the different colours on the screen.

Plasma has a much higher brightness than LCD’s (up to 1,500 cd / m2). The image on the Plasma Display is not stable – it flashes because of repeated glimpses of the Plasma. The brightness of a sub-pixel is controlled by the discharge duration (not by the value of voltage).

The electrical consumption is considerable, particularly for displaying a fully white screen which has the highest consumption, because all the sub-pixels are shining at its maximum output. At that moment electrical consumption can be up to 500 watts.

2.6 Holography

Holography is the science and practice of making holograms. Before I move on to a description of how holograms work, I would like to mention some interesting facts about this technology.

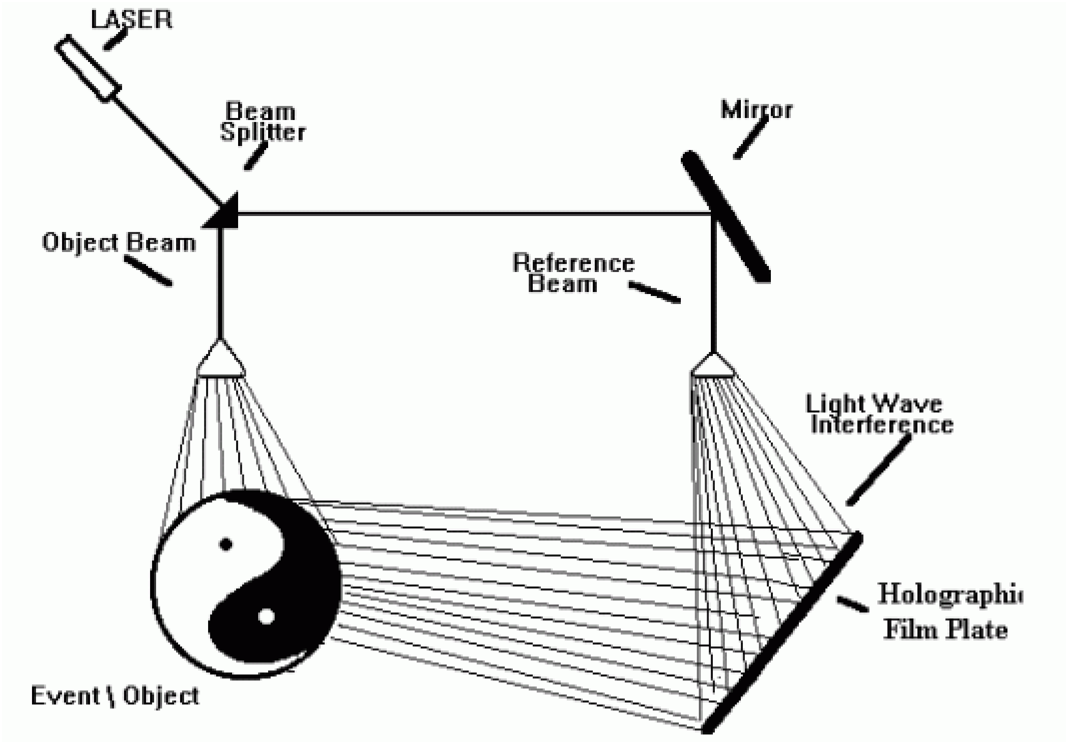
Holograms were first introduced on the music scene. It all started with a music group called Gorilaz with a performance of their song Feel Good at the Grammy Awards in 2006. For those, who do not know or remember, what the video clip of this song looks like, it is an animated story, where animated musicians act. The performance at the Grammys was performed by virtual animated characters from the video clip. We could watch also a virtual illusion of Michael Jackson at the ceremony of the music magazine Billboard in 2014.

In addition to virtual singers illusions that we would otherwise never have an opportunity to see, we can also find purely virtual musicians. The most famous one is the singer Miku Hatsune. She is accompanied at concerts by a live band and she dances and sings with a synthetic voice. This virtual singer was created by the Crypton Future Media company, which develops computer voices for games, computers and electronic musical instruments.

Although it seems to be very modern and advanced, those illusions are based on an old trick called Pepper´s Ghost, which was first described in the sixteenth century. It was then popularized by the British inventor John Henry Pepper in 1862 during a theatrical performance about a ghost who reveals himself as a teacher of Chemistry. Technologically, it is not anything very complicated. The strongly illuminated ghost projection is hidden in the room beneath the stage. In front of it is a system of inclined glass, which reflects its distinctive image on to stage.

Nowadays, there is no need for any hidden room, because of technological improvements. The only thing that is needed is to use a 3D Projector and at an angle of 45 degrees place a modern Hologram Projection Screen called a Musion Eyeliner.

Figure 2. *Holographic storage of information. [11]*



A hologram has two or more light references. The intersecting points of the two light waves contain all the information from the two reference points. As you can see in the **Figure 2**, a Laser is used as the light source, so that the waves are coherent. The Laser is transmitted to a partially silvered mirror, called a Beam Splitter (see fig. 2). This mirror splits the original beam into two beams. One beam travels through a lens that diffuses the light on the object that is being recorded. This light, called the Object beam, is reflected from the object to the film plate. The second beam is reflected from the mirror and then is diffused by a lens directly onto the film plate. This beam is referred to as the Reference beam. The same light source is used in order for both beams to have perfect wave intersections.

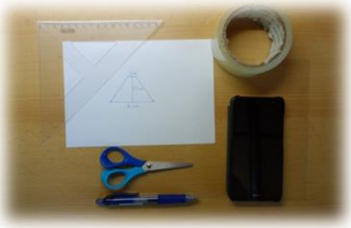
I mentioned previously, holographic performances are used for entertaining purposes and also for exhibitions, where exhibited artworks seem to be unbelievably realistic. In my personal experience, I have never seen a real hologram, so I decided to create my own version of it.

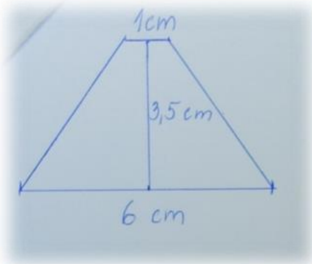
2.6.1 The creation of my own hologram

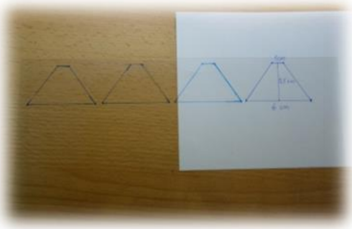
For the demonstration of a hologram I decided to create my own mobile phone hologram. Its principle is simple; it is based on the reflection of an image from the display of the mobile phone to an inclined plastic sheet. In order for the image to be seen from all angles at 360 degrees, it is necessary to create a hologram composed of four inclined plastic sheets. For each of them there is an image on the display of the mobile phone to be reflected.

This hologram can be very simple to create. All the things which are necessary for its creation you can find at home. You need a plastic sheet (I used one that was part of a folder for documents. In this instance, its first or cover page, but you can also use a CD cover). You also need a ruler, pair of scissors, a pen, a piece of paper, a sticky label and a smart phone.

Figure 3, 4, 5. *The procedure of making the hologram.*

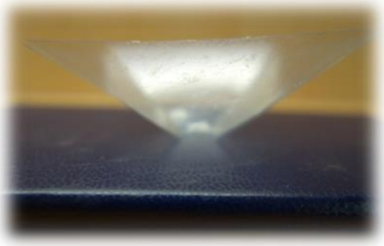


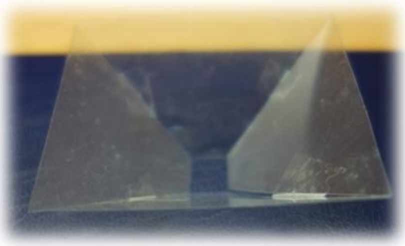




The first step to take is to create the template, as you can see in the picture above. The template is a trapezoid with its longest side equal to 6cm. At the centre of this side we create a perpendicular line 3,5cm long. At the end of this we again do a perpendicular line and draw a line 0,5cm to each side – left and right. Then we connect the endpoints of the sides 6cm long and 1cm long and the desired template of the trapezoid is completed. With the help of this template we make four copies of the trapezoid on the plastic sheet and then cut them out. The last step of creation is putting these pieces of plastic sheets together.

Figure 6, 7, 8. *The result of making the hologram.*

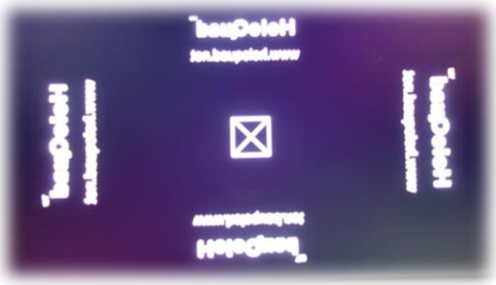


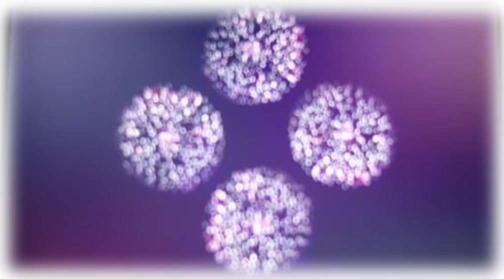


The best way of achieving and completing this hologram is to place these four plastic sheets so that their outer sides touch each other. You then tape them together with small pieces of sticky label (left picture on the previous page). When we have done this, we need to tape the last two sides together and by doing that our “mini, amateurish” hologram is completed (middle and right picture on the previous page).

The only thing which is left to do is to use this product to display a holographic video. We have to search on YouTube website using the search term “hologram mmd” which returns results of finding many videos for this purpose.

Figure 9, 10. *MMD hologram video.*



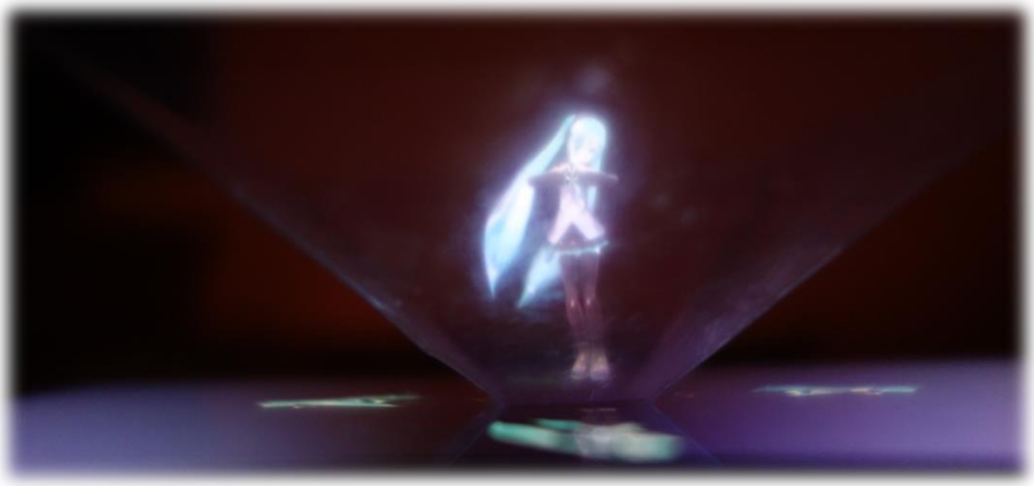


When you launch such a video, there is a square with a cross in the middle which indicates to you where to put the centre of the holograph (the four sides, which are 1cm long). Each of the four images which are shown on the screen on the left, right, up and down are assigned to one of the plastic sheets.

Figure 11. *The application of created hologram.*

This is the end result. The image from the screen is reflected on to the inclined plastic sheets, so that the image “ascends” into space.

Figure 12. *Projection of virtual singer Miku Hatsane.*



In the picture above you can see the image of the virtual singer Miku Hatsune who I mentioned previously. She is dancing to one of her songs and although the picture may seem that it does not look very real, when you see it with your own eyes, I think that it is really “cool”. Furthermore, even though it is not a real hologram, but only simple trick, it demonstrates how the principle of mirroring and backlit imaging works.

3 Displays in Everyday Life

When creating this bachelor thesis I have thought about how big impact displays have had on our lives. I have wondered whether, as in my case, this impact has been consciously observed or simply accepted as something new. We might be happy to use the latest development in technology, but we do not have to track the development directly. In this day and age there are so many changes in this world concerning the development of technologies that I think it is very interesting to know what knowledge, attitudes and thoughts about display technology people have whilst living their “everyday lives.”

That is why I have decided to conduct a little research on this topic. I took advantage of the services provided by the web page survio.com [12]. On this page it is possible to create a survey and send it as an electronic form. I chose this method because of the fact that in these times almost everyone has access to the internet and it is the simplest method of sharing and finding out information. The process of distribution to the potential survey participants was easier with the help of social sites, but only for one age group which is included later in this thesis. The biggest advantage of the online survey is that you do not have to collect all of the answers and count the results. Everything is shown on one web site, evaluated and sorted.

The survey is called the Development of Display Technology. I have created eleven questions; two of them ask about personal information, and nine ask about the knowledge and personal experiences of the participants. Question one is about gender determination – whether is the person a man or a woman. The second question is about the participants age group. The participants are divided into three age groups. The intention of the second question was to acquire information on how great a difference was between generations and whether older generations are able to adapt to the development. Basically most of the other questions are connected with the second one and are evaluated with regards to it.

When I started to collect results from the survey, I had every intention of trying to get thirty responses from each of the age groups. From the beginning it was clear that the number of responses would not be balanced. I believe that this was the result of the youngest age group sharing information via social sites and email, causing them to be the most active group. I was able to collect 31 responses from people in the age group of up to 25 years of age included (hereinafter those referred to as “the first group”). The participants of the next age group, those from 26 to 50 years of age included (“the second group”) sent me 36 responses and the participants of the age group from 51 years and above (“the third group”) sent me 30 responses.

In order to reach a conclusion from the survey, I have decided to analyse some of the results with respect to the age of the respondents and comment on different opinions of the three different age groups. In the cases of questions where the results are similar or where the age has nothing to do with the results I have evaluated the responses independently of age.

3.1 Are you interested in the development of display devices?

That is the most basic question I wanted to ask. It can show us how the development of display technology is, or is not, popular.

It was surprising for me to see the results of the first group. From the 31 participants of this age group 24 were men, and men are widely known for having a better relationship with technology than women. I supposed that the majority of young people are actively interested in new technologies. However, only 29% of the respondents chose this answer. The majority (41.9%) showed interest in the display technology only when they intended to buy one. When buying new equipment 22.6% of participants in this group required advice from the seller, or someone they knew. The rest of this age group (6.5%) entrust it to the care of someone else.

Concerning the second age group, responses from women prevailed with 22 out of a total of 36 people completing the survey. As I expected, the interest of this group about the development of technologies was lower than in the previous case (13.9%). The survey showed that 38.9% of the respondents care about it only when buying a new device and 36.1% take into account the seller´s advice. The number of people who stated that they do not care about display technology is 11.1% of the respondents.

In the last age group the numbers of men and women are almost equal. The fact that older generation does not have as good a relationship with technology as younger people is clearly shown here. The largest slice of the cake (40%) belongs to the answer: *“No, I entrust it to the care of someone else, I do not care.”* – which, in comparison with other age groups, is an absolutely different result. The survey showed that 36.7% of the participants from this group chose the answer: *“No, when buying new equipment,* *I follow the seller´s advice, or advice of someone I know.”.* Only 23.3% of the respondents chose the answer: *“Yes, but only when purchasing new equipment.”* and absolutely no one picked the answer: *“Yes, I'm interested in the development of display devices.”*

These results have shown us how attitudes towards the development of display technology differ across generations. Whilst younger generation has at least some interest in observing the direction in which display technologies are heading, with the increasing age of people this interest radically decreases and in the case of older generation there is almost no interest.

3.2 Do you know which of these types of displays was introduced first?

As display technology has been evolving and significantly changing for a long period of time, the name of the first display technology may be difficult for people to remember. I would like to take this opportunity to remind you that the “big box” CRT was the first type of display.

The results from this question are clear. Whilst the portion of people who know the right answer in the first age group is 80.6%, in the second age group it decreases to 50% and in the third age group it drops even further to 30%.

3.3 Do you know which of these types of displays is currently the most popular?

The popularity of each of the technologies changes with every new invention which comes on to the market and takes the place of its predecessor. I remember the popularity of all of the types of display technology which I have described in this work. When I was at kindergarten and primary school, the CRT displays were popular. At the secondary school they were being replaced by the LCD ones and at high school and university the LCD LED ones started dominating the market. The answers of the respondents may differ according to their latest purchase of a display.

When we look at the market, we can find mostly televisions with the LCD LED technology. The LCD LED technology provides very good display properties at an affordable price. Although the OLED technology provides the best picture quality and the truest colour representation, its price is quite high. For example, prices start at 36,299 CZK in the Alza.cz online shop (April, 2017). The rest of technologies which

I have described (CRT, LCD CCFL, Plasma) are no longer being sold.

Since the OLED, LCD and LCD LED technologies have very similar labels and one might find this confusing, the results of this answer are fairly satisfactory. From the first and third age groups 33.3% selected the right answer and from the second age group 41.7% of the respondents also made the right choice. The next most selected answers were as previously mentioned OLED and LCD technologies.

3.4 Do you own a CRT display device?

With the rapid evolution of new technologies also comes the possibility of replacing older devices with newer ones.

In my own case I inherited one CRT display and use it in my student flat for watching television occasionally. It is a small Tesla television with a diagonal of 35cm. For some people this is an absolutely unbelievable dimension. When buying a new television these days, it is typical to buy one with the diagonal somewhere in the region of 100cm or even higher. There is also no longer the possibility of buying a new CRT display, so they are slowly disappearing from households, being replaced by flat ones. When I observe televisions or displays in my family or friends homes, the flat ones prevail. It is really only very occasionally that you will find a CRT display.

The results of this question confirm my own attitude and experience. The answers from all three age groups are almost identical so it is not necessary to analyse them separately. The majority (63.3%) of the participants have already replaced their old device by a new modern flat panel television.

This is something that can be seen in all technological branches. For example, it is now really rare to see a person with the old Nokia 3310 type of a mobile phone. However, the invention of better technology or damage to the old device are not the only reasons why people change their device for a new one. Further in this thesis I deal with the transition of television broadcasting to a different frequency zone which will have consequences for current devices.

3.5 Do you know which of these LCD panels provides the best display quality?

In this thesis I deal with three different kinds of panels (TN, xVA and IPS). The differences between them are easily recognizable. When you have two devices – one with a TN panel and the second with the IPS one, the differences can be seen at first sight. When buying new LCD equipment it is therefore advisable to know at the very least which of them provides the best image quality. Nowadays the IPS panels are mostly used in the LCD displays (monitors) so it is not a very big disadvantage if you do not know the differences between them. However, a few years back there was an even distribution of all the kinds of panel technologies in the available displays.

Since panel technology is not a widely known parameter, the answer: “I do not know.” from 72.2% of the respondents was not surprising. The majority of the rest (24.7%) chose the correct option: “IPS.” Two people selected: “TN” and one answered: “xVA”. All the right answers except one came from the members of the first and second age group.

3.6 What is the difference between LCD and LED displays?

The only difference (as described earlier in this essay) between the so called LED display and LCD one is in the usage of a different kind of back-lighting. Even though the displays which use the LED back-lighting provide better image quality than the displays using the Cold Cathode Fluorescent Lamps technology, it is still based on the same principle of Liquid Crystal Displays.

The manner of changing labels describing display technology used in devices can be seen every few years. After a period of time when the label has appeared to be popular, the sellers usually come up with what they consider to be a new and “fresh” one. Those LED displays should be referred to as the LCD LED devices, but it would not be so attractive to a potential customer and it would quickly lose its novelty. Nowadays the term LED TV, for example, also does not have the popularity it used to have. The sellers use labels such as 4K SMART TV (4K referring to the higher resolution, and SMART indicating the possibility of connecting to the Internet and the advantages related to that).

The results show that more than one third (36.1%) of the respondents think that the LCD and LED displays are absolutely different technologies. In my opinion it is quite a large number. However, it is possible that it could be high percentage as the result of not adding the word LCD to the LED display labels. The biggest number of respondents who answered that the only difference is in the usage of the different kind of back-light belongs to the first age group and those who answered incorrectly belong mainly to the third age group.

3.7 What kind of display device do you own?

In the past two decades there have appeared new technologies such as smartphones, tablets, mp3 players and smart watches which have easily found their way into our homes and pockets. The aim of this question was to find out which types of the display technology device respondents own with regards to the development of display technology. To make this easier to understand I have created charts with the results of the individual age groups.

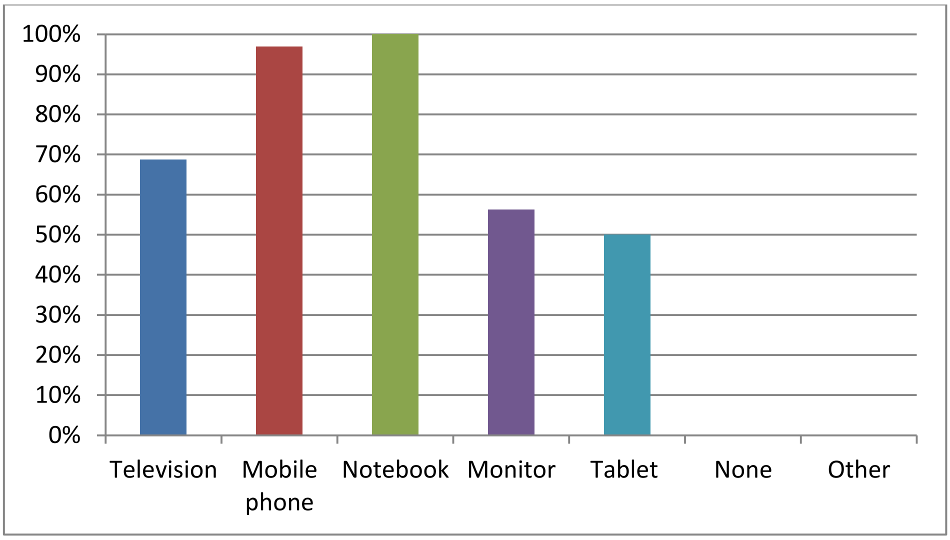
Figure 13. *Worldwide device shipments by segment (thousands of units).[14]*

Device Type	2013	2014	2015
Traditonal PCs (Desk-Based and Notebook)	296,131	276,221	261,657
Ultramobiles, Premium	21,517	32,251	55,032
PC Market Total	**317,648**	**308,472**	**316,689**
Tablets	206,807	256,308	320,964
Mobile Phones	1,806,964	1,862,766	1,946,456
Other Ultramobiles (Hybrid and Clamshell)	2,981	5,381	7,645
Total	**2,334,400**	**2,432,927**	**2,591,753**

Source: Gartner (June 2014)

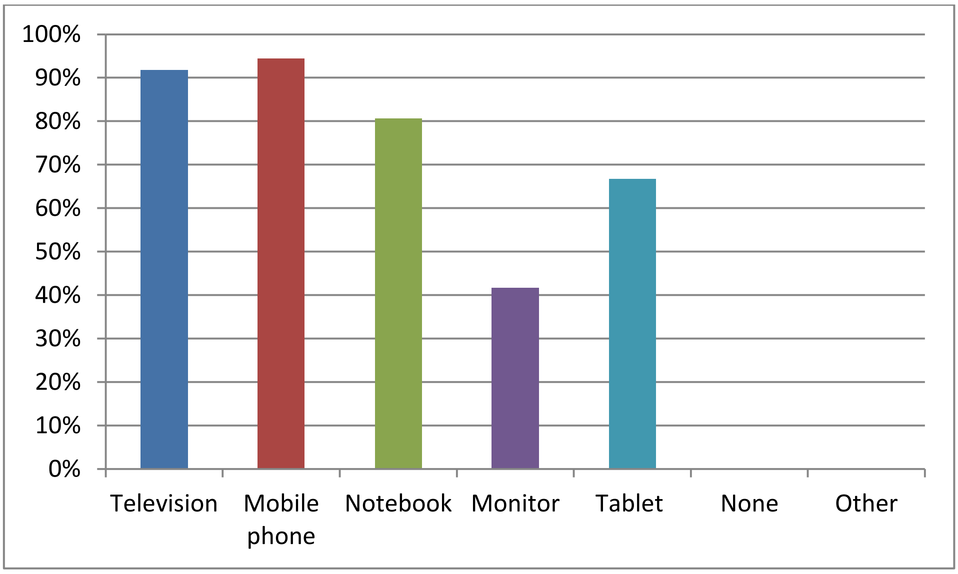
As you can see in the graph below, everyone from the youngest age group owns a notebook. The requirement of this day and age, especially for students, is to be able to deal with many projects, the creation of which is greatly facilitated by the use of portable devices. Textbooks have been replaced in many cases by electronic documents for viewing which obviously makes it necessary to own a display device. Almost everyone claimed to have a mobile phone, although one respondent did not select this option. Personally, I do not know any young person who does not have a mobile phone of his/her own. The great advantage of mobile phones is not only that you can be in contact with anyone at any time (depending on network availability), but also that modern smart devices with display sizes of around 5 inches provide the user with the possibility of actually carrying out and storing a lot of work on it. A tablet may replace the role of computers, because it is increasingly becoming a more and more efficient device capable of providing most of the utilization that a desktop computer can do. When you have a look at Figure 13 on the previous page, you find that in 2015 the number of tablets sold exceeded the number of desktops and notebooks that had been sold. Steve Jobs predicted this result as a “Post-PC Era”. [14] To come back to the results of the first age group of respondents, exactly half (50%) of them selected that they own a tablet and a slightly larger amount (56.3%) owns a monitor. The percentage assigned to the monitor may also give an indication as to whether the respondents own a desktop computer (unless the monitor is used as a second screen for a notebook). The results also show that 68.8% of the participants own a television, which is the lowest number in the three age groups.

Graph 1. *The results of the first age group.*



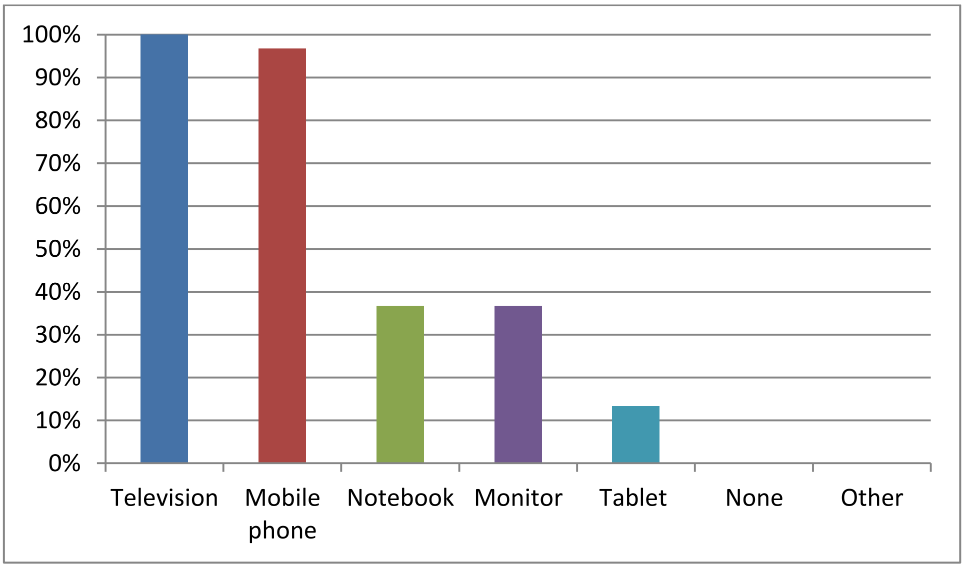
The results of the second age group show that the percentage of notebooks (80.6%) radically prevails over the percentage of monitors (41.7%) and at the same time the portion of tablets (66.7%) is getting very close to the amount of notebooks. The statistics show that people prefer buying portable devices, either notebooks or tablets. It is to be expected that in the years to come the manner of purchasing Post-PC devices will continue [14] and tablets will be the number one choice. More respondents than in the first age group own a television (91.7%) and almost the same amount (94.4%) has a mobile phone.

Graph 2. *The results of the second age group.*



According to the responses, all the participants of the third age group have a television, most of them (96.7%) own a mobile phone, 36.7% have a monitor, and the same percentage owns a notebook, whilst only 13.3% have a tablet. The results confirm my point of view that for the older generation having a television is more important than owning a portable device.

Graph 3. *The results of the third age group.*



3.8 Have you ever seen a holographic video?

The possibility of being able to see a real hologram is not very great. Basically, the occasions where they can be seen are usually at presentations, expositions or performances with the aim of either exhibiting new holographic technology or, as in most cases, providing a holographic appearance of an object or a person. On the other hand, the Internet (especially the website Youtube.com) is full of videos which show how great the capabilities of holography are.

The rare opportunity to be able to see a hologram with your own eyes is the main reason why only 5.2% of the respondents selected the answer: “Yes, I have seen it with my own eyes.” In my personal experience I have never seen a real hologram, only one shown as a video on the Internet. Some 24.7% of the respondents share this personal experience with me. The majority of the respondents (36.1%) stated they had knowledge of holograms, but at the same time they had no personal experience of seeing them. The rest, (34%) selected the answer: “No, I have not heard about holograms before.” These participants belong mainly to the third age group.

Holography is not perceived as the technology which could serve as a device for displaying information in households. The future of the development of display technology is still heading in the direction of flat panels – displaying two dimensional images which may be enhanced by technologies that in the future may have the ability to provide a third dimension (the 3D televisions which are nowadays used should be rather called 2.5D because they do not provide a true three dimensional image – we cannot look at them from all angles).

3.9 How will you deal with the transition to the standard DVB-T2?

The Czech Republic currently broadcasts using the digital terrestrial television standard DVB-T. Although it is not long since the analogue transmitters were turned off and switched to digital ones, another change is going to happen in the near future.

The new standard DVB-T2 (Digital Video Broadcasting) which is going to replace the current DVB-T is capable of inserting a larger number of TV stations into one broadcasting multiplex.

The transmission in the DVB-T2 range provides increased usable bandwidth for the transmission of image, and broadcasts only in the compression format H265/HEVC.

Since costs associated with broadcasting will be cheaper, it is possible that more television stations will transmit there.

Displays which are able to receive DVB-T signals are not compatible with DVB-T2 broadcasting. Even a new television might not support it unless it states in its specifications that it is compatible. The same is true for set top boxes.

Actually there are different types of DVB-T2 standards. The device with a DVB-T2 tuner itself is not enough for successful reception of a signal. In that case the signal would be received, but there would be no image on the display. Only the combination of the DVB-T2 tuner with the HEVC format provides the fruitful signal transmission.

New temporary multiplexes in the DVB-T2 + HEVC standard are currently gradually being launched. The gradual shutting down of DVB-T should begin in 2018 and is due to finish in 2021.

The main reason for the transition to the DVB-T2 standard is the binding decision of the European Parliament to leave the frequency band of 700 MHz for the use of mobile operators and networks.

The total costs associated with the transition to the new type of the digital DVB-T2 standard are estimated from 2 to 5 billion CZK for the population as a whole. The Ministry of Industry and Trade have stated that the Government may cover part of the costs for the people from public sources. This concerns mainly social and health facilities. [13]

Since I have conducted my research on this topic I am aware that a campaign about this transition should have started in the autumn of 2016. The results of this question should predominantly confirm the knowledge of people about this change that is going to occur.

When we take a closer look at the answers of the respondents according to their different age groups, we might find that the results are quite surprising. With the understanding that the youngest age group is most of the time “online”, I would consider them to be the most well informed about the transition to the DVB-T2. However, this group has the poorest results of all the age groups. The majority with 38.7% of the participants have no idea about the transition. The second biggest portion (25.8%) plans to buy a new TV that supports the standard, 19.4% plan to buy a new set-top box that supports the standard, 9.7% claim that they do not have a television and 6.5% state that they have a TV that supports it.

The results of the second age group have almost even distribution of the responses to each of the questions with 33.3% of the respondents stating they are ignorant of the transition. Buying a new television is the intent of 19.4% of the respondents, exactly the same number of participants relies on the purchase of a new set top box and at the time of the survey 16.7% of the respondents had already bought a new one. The rest of the second age group (11.1%) have a different attitude to the transition. Their responses were “I watch TV via the Internet.”, or “My husband takes care of it.” and “Until it comes, I do not care about it, then I will solve it.”.

I expected that the third age group would be informed the least; however, the results show quite the opposite. Almost one third (30%) responded with the answer: “I plan to buy a new set-top box that supports the standard.” and the same portion belongs to the answer: “I plan to buy a new TV that supports the standard.” The answer: “I do not know anything about the transition to the DVB-T2.” was chosen by 23.3% of the participants. The second least frequent response (13.3%) was “I have a TV that supports it.” And one respondent (3.3%) has mentioned in the option: “Other:” that he has a different opinion about that.

In my opinion, the reason why the oldest age group is best informed is that the information campaign is presented mainly by television broadcast – mainly on the news programs that the youngest group is not likely to watch too much. The results have also shown that older people tend to watch more television than the younger ones – some of the younger participants do not even own one. The general results are, however, still not gratifying. There can still be found new televisions that do not support the DVB-T2 standard on the market, so it is possible that someone may buy a new television and then find out that it will be necessary to buy another device to be able to receive the new signal. This depends mainly on the sellers whether they are honest and inform people about the transition. Most of the sellers provide the advice, a lot of them even use the DVB-T2 standard as a new attraction for customers.

Conclusion

The purpose of this Bachelor Thesis is to provide a brief summary of the Display Technology development, how the specific technologies work and what their parameters are.

As I worked through the majority of technologies which were developed for displaying information, I realized just how great progress has been made in this field. This progress has taken place mainly in the twenty-first century and is going to continue in the exponential manner. I am sure that such progress will hold many surprises for all of us. The differences between CRT and OLED can be used as an example as to how different technologies can be compared to their earlier predecessors.

This thesis might also serve as a brief overview of the development of display technology for someone who is interested in it or who is intending to buy a new device. Although the CRT and Plasma types are no longer in production, it is still very interesting to know and understand the principle of their working. All other display technologies (LCD, LED, OLED) are currently available on the market, and it is possible to use this thesis with its described principles and parameters as a helpful textbook when deciding in favour of a new device or when we simply want to know what the basic technological differences are between each of them. Although the real holographic videos are not widely publicly accessible, there is great potential in this technology. The hologram is the only technology as described in this work which is capable of displaying a true 3D image that can be watched from all angles.

The aim of the survey which I had created was to gain information about the knowledge that people in different age groups had about displays. Since the number of participants was around 30 from each of these groups, the results can be used only as a general guide of what the relationship toward this kind of technology and people in society might look like. My intention was to provide a brief idea about the relationship between the technology and the participants (reflected in broader terms). The general conclusion which I believe I can make is – which I initially assumed – that interest about the development of display technology is the highest in the case of the first age group and with each of the other groups slowly decreases. It is, in my opinion, given mainly by the fact that the first age group has been affected the most by display technology and it is primarily the result of technology supported education. However, this is not true for all of the questions from the survey. In the case of the last question, currently a very important one dealing with the transition to the other type of broadcasting standard, the third age group has shown to be best informed. It can be said that while younger people tend to know the parameters and qualities of individual types of display, the older ones have the knowledge that is practically usable or very important for them. Since the number of men and women in each of the age groups is not evenly distributed in this survey (and each age group has a different attitude towards the development of display technology), I have decided to summarize only generally what the main differences between the results of these two genders are. Men have generally proven higher knowledge of this kind of technology and also their interest in this field is noticeably bigger. However, when it comes again to the results of the last question which deals with the transition to the DVB-T2 standard, women have shown the same knowledge and also seem to be in the similar stage of preparation for that situation.

I am fairly certain that a decade from now there will exist absolutely new forms of Display Technology, which we nowadays cannot possibly imagine. Personally, I am amazed when each new technological development arises, and I have great expectations for the ones that will follow.

Attachment – the survey Development of Display Technology

Hello,

please take a few minutes of your time to complete the following survey which is an attachment and source of information for a Bachelor Thesis on the Development of Display Technology. The survey is aimed at gaining information on the awareness of different age groups about the development of displays that are part of a device such as a mobile phone, tablet, television, monitor, etc., commonly referred to as a device.

1) What gender are you?
   a) *Man*
   b) *Woman*
2) To which age group do you belong?
   a) *Younger than 26*
   b) *26 – 50*
   c) *Older than 50*
3) Are you interested in the development of display devices?
   a) *Yes, I'm interested in the development of display devices.*
   b) *Yes, but only when purchasing a new equipment.*
   c) *No, when buying a new equipment, I follow the seller´s advice, or advice of someone I know.*
   d) *No, I entrust it to the care of someone else, I do not care.*
   e) *Other (fill in): ……………………………………………..............................*
4) Do you know which of these types of displays was introduced first?
   a) *CRT*
   b) *LCD*
   c) *LED LCD*
   d) *OLED*
   e) *Plasma*
   f) *I do not know.*

5) <u>Do you know which of these types of displays is currently the most popular?</u>
   a) *CRT*
   b) *LCD*
   c) *LED LCD*
   d) *OLED*
   e) *Plasma*
   f) *I do not know.*
6) <u>Do you own a CRT display device?</u>
   a) *Yes.*
   b) *No, they were replaced with a new modern ones.*
7) <u>Do you know which of these LCD panels provides the best display quality?</u>
   a) *TN*
   b) *xVA*
   c) *IPS*
   d) *I do not know.*
8) <u>What is the difference between LCD and LED displays?</u>
   a) *They are absolutely different technologies*
   b) *The only difference is in the different kind of backlight.*
   c) *I do not know.*
9) <u>What kind of display device do you own (you can select more options)?</u>
   a) *Television*
   b) *Mobile phone*
   c) *Tablet*
   d) *Notebook*
   e) *Monitor*
   f) *None*
   g) *Other (fill in): ……………………………………………..............................*
10) <u>Have you ever seen a holographic video?</u>
   a) *Yes, I have seen it in a video on the Internet.*
   b) *Yes, I have seen it with my own eyes.*
   c) *No, I have not seen that but I have heard about it.*
   d) *No, I have not heard about hologram before.*

11) <u>How will you deal with the transition to the standard DVB-T2?</u>

a) *I have a TV that supports it.*

b) *I plan to buy a new set-top box that supports the standard.*

c) *I plan to buy a new TV that supports the standard.*

d) *I do not know anything about the transition to DVB-T2.*

e) *Other (fill in): ………………………………………….............................*

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