Plasma display
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A plasma display panel (PDP) is a type of flat panel display common to large TV displays 30 inches (76 cm) or larger. They are called "plasma" displays because the technology utilizes small cells containing electrically charged ionized gases, or what are in essence chambers more commonly known as fluorescent lamps.

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General characteristics

Plasma displays are bright (1,000 lux or higher for the module), have a wide color gamut, and can be produced in fairly large sizes—up to 150 inches (3.8 m) diagonally. They have a very low-luminance "dark-room" black level compared to the lighter grey of the unilluminated parts of an LCD screen (i.e. the blacks are blacker on plasmas and greyer on LCDs).[1] LED-backlit LCD televisions have been developed to reduce this distinction.
The display panel itself is about 6 cm (2.5 inches) thick, generally allowing the device's total thickness (including electronics) to be less than 10 cm (4 inches). Plasma displays use as much power per square meter as a CRT or an AMLCD television.\[\text{citation needed}\]

Power consumption varies greatly with picture content, with bright scenes drawing significantly more power than darker ones – this is also true of CRTs. Typical power consumption is 400 watts for a 50-inch (127 cm) screen. 200 to 310 watts for a 50-inch (127 cm) display when set to cinema mode. Most screens are set to 'shop' mode by default, which draws at least twice the power (around 500–700 watts) of a 'home' setting of less extreme brightness.\[2\] Panasonic has greatly reduced power consumption ("1/3 of 2007 models") [3][4] Panasonic states that PDPs will consume only half the power of their previous series of plasma sets to achieve the same overall brightness for a given display size. The lifetime of the latest generation of plasma displays is estimated at 100,000 hours of actual display time, or 27 years at 10 hours per day. This is the estimated time over which maximum picture brightness degrades to half the original value.\[5\]

Plasma display screens are made from glass, which reflects more light than the material used to make an LCD screen.\[\text{citation needed}\] This causes glare from reflected objects in the viewing area. Companies such as Panasonic coat their newer plasma screens with an anti-glare filter material.\[\text{citation needed}\] Currently, plasma panels cannot be economically manufactured in screen sizes smaller than 32 inches. Although a few companies have been able to make plasma EDTVs this small, even fewer have made 32in plasma HDTVs. With the trend toward larger and larger displays, the 32in screen size is rapidly disappearing. Though considered bulky and thick compared to their LCD counterparts, some sets such as Panasonic's Z1 and Samsung's B860 series are as slim as one inch thick making them comparable to LCDs in this respect.

Competing display technologies include CRT, OLED, LCD, DLP, SED, LED, FED, and QLED.

**Plasma display advantages and disadvantages**

*Further information: Comparison CRT, LCD, Plasma*

**Advantages**

- Picture quality
  - Capable of producing deeper blacks allowing for superior contrast ratio\[6][7][8\]
  - Wider viewing angles than those of LCD; images do not suffer from degradation at high angles like LCDs\[6][7\]
  - Less visible motion blur, thanks in large part to very high refresh rates and a faster response time, contributing to superior performance when displaying content with significant amounts of rapid motion\[6][7][9][10\]

- Physical
  - Slim profile
  - Can be wall mounted
  - Less bulky than rear-projection televisions
Disadvantages

- Picture quality
  - Earlier generation displays were more susceptible to screen burn-in and image retention, although most recent models have a pixel orbiter that moves the entire picture slower than is noticeable to the human eye, which reduces the effect of burn-in but does not prevent it.[11]
  - Earlier generation displays (2006 and prior) had phosphors that lost luminosity over time, resulting in gradual decline of absolute image brightness (newer models are less susceptible to this, having lifespans exceeding 100,000 hours, far longer than older CRT technology)[5][8]
  - Earlier generation (circa 2001 and earlier) models were susceptible to "large area flicker"[12]
  - Heavier screen-door effect when compared to LCD or OLED based TVs[citation needed]

- Physical
  - Generally do not come in smaller sizes than 37 inches[6][7]
  - Heavier than LCD due to the requirement of a glass screen to hold the gases

- Other
  - Use more electricity, on average, than an LCD TV
  - Do not work as well at high altitudes due to pressure differential between the gases inside the screen and the air pressure at altitude. It may cause a buzzing noise. Manufacturers rate their screens to indicate the altitude parameters.[13]
  - For those who wish to listen to AM radio, or are Amateur Radio operators (Hams) or Shortwave Listeners (SWL), the Radio Frequency Interference (RFI) from these devices can be irritating or disabling.[14]
  - Due to the strong infrared emissions inherent with the technology, standard IR repeater systems can not be used in the viewing room. A more expensive "plasma compatible" sensor must be used.[citation needed]

Native plasma television resolutions

Further information: Native resolution

Fixed-pixel displays such as plasma TVs scale the video image of each incoming signal to the native resolution of the display panel. The most common native resolutions for plasma display panels are 853×480 (EDTV), 1,366×768 or 1,920×1,080 (HDTV). As a result picture quality varies depending on the performance of the video scaling processor and the upscaling and downscaling algorithms used by each display manufacturer. [15][16]

Enhanced-definition plasma television

See also: Enhanced-definition television

Early plasma televisions were enhanced-definition (ED) with a native resolution of 840×480 (discontinued) or 853×480, and down-scaled their incoming high definition signals to match their native display resolution.[17]

ED Resolutions
High-definition plasma television

Early high-definition (HD) plasma displays had a resolution of 1024×1024 and were alternate lighting of surfaces (ALiS) panels made by Fujitsu/Hitachi.[18][19] These were interlaced displays, with non-square pixels.[20]

Modern HDTV plasma televisions usually have a resolution of 1,024×768 found on many 42 inch plasma screens, 1,280×768, 1,366×768 found on 50 in, 60 in, and 65 in plasma screens, or 1,920×1,080 found in plasma screen sizes from 42 inch to 103 inch. These displays are usually progressive displays, with square pixels, and will up-scale their incoming standard-definition signals to match their native display resolution.[21]

HD Resolutions

- 1024×1024
- 1024×768
- 1280×768
- 1366×768
- 1280×1080
- 1920×1080

How plasma displays work

See also: Plasma (physics)

A panel typically has millions of tiny cells in compartmentalized space between two panels of glass. These compartments, or "bulbs" or "cells", hold a mixture of noble gases and a minuscule amount of mercury. Just as in the fluorescent lamps over an office desk, when the mercury is vaporized and a voltage is applied across the cell, the gas in the cells form a plasma. With flow of electricity (electrons), some of the electrons strike mercury particles as the electrons move through the plasma, momentarily increasing the energy level of the molecule until the excess energy is shed. Mercury sheds the energy as ultraviolet (UV) photons. The UV photons then strike phosphor that is painted on the inside of the cell. When the UV photon strikes a phosphor molecule, it momentarily raises the energy level of an outer orbit electron in the phosphor molecule, moving the electron from a stable to an unstable state; the electron then sheds the
excess energy as a photon at a lower energy level than UV light; the lower energy photons are mostly in the infrared range but about 40% are in the visible light range. Thus the input energy is shed as mostly heat (infrared) but also as visible light. Depending on the phosphors used, different colors of visible light can be achieved. Each pixel in a plasma display is made up of three cells comprising the primary colors of visible light. Varying the voltage of the signals to the cells thus allows different perceived colors.

A plasma display panel is an array of hundreds of thousands of small, luminous cells positioned between two plates of glass. Each cell is essentially a tiny neon lamp filled with rarefied neon, xenon, and other inert gases; the cells are luminous when they are electrified through "electrodes". The long electrodes are stripes of electrically conducting material that also lie between the glass plates, in front of and behind the cells. The "address electrodes" sit behind the cells, along the rear glass plate, and can be opaque. The transparent display electrodes are mounted in front of the cell, along the front glass plate. As can be seen in the illustration, the electrodes are covered by an insulating protective layer. Control circuitry charges the electrodes that cross paths at a cell, creating a voltage difference between front and back. Some of the atoms in the gas of a cell then lose electrons and become ionized, which creates an electrically conducting plasma of atoms, free electrons, and ions. The collisions of the flowing electrons in the plasma with the inert gas atoms leads to light emission; such light-emitting plasmas are known as glow discharges.

In a monochrome plasma panel, the gas is usually mostly neon, and the color is the characteristic orange of a neon-filled lamp (or sign). Once a glow discharge has been initiated in a cell, it can be maintained by applying a low-level voltage between all the horizontal and vertical electrodes–even after the ionizing voltage is removed. To erase a cell all voltage is removed from a pair of electrodes. This type of panel has inherent memory. A small amount of nitrogen is added to the neon to increase hysteresis. In color panels, the back of each cell is coated with a phosphor. The ultraviolet photons emitted by the plasma excite these phosphors, which give off visible light with colors determined by the phosphor materials. This aspect is comparable to fluorescent lamps and to the neon signs that use colored phosphors.

Every pixel is made up of three separate subpixel cells, each with different colored phosphors. One subpixel has a red light phosphor, one subpixel has a green light phosphor and one subpixel has a blue light phosphor. These colors blend together to create the overall color of the pixel, the same as a triad of a shadow mask CRT or color LCD. Plasma panels use pulse-width modulation (PWM) to control brightness: by varying the pulses of current flowing through the different cells thousands of times per second, the control system can increase or decrease the intensity of each subpixel color to create billions of different combinations of red, green and blue. In this way, the control system can produce most of the visible colors. Plasma displays use the same phosphors as CRTs, which accounts for the extremely accurate color reproduction when viewing television or computer video images (which use an RGB color system designed for CRT display technology).

Plasma displays should not be confused with liquid crystal displays (LCDs), another lightweight flat-screen display using very different technology. LCDs may use one or two large fluorescent lamps as a backlight source, but the different colors are controlled by LCD units, which in effect behave as gates that allow or block the passage of light from the backlight to red, green, or blue paint on the front of the LCD panel.

**Contrast ratio**

Contrast ratio is the difference between the brightest and darkest parts of an image, measured in discrete steps,
An example of a plasma display that has suffered severe burn-in from stationary text at any given moment. Generally, the higher the contrast ratio, the more realistic the image is (though the "realism" of an image depends on many factors including color accuracy, luminance linearity, and spatial linearity.) Contrast ratios for plasma displays are often advertised as high as 5,000,000:1. On the surface, this is a significant advantage of plasma over most other current display technologies, a notable exception being organic light-emitting diode. Although there are no industry-wide guidelines for reporting contrast ratio, most manufacturers follow either the ANSI standard or perform a full-on-full-off test. The ANSI standard uses a checkered test pattern whereby the darkest blacks and the lightest whites are simultaneously measured, yielding the most accurate "real-world" ratings. In contrast, a full-on-full-off test measures the ratio using a pure black screen and a pure white screen, which gives higher values but does not represent a typical viewing scenario. Some displays, using many different technologies, have some "leakage" of light, through either optical or electronic means, from lit pixels to adjacent pixels so that dark pixels that are near bright ones appear less dark than they do during a full-off display. Manufacturers can further artificially improve the reported contrast ratio by increasing the contrast and brightness settings to achieve the highest test values. However, a contrast ratio generated by this method is misleading, as content would be essentially unwatchable at such settings.

Plasma is often cited as having better (i.e. darker) black levels (and higher contrast ratios), although both plasma and LCD each have their own technological challenges.

Each cell on a plasma display has to be precharged before it is due to be illuminated (otherwise the cell would not respond quickly enough) and this precharging means the cells cannot achieve a true black, whereas an LED backlit LCD panel can actually turn off parts of the screen. Some manufacturers have worked hard to reduce the precharge and the associated background glow, to the point where black levels on modern plasmas are starting to rival CRT. With LCD technology, black pixels are generated by a light polarization method; many panels are unable to completely block the underlying backlight. However, more recent LCD panels (particularly those using white LED illumination) can compensate by automatically reducing the backlighting on darker scenes, though this method — analogous to the strategy of noise reduction on analog audio tape — obviously cannot be used in high-contrast scenes, leaving some light showing from black parts of an image with bright parts, such as (at the extreme) a solid black screen with one fine intense bright line. This is called a "halo" effect which has been almost completely minimized on newer LED backlit LCD's with local dimming. Edgelit models cannot compete with this as the light is reflected via a light funnell to distribute the light behind the panel.

Screen burn-in

Main article: Screen burn-in

Image burn-in occurs on CRTs and plasma panels when the same picture is displayed for long periods of time. This causes the phosphors to overheat, losing some of their luminosity and producing a "shadow" image that is visible with the power off. Burn-in is especially a problem on plasma panels because they run hotter than CRTs. Early plasma televisions were plagued by burn-in, making it impossible to use video games or anything else that displayed static images.

Plasma displays also exhibit another image retention issue which is sometimes confused with screen burn-in damage. In this mode, when a group of pixels are run at high brightness (when displaying white, for example) for an extended period of time, a charge build-up in the pixel structure occurs and a ghost image can be seen. However, unlike burn-in, this charge build-up is transient and self corrects after the image condition that caused the effect has been
Plasma displays were first used in PLATO computer terminals. This PLATO V model illustrates the display’s monochromatic orange glow as seen in 1988.

Plasma manufacturers have tried various ways of reducing burn-in such as using gray pillarboxes, pixel orbiters and image washing routines, but none to date have eliminated the problem and all plasma manufacturers continue to exclude burn-in from their warranties.[8][32]

Environmental impact

Plasma screens have been lagging behind CRT and LCD screens in terms of energy consumption.[33] To reduce the energy consumption, new technologies are also being found.[34] Although it can be expected that plasma screens will continue to become more energy efficient in the future, a growing problem is that people tend to keep their old TVs running and an increasing trend to escalating screen sizes.[35][36][37][38][39][40]

History

In 1936 Kálmán Tihanyi described the principle of "plasma television" and conceived the first flat-panel television system.[42]

The monochrome plasma video display was co-invented in 1964 at the University of Illinois at Urbana-Champaign by Donald Bitzer, H. Gene Slottow, and graduate student Robert Willson for the PLATO Computer System.[43] The original neon orange monochrome Digivue display panels built by glass producer Owens-Illinois were very popular in the early 1970s because they were rugged and needed neither memory nor circuitry to refresh the images. A long period of sales decline occurred in the late 1970s because semiconductor memory made CRT displays cheaper than the 2500 USD 512 x 512 PLATO plasma displays. Nonetheless, the plasma displays' relatively large screen size and 1 inch thickness made them suitable for high-profile placement in lobbies and stock exchanges.

Electrical engineering student Larry F. Weber became interested in plasma displays while studying at the University of Illinois at Urbana-Champaign in the 1960s, and pursued postgraduate work in the field under Bitzer and Slottow. His research eventually earned him 15 patents relating to plasma displays. One of his early contributions was development of the power-saving "energy recovery sustain circuit", now included in every color plasma display.[44]

Burroughs Corporation, a maker of adding machines and computers, developed the Panaplex display in the early 1970s. The Panaplex display, generically referred to as a gas-discharge or gas-plasma display,[45] uses the same technology as later plasma video displays, but began life as seven-segment display for use in adding machines. They became popular for their bright orange luminous look and found nearly ubiquitous use in cash registers, calculators, pinball machines, aircraft avionics such as radios, navigational instruments, and stormscopes; test equipment such as frequency counters and multimeters; and generally anything that previously used nixie tube or numitron displays with a high digit-count throughout the late 1970s and into the 1990s. These displays remained popular until LEDs gained popularity because of their low-current draw and module-flexibility, but are still found in some applications where their high-brightness is desired, such as pinball machines and avionics.
Pinball displays started with six- and seven-digit seven-segment displays and later evolved into 16-segment alphanumeric displays, and later into 128x32 dot-matrix displays in 1990, which are still used today.

1983

In 1983, IBM introduced a 19-inch (48 cm) orange-on-black monochrome display (model 3290 'information panel') which was able to show up to four simultaneous IBM 3270 terminal sessions. Due to heavy competition from monochrome LCD's, in 1987 IBM planned to shut down its factory in upstate New York, the largest plasma plant in the world, in favor of manufacturing mainframe computers.[44] Consequently, Larry Weber co-founded a startup company Plasmaco with Stephen Globus, as well as James Kehoe, who was the IBM plant manager, and bought the plant from IBM. Weber stayed in Urbana as CTO until 1990, then moved to upstate New York to work at Plasmaco.

1992

In 1992, Fujitsu introduced the world's first 21-inch (53 cm) full-color display. It was a hybrid, the plasma display created at the University of Illinois at Urbana-Champaign and NHK Science & Technology Research Laboratories.

1994

In 1994, Weber demonstrated color plasma technology at an industry convention in San Jose. Panasonic Corporation began a joint development project with Plasmaco, which led in 1996 to the purchase of Plasmaco, its color AC technology, and its American factory.

1997

In 1997, Fujitsu introduced the first 42-inch (107 cm) plasma display; it had 852x480 resolution and was progressively scanned.[46] Also in 1997, Philips introduced a 42-inch (107 cm) display, with 852x480 resolution. It was the only plasma to be displayed to the retail public in 4 Sears locations in the US. The price was US$14,999 and included in-home installation. Later in 1997, Pioneer started selling their first plasma television to the public, and others followed.

2006–present

In late 2006, analysts noted that LCDs overtook plasmas, particularly in the 40-inch (1.0 m) and above segment where plasma had previously gained market share.[47] Another industry trend is the consolidation of manufacturers of plasma displays, with around fifty brands available but only five manufacturers. In the first quarter of 2008 a comparison of worldwide TV sales breaks down to 22.1 million for direct-view CRT, 21.1 million for LCD, 2.8 million for Plasma, and 0.1 million for rear-projection.[48]

Until the early 2000s, plasma displays were the most popular choice for HDTV flat panel display as they had many benefits over LCDs. Beyond plasma's deeper blacks, increased contrast, faster response time, greater color spectrum, and wider viewing angle; they were also much bigger than LCDs, and it was believed that LCD technology was suited only to smaller sized televisions. However, improvements in VLSI fabrication technology have since narrowed the technological gap. The increased size, lower weight, falling prices, and often lower electrical power consumption of LCDs now make them competitive with plasma television sets.[citation needed]

Screen sizes have increased since the introduction of plasma displays. The largest plasma video display in the
world at the 2008 Consumer Electronics Show in Las Vegas, Nevada, was a 150-inch (381 cm) unit manufactured by Matsushita Electric Industrial (Panasonic) standing 6 ft (180 cm) tall by 11 ft (330 cm) wide.[49][50] At the 2010 Consumer Electronics Show in Las Vegas, Panasonic introduced their 152” 2160p 3D plasma. In 2010 Panasonic shipped 19.1 million plasma TV panels. [51]

Notable plasma display manufacturers

- Panasonic Corporation (formerly Matsushita)
- Samsung Electronics
- LG Electronics
- Gradiente
- Lanix
- ProScan
- Sanyo
- Funai

Notable manufacturers that abandoned Plasma

- Sony
- Hitachi Ltd.
- Philips
- Vizio
- Toshiba
- RCA
- NEC
- Pioneer Corporation (in March 2009 as well as television manufacturing altogether)[52]
- Fujitsu[53]

See also

- Display examples
- Large-screen television technology

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