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A. Human Eye

The human eye is a precise and sensitive optical system, which can adapt to a visual object and change according to different visual environments. The basic structure of the eye is very similar to a camera, including the lens, aperture, and film. A complete optical system projects the image onto the film, which is the retina in our eyes. In order to have a clear image, the light must be able to focus on the retina.

1. Cornea – Lens

The first element that encounters light entering the eyes is the cornea. Its function is to allow light to enter the eye freely.

2. The pupil (iris) - Aperture

After light passes through cornea, it reaches the iris. The iris serves like a camera aperture; it controls the amount of light entering the eye and the center of the hole is called the pupil. The iris is a disc-shaped element and its diameter changes according to the amount of light that enters. In a bright viewing environment, the pupil will contract and in dark viewing conditions the pupil will enlarge. This mechanism controls the amount of light entering the eye and the exposure of the retina (film). Overexposure creates an excess of light interference on the image, but underexposure will result in a very dark, indistinguishable image. Thus, the iris automatically adjusts the size of the aperture to determine the appropriate brightness.

3. Retina - Film

The retina functions like a sensor in a digital camera or film in a traditional camera. When the image passes through the lens (refractive element) and shines onto the retina, the optical image will be converted into neural signals and transmitted to the brain.
As people spend more time on computers, smartphones, tablets, and television. There is a strong correlation between the use of monitors and eyestrain. Monitors displays consist of many dots of light and the frequent flickering, blue light, contrast, brightness and color of the dots can cause the eyes discomfort. If the eyes don’t rest enough during the day, it can lead to difficulty focusing, blurred vision, eye strain, and headaches.
C. Flicker

i. What is Flicker?

In general terms the human visual system perceives flicker where there is a significant change in the brightness of light reaching the eyes during short time intervals. The frequency of these shifts between lighter and darker light is defined by the number of times per second the change occurs. At around 3 shifts per second (3Hz) the changes in brightness are very noticeable as you might expect. While the very visible flicker of 3Hz may decrease with higher frequencies, visual disturbances are still very problematic up to around 20Hz. Above 20Hz the issues decrease slowly as the frequency is increased, until around 50Hz where the flicker commonly expands into an impression of constant light to the eyes for most users. The frequency of this transition point is called the flicker-fusion threshold. This threshold may of course vary by person and can also vary in peripheral fields of vision.

Perhaps most significantly, monitor flicker has been attributed to issues with eye strain and headaches when using displays for many years. It is important to understand that monitor flicker in LCD displays is different from older CRT displays. These CRT’s refresh at a certain frequency from top to bottom as the cathode ray gun is fired across the screen, with only part of the screen illuminated at any one time.

At low refresh rates the frequency is low enough that it can produce visible flicker for and can commonly lead to issues for the user. A refresh frequency of 72Hz or above is commonly considered suitable to eliminate flicker from CRT’s for most users (TCO 92). LCD displays are not refreshed in the same way as their image is constant and updates on a pixel by pixel basis when the image requires the change. While a 60Hz refresh rate on a CRT would be considered problematic to many users when it comes to flicker, most LCD monitors are designed to work at 60Hz but they do not produce flicker in the same way. Flicker on LCD displays is still a possibility and cause for concern for users, especially those who are using the screen for long periods of time.
ii. Causes of Monitor Flicker - Pulse Width Modulation (PWM)

Perhaps the most common, yet not widely understood cause of flicker and related symptoms, is the use of Pulse Width Modulation (PWM) in desktop LCD monitors. This technology is used in the majority of desktop monitors to control backlight dimming, and has been utilized for many years. Nearly all monitors offer the user a direct control over the intensity of the backlight unit through the brightness control in the On Screen Display (OSD), in turn allowing the user to obtain a suitable luminance for their requirements. To achieve this, in simple terms, PWM is a technique used to rapidly turn the backlight unit off and on to simulate a lower perceived luminance for the user, in theory at a level which should be undetectable for the user. At the maximum brightness setting (100%) this technique is not needed and the backlight is illuminated continuously. As the brightness setting is lowered, the luminance intensity is decreased using this PWM technique. Its operation is explained in the following section. This cycling of the backlight off and on is happening all the time, not only in changing images of games and movies, but when viewing static images for general day-to-day use. Word processing, spreadsheets, email and internet browsing with their large bright backgrounds are perhaps most problematic when it comes to issues with PWM backlight techniques. PWM as a technology allows for wide adjustment ranges, helping to offer both high maximum luminance and low luminance control for those who need to use the screen in darker ambient lighting conditions. PWM has been used for many years with success and offers an established, simple circuit design making it a cost-effective and simple route for manufacturers to utilize.

PWM Operating Parameters

![PWM Diagram](image-url)
PWM cycling typically occurs at a fixed frequency, and the fraction of each cycle for which the backlight is on is called the duty cycle. By altering the duty cycle the total light output of the backlight is changed. As a user lowers the brightness setting, the duty cycle typically becomes progressively shorter, resulting in a reduced luminance. As a result, the lower the brightness setting, the longer the “off” periods are, and the more pronounced any flicker may become. PWM operating frequency determines how many times per second the backlight is cycled on and off, with lower frequencies potentially being more problematic when it comes to flickering.

**iii. Health Concerns of Flicker**

Backlight flicker may or may not be perceptible to a given user, but there are still concerns which affect many people. Flicker and the use of PWM dimming methods, even where not directly visible, have been linked to eye fatigue, eye strain, headaches, and nausea. Again, this varies significantly from person to person, but with the increased popularity of LED backlight units it appears to be more of a widespread concern and certainly now better understood in the industry.

Concerns around flicker can affect any user, but may be especially problematic for anyone using a screen for long periods at a time. Web developers, writers, students, office workers, and anyone who needs to sit in front of a screen for a long time may find they are more prone to issues associated with flicker and the use of PWM than casual users.

**iv. How to Test for PWM**

Most screens will not list whether PWM is used for backlight dimming and in many cases the manufacturer may not even know. Fortunately there are some simple tests that can be carried out to establish whether PWM is used or not. There are also some more advanced tests used in the industry to more accurately measure PWM frequencies.

Basic Visual Tests—Take a picture of your screen with a camera. This is a simple test may be able to see where PWM is used. The user can quickly perform a basic test for monitor flicker.
v. Alternative Backlight Dimming Techniques

Other options for backlight dimming do exist, although are not widely used. These include Direct Current (DC) control, which does not cycle the backlight off and on at all, but can be more complicated to implement. In some cases there is also difficulty controlling the colour in darker images and so DC backlight control is less common.

In a study conducted by Kitasato University Japan, School of Allied Health Sciences, it was established that DC resulted in the lowest levels of flicker and eye fatigue, and was overall easiest to view for prolonged working conditions.

<table>
<thead>
<tr>
<th>Backlight Dimming Technique</th>
<th>Pulse Width Modulation (PWM)</th>
<th>Direct Current (DC)</th>
</tr>
</thead>
</table>
| **Pros**                    | • Wide adjustment range for monitor brightness/luminance  
• Simple and cost-effective circuit design  
• Established technique used for many years | • No flicker |
| **Cons**                    | • Possible visible flicker for the user  
• Associated health concerns including eye fatigue, headaches, nausea  
• Even where flicker isn’t directly visibly to the user, PWM may adversely affect the user | • Complicated circuitry  
• Not widely used and less established than PWM for backlight dimming  
• Trouble controlling colour in darker images in some cases |
vi. BenQ Flicker-free Monitor Range

With the increased focus and awareness of monitor flicker and the associated medical concerns, BenQ has introduced a range of flicker-free monitors. These monitors are designed to address user concerns around eye fatigue and other health issues associated with flickering displays. They are based on a Direct Current backlight system where Pulse Width Modulation is not used. As a result, the main cause of monitor flicker is eliminated, making the flicker-free range suitable for even the most demanding users.

Each horizontal grid represents a 20ms period in this scale

**Brightness Setting = 100%**
The straight line indicates a constant backlight illumination at maximum brightness setting as normal.

**Brightness Setting = 50%**
When reduced to 50% brightness, the straight line confirms no PWM is being used, and the backlight is not being cycled on or off.

**Brightness Setting = 0%**
Even at the lowest backlight setting, PWM is not used and the illumination is constant.
D. Blue light

i. What is Blue Light?

Light can be divided into visible light and invisible light. The part that can be perceived by the human eye is called visible light, and comprises wavelength from 420 nm to 780 nm. The colors we usually see, for example, red, orange, yellow, green, turquoise, blue, and violet, all belong to the visible light spectrum. Light having a wavelength longer than 780 nm is called infrared light, and wavelength shorter than 420 nm is called ultraviolet light (UV).

Recent studies have shown that UV light may damage biological tissues, including skin and eyes. People now understand that using sun block products can prevent skin damage. While it is highly unlikely for humans to stare directly at sun light (UV) or infrared light under normal circumstances, chances for infrared light and ultraviolet light damage to eyes are generally quite slim. However, visible blue light is allowed to enter the retina. We can separate visible blue light into two groups - short wavelength blue light (420 nm to 455 nm) and long wavelength blue light (455 nm to 480 nm).

ii. Effects of Blue Light

1. Short wavelength blue light may cause vision problems

Studies have shown that short wavelength blue light from 420 to 455nm (near ultraviolet range), is considered a potential hazard to the retina and can lead to vision-related problems such as eyestrain and blurred vision. Long-term exposure may contribute to eye-related diseases such as macular disease (AMD) and cataracts.

2. Long wavelength blue light can boost attention, and reaction efficiency

Studies have proven that long wavelength blue light (455-480nm) is beneficial to humans during daytime hours because it can boost attention, shorten reaction times, and positively affect the mood control centers of the brain.
iii. BenQ New Backlight Module

The LED screens currently on the market use WLED (White LED) backlighting. The working principle of WLED is to use emissions from a blue chip to excite yellow phosphor on chip to produce white light. However, emissions from the blue chip become short wavelength blue light and may cause vision problems after prolonged usage. BenQ Low Blue Light Plus technology utilizes a specially designed blue chip to avoid short wavelength blue light, preventing potential vision problems and providing ultimate image quality.

iv. BenQ Low Blue Light Plus Technology

BenQ Low Blue Light Plus Technology filters out short wavelength blue light (420 nm ~ 455 nm) emission while retaining the long wavelength blue light (455 nm ~ 480 nm), allowing users to experience the ultimate color reproduction with undistorted colors, high sharpness, and contrast.
E. Inconsistent Lighting

1. Why Inconsistent Lighting can Damage Eyes?

Shadows and reflections produced by ambient light combined with uneven light from the monitor can cause eyestrain. For example, when using the monitor beside a bright window, eyes will need to work harder to avoid the glare caused by the reflection, resulting in eyestrain. Additionally, strong differences in ambient light and the light from the display can cause eyestrain. For example, if the user has a very bright display in a dimly lit room, his or her eyes need to use more energy to focus. Or, when switching from dark to bright scenes on screen, our eyes need to constantly adjust the pupils to accommodate the brightness difference, which can also cause eyestrain, headaches and blurred vision.

2. BenQ Brightness Intelligence Technology

Brightness Intelligence Technology detects the amount of ambient light in the viewing environment and automatically adjusts the brightness for the most comfortable viewing experience possible. Brightness Intelligence Technology also utilizes BenQ Luminance Engine and Color Engine which detect the intensity of the content and adjust the image to ensure that bright scenes don’t get overexposed and dark areas automatically adjust to maintain a visible level of contrast, helping to reduce eyestrain.
i. Ambient Light sensor

When on-screen brightness matches the brightness of ambient light, the eyes don't have to constantly adapt to the difference between dark and light areas. Brightness Intelligence Technology utilizes the Ambient Light Sensor to detect the amount of ambient light in the viewing environment and automatically adjusts display brightness to the most suitable levels.

Without Ambient Light Sensor Control

![Images showing the difference in brightness without ambient light sensor control]

Light Environment

Dark Environment

With Ambient Light Sensor Control

![Images showing the difference in brightness with ambient light sensor control]

Light Environment

Dark Environment
The exclusive algorithm in Brightness Intelligence Technology calculates the appropriate screen brightness for ambient light conditions in real time. As shown in the following diagrams, X-axis represents the ambient light brightness level, Y-axis represents the screen brightness, X1 corresponds to Y1, X2 corresponds to Y2... and so on. There is a corresponding Y value for every X value, and through unique firmware adjustment, the transition will be smooth and gradual. There will be no flicker ensuring users enjoy smooth transitions.

General Light sensor

Ambient Light

Brightness Intelligence Technology

Ambient Light

*Previous generation of Eye Protection function only offers seven kinds of brightness setting for ambient light. New Brightness Intelligence Technology offers more fine adjustment and provides better response (in terms of screen brightness) to different ambient lighting conditions.
ii. BenQ Luminance Engine

The BenQ Luminance Engine provides the best dynamic adjustment from dark to light and light to dark. The details in dark areas will be revealed without overexposing the details in bright areas. BenQ Luminance Engine sets up a smooth transition curve using multiple corresponding points across different gray level values. Therefore, Brightness Intelligence Technology can provide not only the best screen brightness optimization, but also the best dark to light and light to dark transition adjustments.

*BenQ Luminance Engine will provide dynamic brightness adjustment heaps of times for different content in real time.*
iii. BenQ Color Engine

The BenQ Color Engine utilizes six-axis color adjustment technology that allows the hue and saturation to be adjusted independently. With this technology, color reproduction is enhanced and extremely fine intermediate shades of colors can be accurately produced on the display. When the screen brightness is dimmed on a traditional monitor, original colors can become distorted, but with BenQ Color Engine, original colors are retained more often.
The color map below consists of all the colors the human eye can see and can be divided into 6 color shades: Red, Green, Blue, Yellow, Cyan, and Magenta. BenQ Color Engine allows each color to be enhanced in saturation and hue independently without affecting other colors to improve color accuracy and provide more vivid color.

BenQ Color Engine adjusts colors in a three-dimensional fashion. In the following diagram, Angle θ represents the hue angle between two colors. There are two examples shown in the following:
1. Moving from A to A': Enhanced Color Saturation. Green will become more vivid.
2. Moving from A to B: The green hue will move closer to yellow to show a more like yellowish green. This will result in more intermediate shades of between green and yellow.