

1-7-1: What is LCD Flicker?

When an LCD panel is displaying a net or checkerboard pattern image, (such as when shutting down Windows), the screen may seem to shimmer and become extremely hard to view. This shimmering is called "LCD flicker" (hereafter referred to as "flicker"). The mechanism by which flicker occurs is explained in the next section

1-7-1-1: How Flicker Occurs

It is known that continuously supplying a DC image signal to a liquid crystal display device shortens the life of the LCD panel. In addition, LCD devices respond to negative voltages as well as positive voltages. Because of this, generally the polarity of the image signal input to a liquid crystal device is reversed every frame (vertical synchronization period).

Let's consider the case where the same image is displayed on the screen continuously. For the image of each frame, the reference voltage must be equal to the center of amplitude of the image signal, as shown in Figure 1-7-1. However, if the position of the reference voltage is shifted as in Figure 1-7-2, the positive and negative components of the image signal become different. As a result of this, the image signal changes at a frequency equal to $1/2$ the frame rate frequency.

For example, if the vertical synchronization frequency is 60Hz, the image signal changes at the frequency of 30Hz. Since this is below the perception threshold frequency for humans, humans perceive shimmering.

If flicker occurs on an LCD, it is extremely annoying to view. In general, the reference voltage of LCD panels is adjusted during the manufacturing process.

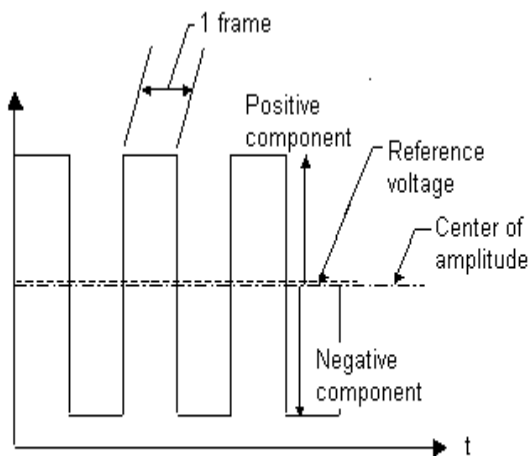


Figure 1-7-1: Frame image signal level and reference voltage (ideal condition)

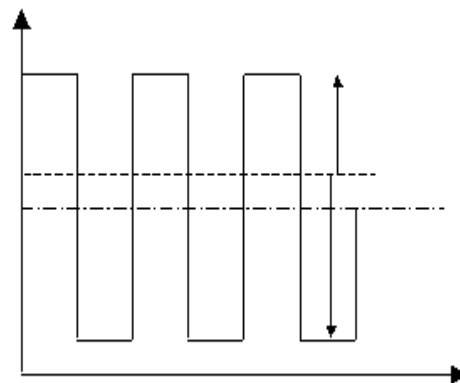


Figure 1-7-2: Frame image signal level and reference voltage (when flicker occurs)

1-7-1-2: LCD Drive Systems and Images Likely to Cause Flicker

Recently, in order to increase the uniformity of the image display, liquid crystal drive elements which receive the signal input to the LCD device and invert the polarity of the signal for each pixel have been developed and are being used in LCD panels.

There are two types of these inverting drive systems:

Line inversion drive system: The signal polarity is inverted for alternate horizontal lines. This system is currently used in a lot of small LCD panels.

Dot inversion drive system: The signal polarity is inverted for alternate pixels in a horizontal line. If the pixels in a given horizontal line had the polarities positive, negative, positive,, then the pixels in the next line would have the polarities negative, positive, negative, ... (checkerboard pattern). This system is currently used in a lot of large-size LCD panels.

If a uniform image fills the entire screen, on an LCD panel using these pixel inversion systems, flicker resulting from the shift in reference voltage described above would occur for the inverted alternate horizontal lines or alternate pixels. In this case, the averaging effect of the human eye results in almost no flicker being perceived.

However, now let's consider the case of a dot-inversion LCD panel displaying a checkerboard pattern (as shown in Figure 1-7-3) where alternating pixels are switched on and off repeatedly. In this case, the pixels which are lit receive the same signal polarity during a given frame period, making inversion of each pixel more likely to occur and causing the entire image to be perceived as flickering.

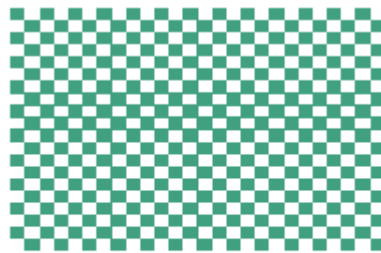


Figure 1-7-3: Example of image likely to cause flicker (checkerboard pattern)

In the same way, for a line-inversion LCD panel displaying an image of horizontal bars like that shown in Figure 1-7-4, the entire image will be perceived as flickering.



Figure 1-7-4: Example of image likely to cause flicker (horizontal line pattern)

At the beginning of this discussion, we said that the image shown when Windows is shutting down is likely to cause flicker. This is because the image is a checkerboard pattern.

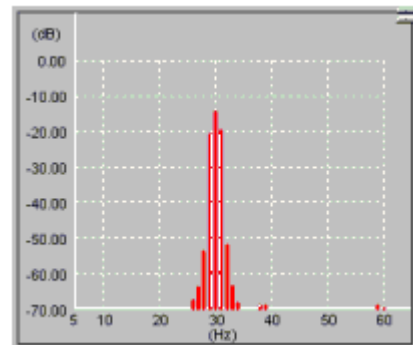
1-7-1-3: Flicker Measurement Examples

Large amount of flicker

JEITA measurement value: -14.5dB

AC/DC measurement value: 68.4%

Measurement AVI file: F_Big.avi

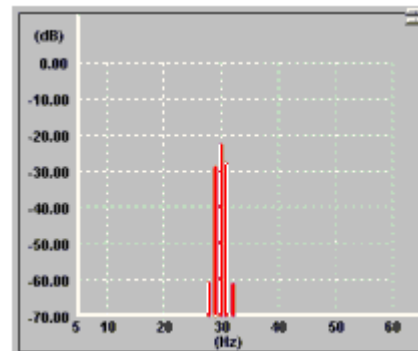


Medium amount of flicker

JEITA measurement value: -22.7dB

AC/DC measurement value: 27.8%

Measurement AVI file: F_Medium.avi

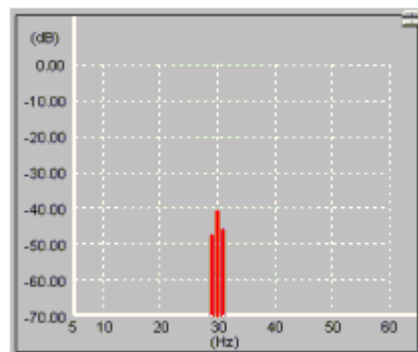


Small amount of flicker

JEITA measurement value: -40.9dB

AC/DC measurement value: 2.7%

Measurement AVI file: F_Small.avi



Note: Microsoft Media Player is necessary to play the measurement AVI files. Media Player is a registered trademark of Microsoft Corp.

Reference:

Takawa, Mikiyu, Display Monthly Vol. 8, No. 6 (June 2002): 51

1-7-2-1: Flicker Measurement

Figure 1-7-5 shows the relationship between luminance and time when flicker occurs. As can be seen in this figure, the luminance changes cyclically; it is clearly recognized that the higher the amplitude of this cycle, the greater the apparent flickering.

In addition, the period of this luminance fluctuation is the same as twice that of the vertical synchronization signal of the display. (See [1-7-1: What is LCD Flicker?](#))

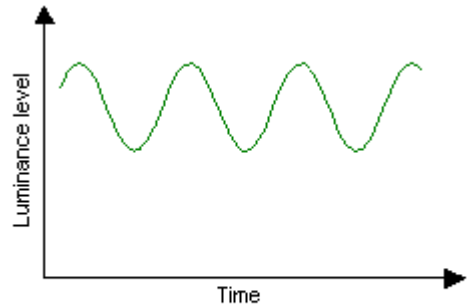


Figure 1-7-5: Luminance level vs. time when flicker occurs

The methods for measuring flicker can be broadly classified into the following two methods:

- 1 Measure the DC and AC components of the luminance fluctuation and determine flicker from the ratio between the two components.
- 2 Analyze the frequency component of the luminance fluctuation and determine flicker from the ratio between the DC component and the maximum AC component at any frequency.

The CA-210 LCD Flicker Measuring Probe can measure flicker using either the contrast method for method (1) or the JEITA method for method (2).

The characteristics of each method are shown in Table 1. The method to be used should be decided according to the measurement purpose. In general, the contrast method is suitable for adjustment and inspection during the manufacture of LCD panels, and the JEITA method is suitable for use in the development and design of LCD panels.

	Contrast Method	JEITA method
Measurement speed	Fast measurement speed (16 times/sec.)	Slow measurement speed (0.5 times/sec.)
Performance features	The relative maximum and minimum of the flicker can be understood. The frequency response characteristics of the human eye are not taken into consideration	The absolute value of the flicker can be understood. The frequency response characteristics of the human eye are taken into consideration.

Table 1-7-1: Characteristics of flicker measurement methods

Both methods will be explained in this section.

1-7-2-2-1: Overview of Flicker Measurement by Contrast Method

When the luminance level of a display fluctuates as shown in Figure 1-7-6, it can be thought of as an AC component added to a DC component. This flicker amount defined as (AC component)/(DC component) is called the "contrast method flicker value" (referred to hereafter as the "contrast flicker value").

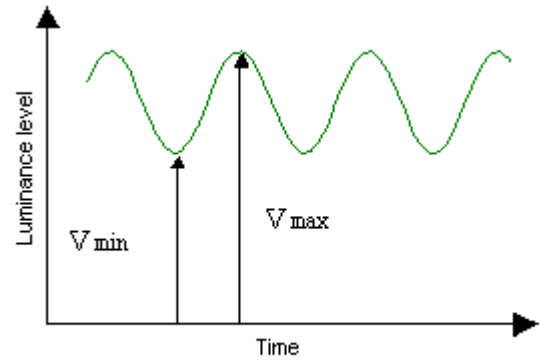


Figure 1-7-6: Vmax, Vmin for Contrast Method

In the contrast method, since the AC component and DC component are defined as:

$$\text{AC component} = V_{\max} - V_{\min}$$

$$\text{DC component} = (V_{\max} + V_{\min})/2$$

the flicker value can be calculated using Equation 1 below:

$$\begin{aligned} \text{Flicker value} &= \frac{(\text{AC component})}{(\text{DC component})} \times 100[\%] \\ &= \frac{(V_{\max} - V_{\min})}{\{(V_{\max} + V_{\min})/2\}} \times 100[\%] \end{aligned}$$

(1-7-1)

1-7-2-2-2: Data Processing for Contrast Method (Details)

The flow of processes which take place inside the instrument from the time the sensor data output is obtained until the flicker value has been calculated will be explained using Figure 1-7-7 below.

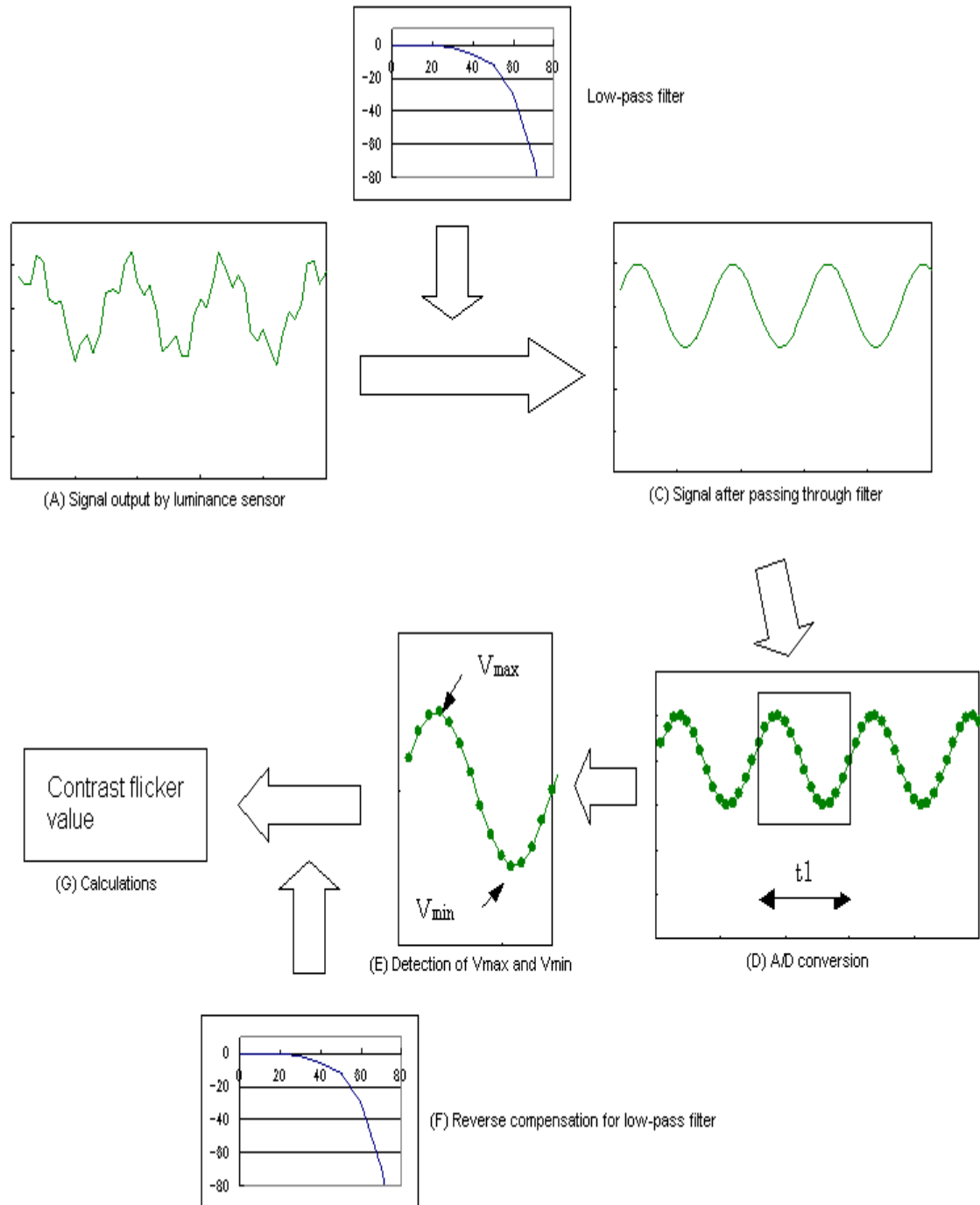


Figure 1-7-7: Flow of processes from luminance sensor output to calculation of flicker value by Contrast Method

(A) to (C) The output signal from the luminance sensor is electrically processed to remove the high-frequency components to obtain the signal to be used for calculating flicker.

(C) to (D) A/D conversion is performed for a specified time (t_1) on the analog signal obtained after removing the high-frequency components to obtain the digital data required for calculations (indicated by $\bullet$ in (D)).

(D) to (E) The maximum and minimum values in the digital data are determined and set as V_{max} and V_{min} respectively.

(E) to (G) These values are then used to calculate the (AC component)/(DC component) ratio and the flicker value according to Equation 1. During the calculation of the AC component, compensation for the reduction which occurred during processing

by the low-pass filter is performed according to the frequency of the AC component.

1-7-2-2-3: Differences from the VESA Standard Contrast Method (Details)

VESA 305-5 specifies a method for measuring flicker based on the ratio between the AC component and the DC component. This section will explain the differences between the VESA specified contrast flicker method and the contrast flicker method used by the CA-210 LCD Flicker Measuring Probe.

Put simply, the VESA standard reflects the frequency response characteristics of the human eye, and the CA-210 LCD Flicker Measuring Probe does not reflect such characteristics in order to provide high-speed measurements.

The VESA standard defines two equations for calculating the flicker value: (Note 1-7-1)

$$\frac{(V_{\max} - V_{\min})}{V_{\max}} \times 100[\%] \quad (1-7-2)$$

$$\frac{(V_{\max} - V_{\min})}{\{(V_{\max} + V_{\min})/2\}} \times 100[\%] \quad (1-7-3)$$

The Vmax and Vmin values defined here include the influence of the frequency response characteristics of the human eye (Note 1-7-2). Further, Equation 1-7-3 is intended for use when the flicker value is small (13% or lower).

To be more specific, in order to obtain the Vmax and Vmin used here, the sensor output signals are processed by a low-pass filter having the frequency response characteristics of the human eye, and the maximum and minimum values of those processed signals are determined.

The frequency response characteristics of the human eye are shown in Figure 1-7-8 and Table 1-7-2.

The contrast flicker calculations used by the CA-210 system are the same as Equation 1-7-3, but the CA-210 LCD Flicker Measuring Probe does not include the influence of the spectral response of the human eye.

However, the flicker frequency is 1/2 the vertical synchronization frequency of the LCD (see 1-7-1: What is LCD Flicker?). The frequency of the AC component f0 can be determined from the vertical synchronization frequency of the LCD. On the other hand, the reduction ratio of f0 can be calculated using Table 1-7-2. Therefore, the flicker value conforming to the VESA standard can be calculated from the contrast flicker value.

For example, if the vertical synchronization signal is 60Hz and the contrast flicker value is 10.0%, then the AC component of the flicker would be

$$60 \times (1/2) = 30[\text{Hz}]$$

The reduction ratio for the AC component due to the frequency response characteristics of the human eye (from Table 2) would be 0.708. Therefore, the flicker value conforming to the VESA standard would be

$$10 \times 0.708 \approx 7.1[\%]$$

Notes

Note 1-7-1:

Equation 3 is actually written

$$\frac{(V_{\max} - V_{\min})}{V_{\text{dc}}} \times 100[\%]$$

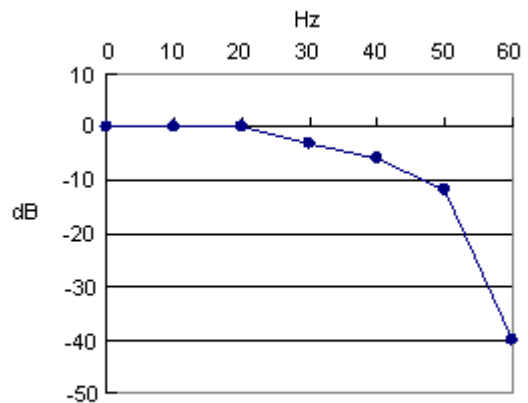


Figure 1-7-8: Spectral response characteristics of the human eye

Frequency (Hz)	Factor	
	dB	Ratio
0	0	1.000
10	0	1.000
20	0	1.000
30	-3	0.708
40	-6	0.501
50	-12	0.251
60	-40	0.010

Table 1-7-2: Frequency response characteristics of the human eye

Here, we are using

$$V_{dc} = (V_{max} + V_{min})/2$$

Note 1-7-2:

The human perception of a flashing light. The characteristic of the human eye to have a sensitivity to flashing light which decreases gradually as frequency increases from around 30Hz; at over 60Hz, the flashing is no longer perceptible to the eye.

1-7-2-3-1: Overview of Flicker Measurement by JEITA Method

The JEITA method of flicker measurement is a method for quantifying the flicker value while accurately reflecting the frequency response characteristics of the human eye.

When the luminance level of a display is fluctuating as shown in Figure 1-7-6, the flicker light can be considered to be several frequency components added to a DC component. Therefore, first, the luminance fluctuation data over time is separated into its frequency components (DC component and each AC component; [Note 1-7-3](#)). Next, each frequency component is converted into a value which takes into consideration the frequency characteristics of the human eye.

Of the various frequency components obtained, the power spectrum of the component other than the 0Hz (DC) component with the maximum power spectrum is set as P_x and the power spectrum of the DC component is set as P_0 and Equation 4 below is used to determine the flicker value (referred to hereafter as the JEITA flicker value).

$$\text{Flicker value} = 10 \times \log_{10} (P_x / P_0) \quad (1-7-4)$$

Notes

Note 1-7-3:

Under the condition that the flicker component is only the component at a frequency of 1/2 the vertical synchronization frequency. If this condition is not satisfied and other frequency components are included, those other frequency components will be a source of measurement error.

1-7-2-3-2: Data Processing for JEITA Method (Details)

Figure 1-7-10 shows an example of the flow of processes which take place inside the instrument up to the calculation and output of the JEITA flicker value. For this example, the light source to be measured will be as shown as (4) in Figure 1-7-9; it is a combination of the 3 types of light sources shown as (1), (2), and (3) in Figure 1-7-9.

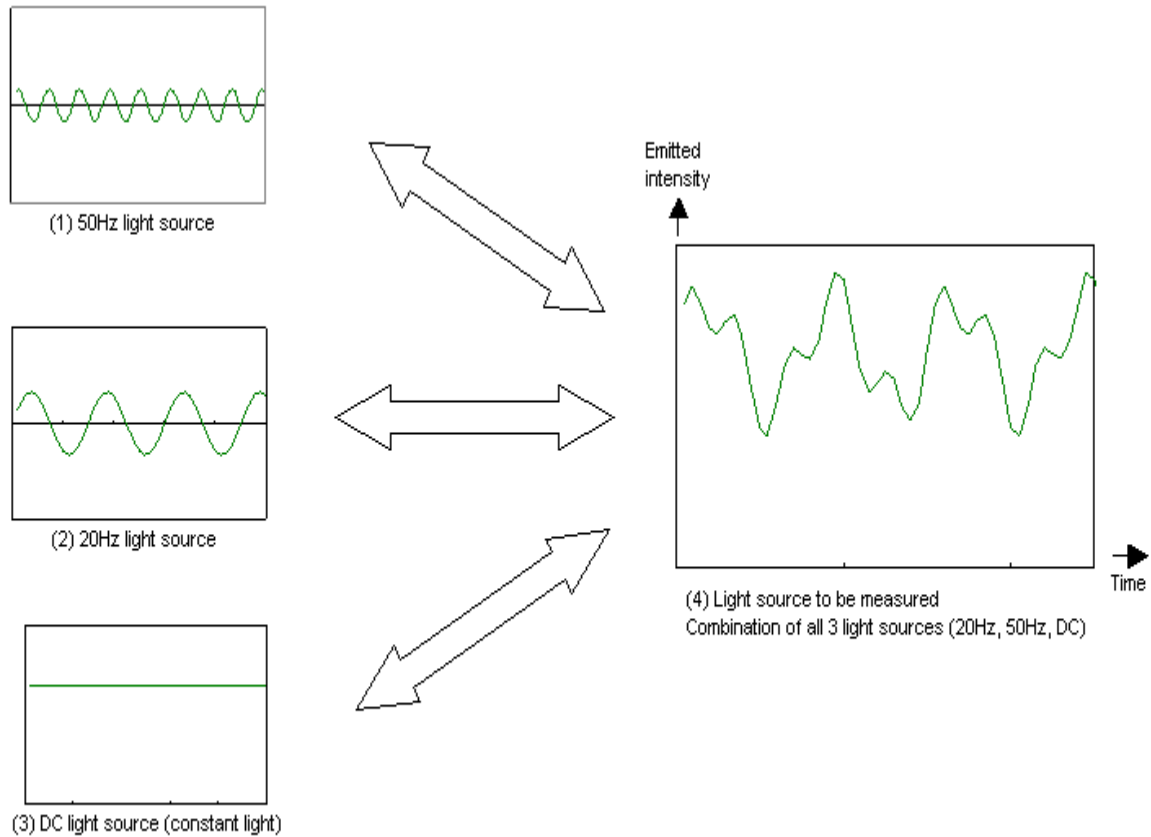


Figure 1-7-9: Light source to be measured

(A) A/D conversion is performed repeatedly over a specified time (t_2) on the output signal of the sensor to obtain the digital data required for calculations (indicated by • in (A)). (Note 1-7-4)

(A) to (B) The digital values obtained are passed through a Fourier transform and separated into the individual frequency components. In other words, since the light source to be measured is a combination of the 3 light sources (1), (2), and (3) as shown in Figure 1-7-9, separation into the individual frequency components means obtaining the frequency and amplitude value of light sources (1), (2), and (3). The data obtained would be as shown in (B).

Further, in order to reduce error due to the characteristics of the digital Fourier transform, the appropriate window function process is applied to these digital data. (Note 1-7-5)

(B) to (D) These frequency components are then processed by an integrator to reflect the frequency response characteristics of the human eye as shown in (C) and in Table 1-7-2. As can be understood from Table 1-7-2, the 0Hz (DC) and 20Hz components are not reduced at all, but the 50Hz component is reduced to 0.251 times the original value. The data obtained would be as shown in (D). (Note 1-7-6)

(D) to (E) From the data in (D), the maximum component other than the 0Hz component is selected and used as the AC component. (In this example, it would be the 20Hz component.) The 0Hz component is used as the DC component.

The power spectrums of these DC and AC components are set as P0 and P1 respectively, and the JEITA flicker value is calculated using Equation 1-7-4.

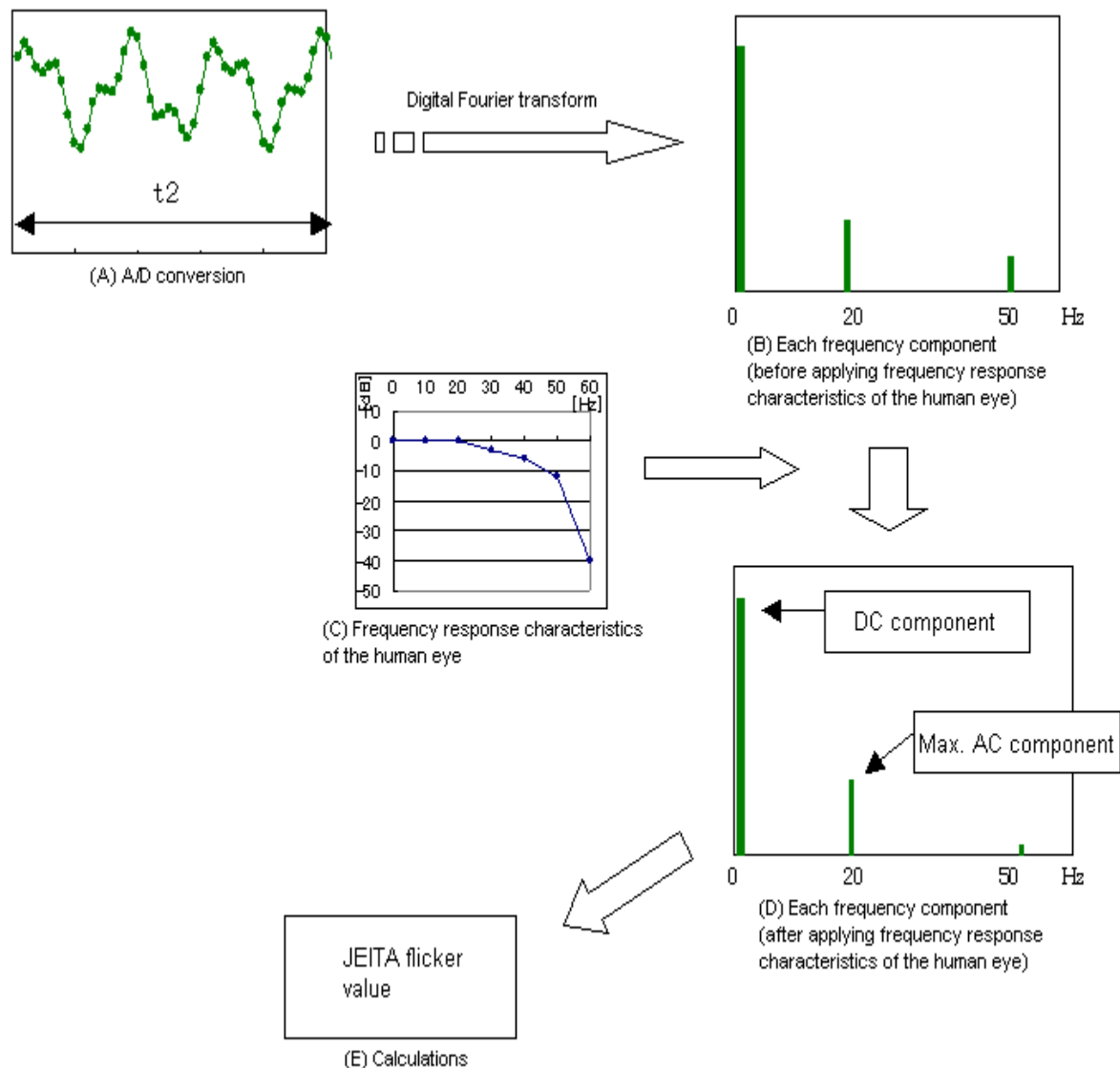


Figure 1-7-10: Flow of processes leading to the calculation of flicker value by JEITA Method

Notes

Note 1-7-4:

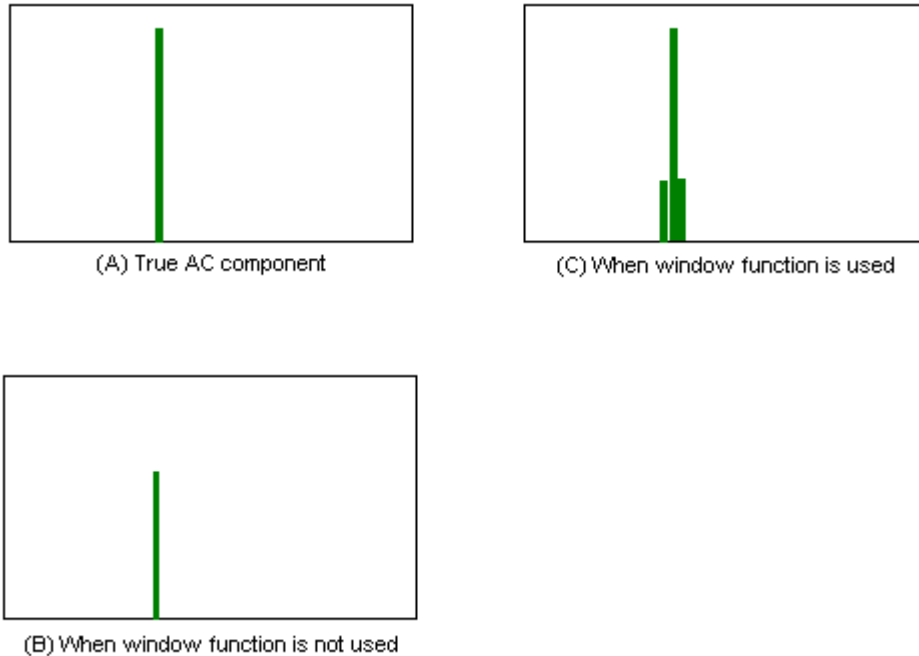
The digital values are obtained over a total sampling time of 1 sec. ($=t_2$) and a total sample count of 512 values.

Note 1-7-5:

The error due to the characteristics of the digital Fourier transform is the error caused by the fact that the digital Fourier transform is intended for use with data taken over an unlimited period of time, but in actual use the digital Fourier transform is used with data taken during a limited period of time.

There is a tendency for the error to increase as the difference between the data sampling time t_2 and an integer multiple of the frequency component period increases. A window function is generally used to reduce this error.

As a result, the frequency component detection accuracy increases, but conversely, the detection resolution decreases. For example, if there is a frequency component (for example, at 30Hz) present as shown in the figure below, if the digital Fourier transform is used without the window function, a value which is lower than the true value is calculated as shown in (B) of the figure. On the other hand, if the digital Fourier transform is used with the window function, the 30Hz component can be accurately obtained, but components to either side of the 30Hz component are also output. However, since the true value of the 30Hz component is obtained, the JEITA flicker value can be determined accurately.



Note 1-7-6:

The process of calculating flicker is performed as follows:

JEITA standard	1 Obtain measured luminance signal.
	2 Pass through integrator.
	3 Pass through FFT analyzer.
	4 Calculate power spectrum.
CA-210 LCD Flicker Measuring Probe	1 Obtain measured luminance signal.
	2 Pass through FFT analyzer.
	3 Pass through integrator.
	4 Calculate power spectrum.

The order of "Pass through integrator" and "Pass through FFT analyzer" is reversed.

However, since the data which is input to step 4 ("Calculate power spectrum") is the same in both cases, the same flicker value will be obtained from either process. In other words, equivalent data processing is being performed.

References:

VESA 305-4, 305-5

EIAJ ED-2522

Shigeo Minami, Waveform Data Processing for Optical Measurements (CQ Publishing)

Shougo Nakamura, Digital Fourier Transforms (Tokyo Institute of Electronics Publications)

1-7-2-3-2-1: Differences from Contrast Method

When the light source is like that shown as (4) in Figure 1-7-9, the contrast method uses the sensor output signal "as is" and uses the difference between the maximum and minimum values (as indicated by the arrows in the top diagram in Figure 1-7-11) as the AC component. On the other hand, in the JEITA method, since the signal is separated into its frequency components, only the maximum component (the 20Hz component in the example) is selected, and the difference between its maximum and minimum values (as indicated by the arrows in the bottom diagram in Figure 1-7-11) is used as the AC component. Another difference is that if the frequency of the maximum AC component is greater than 20Hz, the reduction ratio due to the frequency characteristics of the human eye is taken into consideration.

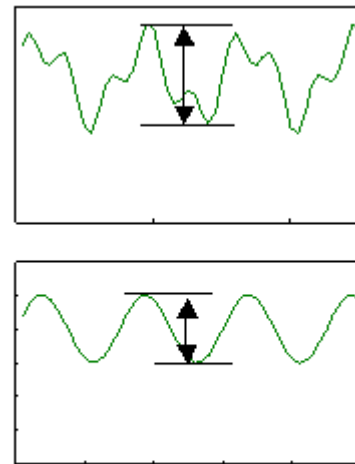


Figure 1-7-11: Difference between Contrast Method and JEITA Method

1-7-2-3-3: CA-210 Data Processing for JEITA Method (Details)

The flow of processes in the CA-210 LCD Flicker Measuring Probe from obtaining the sensor output, passing it through the digital Fourier transform process, and calculating the JEITA flicker value will be explained in the following sections.

1-7-2-3-3-1: Equation Used by CA-210 for JEITA Method

The CA-210 calculates the JEITA flicker value using the following equation:

$$20 \times \log \left(\frac{\sqrt{2} \times \text{weight}(k) \times \text{FFT}(k)}{\text{weight}(0) \times \text{FFT}(0)} \right) \quad (1-7-5)$$

where

- k: Frequency
- weight(k): Integrator constant for frequency k
- FFT(k): Maximum value of weight(k) × FFT(k) obtained from the FFT output for frequency k (k>0)
- FFT(0): FFT output for the DC component

1-7-2-3-3-2: Explanation of JEITA Method Equation

The flicker value obtained by the JEITA Flicker Method is defined by the following equation:

$$10 \times \log \left(\frac{P_x}{P_0} \right) \quad (1-7-6)$$

where

Px: Maximum power spectrum of AC component after passing through integrator

P0: Power spectrum of DC component after passing through integrator

(From EIAJ ED2522)

The relationship between ratios for the FFT output and the power spectrum for the DC component (x=1) and the AC component (x=sin(t)) is shown in the following table:

	(1) DC component (x=1)	(2) AC component (x=sin(t))
FFT output	1	0.5
Power spectrum	2	1

Table 1-7-3: Relationship between ratios for FFT output and power spectrum

For (1) and (2), they should be the same from the concept of amplitude, but the FFT outputs have the ratio 1:0.5, so by doubling only the frequency component, they can be made the same (or in other words, the FFT outputs the AC component as 1/2 the DC component).

Therefore, the correlation between the DC and AC components is:

$$\text{Amplitude of frequency component} = 2 \times \text{FFT}(k) \quad (=A_k) \quad (1-7-7)$$

$$\text{Amplitude of DC component} = \text{FFT}(0) \quad (=A_0) \quad (1-7-8)$$

When converting this to the power spectrum, since the DC component is the square of the amplitude and the AC component is 1/2 the square of the amplitude, Equation 6 becomes:

$$\begin{aligned} &= 10 \times \log \left(\frac{(2 \times wFFT(k))^2 / 2}{wFFT(0)^2} \right) \\ &= 10 \times \log \left(\frac{(\sqrt{2} \times wFFT(k))^2}{wFFT(0)^2} \right) \\ &= 20 \times \log \left(\frac{\sqrt{2} \times wFFT(k)}{wFFT(0)} \right) \end{aligned} \quad (1-7-9)$$

where

$$wFFT(k) = \text{weight}(k) \times \text{FFT}(k)$$

$$wFFT(0) = \text{weight}(0) \times \text{FFT}(0)$$

and thus we end up with Equation 5.

1-7-2-3-3: Additional Information Regarding JEITA Equation

If we think about the effective value, since we can divide only the AC value by $\sqrt{2}$ in Equation 1-7-6, we get:

$$10 \times \log \left(\frac{(A_k / \sqrt{2})^2}{A_0^2} \right) \quad (1-7-10)$$

where A_k and A_0 are the amplitudes of the AC component and DC component respectively.

If we then apply Equations 7 and 8, we get:

$$\begin{aligned} &= 10 \times \log \left(\frac{(\sqrt{2} \times wFFT(k))^2}{wFFT(0)^2} \right) \\ &= 20 \times \log \left(\frac{\sqrt{2} \times wFFT(k)}{wFFT(0)} \right) \end{aligned} \quad (1-7-11)$$

which is the same as Equation 1-7-5. In other words, Equation 1-7-5 corresponds to the effective value.

1-7-2-3-3-4: Differences from the VESA Standard

VESA 305-4 defines a flicker measurement method based on the separation of the AC component into its frequency components. In the standard, the flicker value is defined by the following equation:

$$20 \times \log \left(\frac{2 \times wFFT(k)}{wFFT(0)} \right) \quad (1-7-12)$$

(The amplitudes of the AC and DC components are just squared.)

If we compare this to Equation 5, we see that the value inside the log function is different.

In order to calculate the VESA flicker value from the JEITA flicker value, we must do the following:

$$\begin{aligned} \text{VESA flicker value} &= 20 \times \log \left(\frac{2 \times wFFT(k)}{wFFT(0)} \right) \\ &= 20 \times \log \left(\frac{\sqrt{2} \times wFFT(k)}{wFFT(0)} \right) + (20 \times \log \sqrt{2}) \\ &= (\text{JEITA flicker value}) + (20 \times \log \sqrt{2}) \end{aligned} \quad (1-7-13)$$

In other words, we can obtain the VESA flicker value by adding approximately 3.01[dB] ($=20 \times \log \sqrt{2}$) is added to the JEITA flicker value.