

High-Speed, High-Voltage Diodes for High Resolution Monitors

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1. Introduction

In today's multimedia orientated society, display devices used as man-to-machine interfaces to facilitate communication have become an indispensable part of daily life in both the public and industrial sectors. CRTs (cathode ray tubes) are the most widely used electric display devices because they provide a low cost, large screen, full-color image with high resolution, high brightness, and quick response.

The demand for large sized CRT tubes with high resolution to display high density and large capacity graphics has increased year by year, especially in the recent field of monitors, due to the popularization of CAD, computer graphics and Windows* software. Prior to the appearance of Windows 95 software, the standard size and horizontal deflection frequency of CRTs were 14 through 15 inches and about 48kHz respectively. However, since the introduction of Windows 95, the standard size and frequency have tended

* Windows is a registered trade mark of Microsoft Corporation, USA.

to increase to 17 inches and approximately 70kHz, respectively. Furthermore, demand in the monitor market for greater than 100kHz frequency and 17 through 21-inch class CRTs will increase if device costs are reduced.

In addition to personal computers, devices that can connect TVs to the internet have appeared in response to the increasing number of users who are interested in the internet. TVs larger than 20 inches in size, with horizontal deflection frequencies of 16 through 48kHz, and having the same operating frequency as standard monitors already exist and future advances are expected.

The larger size and higher resolution CRT display needs operation at higher frequency and larger current for high-voltage diode to scan larger beam with higher speed.

This paper outlines the high-speed, high-voltage diode ESJA18-08 for large screen and high resolution monitors, developed to satisfy such market requirements.

2. Applications of High-Voltage Diodes

High-voltage diodes are applied in the voltage output circuit for the horizontal deflection of a monitor display. Figure 1 shows a horizontal deflection circuit for a CRT monitor.

A horizontal deflection circuit horizontally deflects and scans the CRT beam current. The high-voltage output circuit supplies a high voltage to the CRT anode. The beam is scanned to the CRT fluorescence screen synchronizing with the horizontally deflection. The high-voltage diode is mounted in a flyback transformer (FBT) which generates the high voltage.

3. Improving The ESJA18-08 High-Speed High-Voltage Diode

3.1 Low loss, high frequency operation

In order to be able to operate the diode at high frequency, it is necessary to reduce the loss. Total loss (W_t) consists of forward loss (W_f), reverse loss (W_r), and switching loss (W_{sw}) when operating the FBT. As

Fig.1 Horizontal deflection circuit for CRT monitor

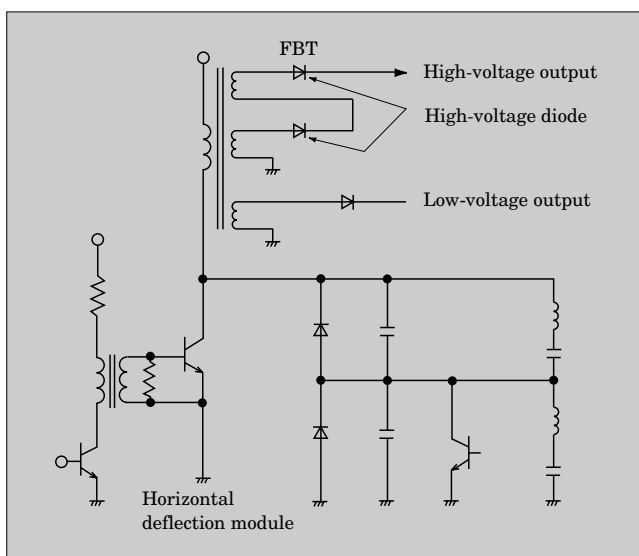
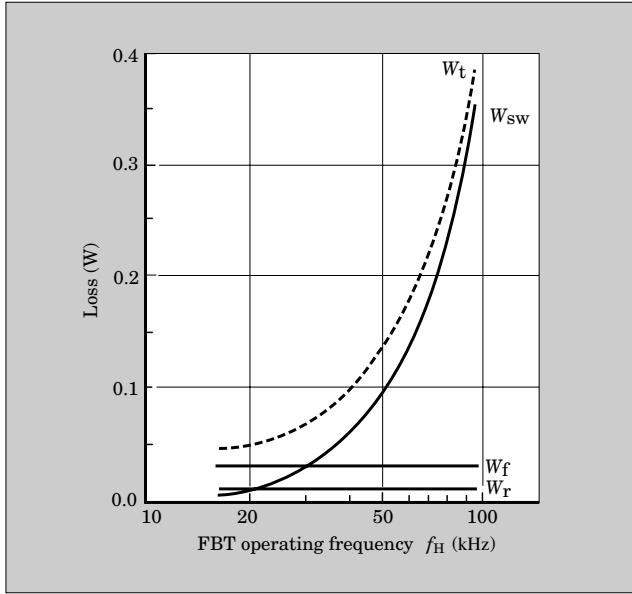


Fig.2 FBT operating frequency versus loss



shown in the graph of Fig. 2 (loss versus operating frequency), W_f and W_r remain constant, while W_{sw} increases suddenly with increasing frequencies.

Therefore, reduction of W_{sw} is crucial to enabling operation of the diode at high frequencies. The goal in developing the ESJA18-08 diode was to operate at higher than 80kHz and to reduce reverse recovery time (t_{rr}) compared to the former ESJA08-08 diode. Reverse recovery time has a trade-off in the relation between forward voltage (V_F) and reverse current (I_R). Assuming an improvement in the trade-off, the goal was to develop a new diode with V_F and I_R at the same level as the former diode.

3.2 Large reverse surge capability

The FBT structure was changed from the former slot type into a multilayer type, suitable for high frequency. In the case of multilayer type FBTs, there is a problem in applying the reverse surge voltage to the high-voltage diode when flash-over is generated in the CRT. Furthermore, today's severe price competition has created a need to lower the manufacturing cost of FBTs, and as a result, protective resistance that reduces the surge voltage of flash-over in CRTs has tended to be omitted in FBT.

Moreover, larger sized CRT screens have caused the FBT voltage output to increase. This has been accompanied by corresponding increases in generated surge voltage. Therefore, obtaining large surge capability is as important as low loss at high frequency operation in the development of higher-voltage diode. During development, a flash-over test circuit as shown in Fig. 3 was used for the simulation of flash-over in the CRT.

Usually, when flash-over is generated in a CRT that uses a layer type FBT, the structure of the secondary circuit of FBT is so that the highest reverse

Fig.3 Flash-over test circuit

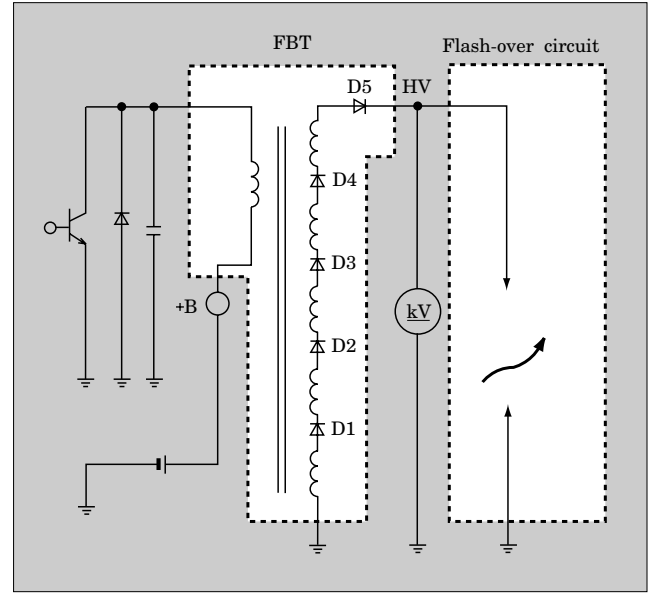
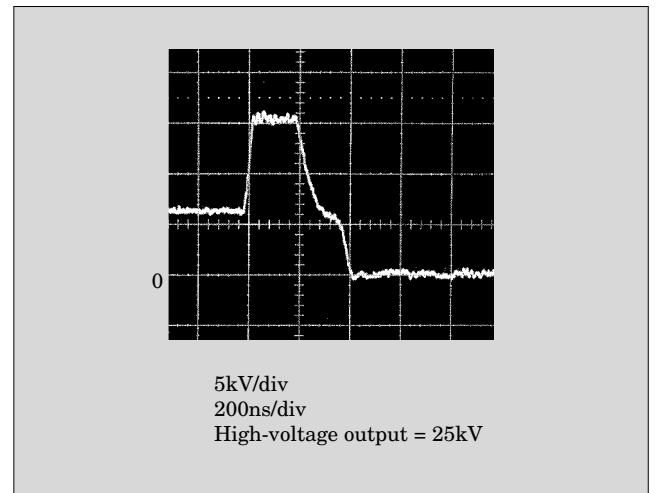


Fig.4 Waveform of flash-over obtained from high-voltage diode



surge voltage is applied to the second diode from the high-voltage output. The value of this reverse surge voltage depends on the composition and the high-voltage output of the FBT. In this case this reverse surge just under 20kVp-p was observed for a 5-layer, 5-diode type FBT (secondary windings of the FBT are wound one above the other into 5 sections with high-voltage diodes) when the output voltage was 25kV. Although it is extremely effective to use high-voltage diodes that have higher voltages than the surge voltage, in consideration of manufacturing costs, space constraints, and the applied voltage during regular operation, high-voltage diodes have 8kV of reverse voltage (V_{rm}) are normally used in layer type FBTs. Figure 4 shows a typical waveform of the diode at the secondary step ($V_{rm} > 8kV$) from the high-voltage output side during flash-over of the CRT.

It is understood that the high-voltage diode can

operate in the avalanche area because the applied surge voltage is clamped at avalanche breakdown voltage. Furthermore, since dv/dt (250kV/ μ s) of the applied reverse surge voltage is very sharp, the capability to withstand both avalanching and dv/dt is necessary for surge protection.

4. Design Goals

To achieve low loss under high frequency operation and to preserve the large reverse surge capability described in section 3.1 and 3.2, the design had the following goals.

Fig.5 Appearance of ESJA18-08 high-speed, high-voltage diodes

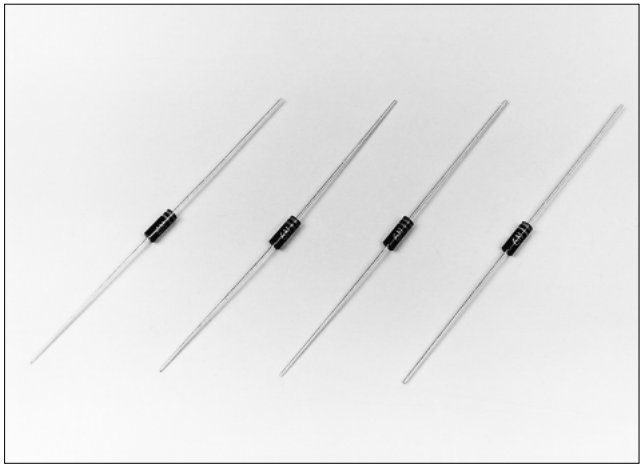


Table 1 Absolute maximum ratings of the ESJA18-08 high-speed, high-voltage diode

Item	Symbol	Rating	Units
Repetitive peak reverse voltage	V_{RM}	8	kV _{peak}
Average forward current	I_O	5	mA
Non-repetitive peak forward current (10ms)	I_{surge}	0.5	A _{peak}
(Allowable) Junction temperature	T_j	120	°C
Storage temperature range	T_{stg}	- 40 to +120	°C
(Allowable) Case temperature	T_c	100	°C

Table 2 Electric characteristics of the ESJA18-08 high-speed, high-voltage diode

Item	Symbol	Condition	Rating	Units
Forward voltage drop	V_F	$I_F=10mA$	≤ 28	V
Reverse current	I_{R1}	$V_R=8kV$	≤ 2	μA
	I_{R2}	at 100°C, $V_R=8kV$	≤ 5	μA
Reverse recovery time	t_{rr}	$I_F/I_R=2/4mA$	≤ 45	ns
Junction capacitance	C_j	$f=1MHz, V_R=0V$	≤ 2	pF

- (1) To optimize resistance and number of layers of Si chips
- (2) To redevelop the lifetime control
- (3) To optimize the base width and diffusion depths of p⁺ and n⁺ layers
- (4) To improve Si surface etching technology

Fuji Electric has developed a high-speed high-voltage diode that processes enhanced high speed switching characteristics, a low forward voltage drop, and enhanced large reverse surge capability.

An overview of the ESJA18-08 diode is presented below.

5. Overview

Figure 5 shows the appearance of the ESJA18-08 diodes. Table 1 and Table 2 list absolute maximum ratings and electric characteristics, respectively.

Fig.6 Comparison of switching waveforms

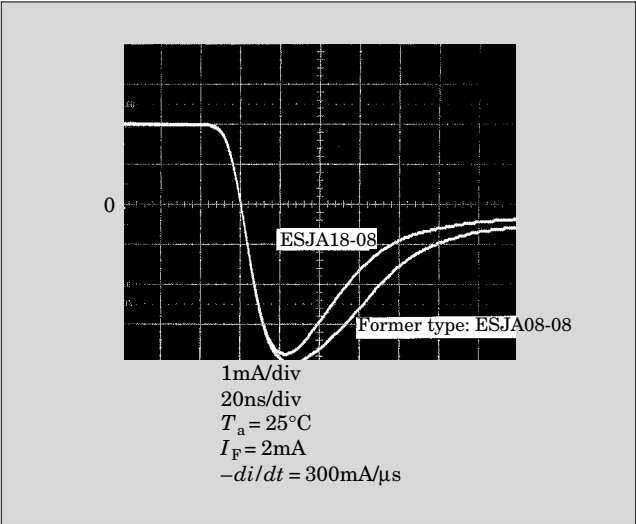


Fig.7 Temperature dependence of reverse recovery time

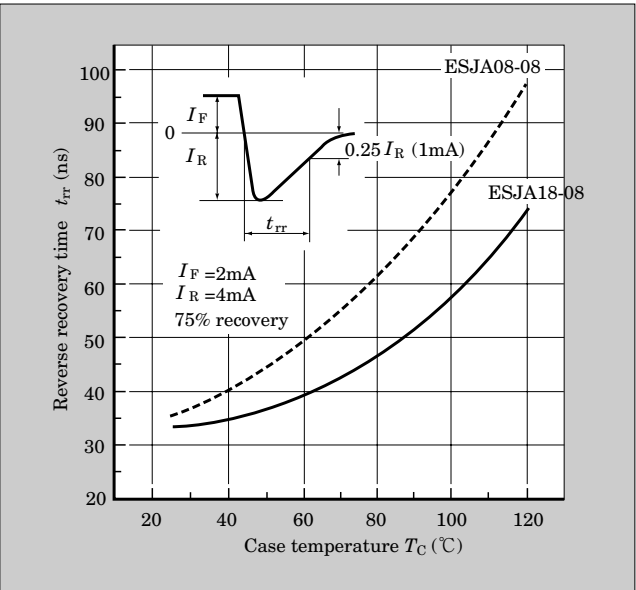
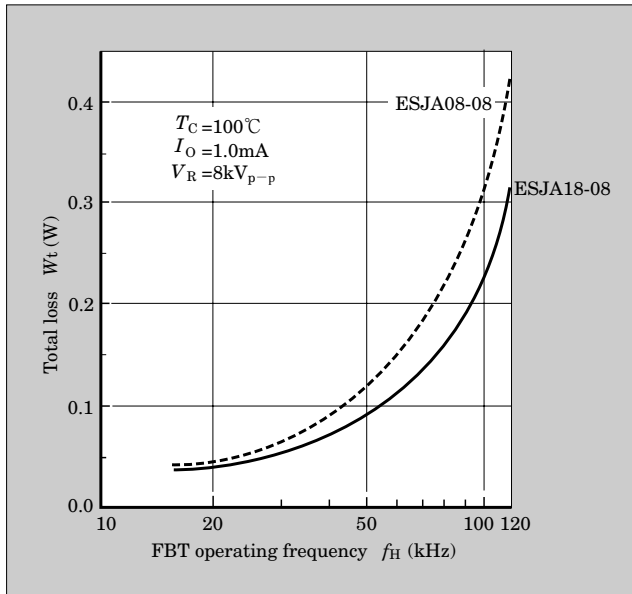


Fig.8 FBT operating frequency versus total loss



A comparison of the main characteristics of the ESJA18-08 and the former ESJA08-08 will also be presented.

5.1 Switching

Figures 6 and 7 compare the switching waveforms of the ESJA18-08 and ESJA08-08 and their temperature dependence versus reverse recovery time, respectively.

Reverse recovery time of ESJA18-08 is less than that of the ESJA08-08 in the high temperature region. Therefore, the switching characteristic of the ESJA18-08 is sharply improved. Figure 8 shows total loss versus FBT operating frequency for the ESJA18-08 and ESJA08-08. The ESJA18-08 may be operated at higher frequencies because its loss in the high frequency region is lower than that of the ESJA08-08.

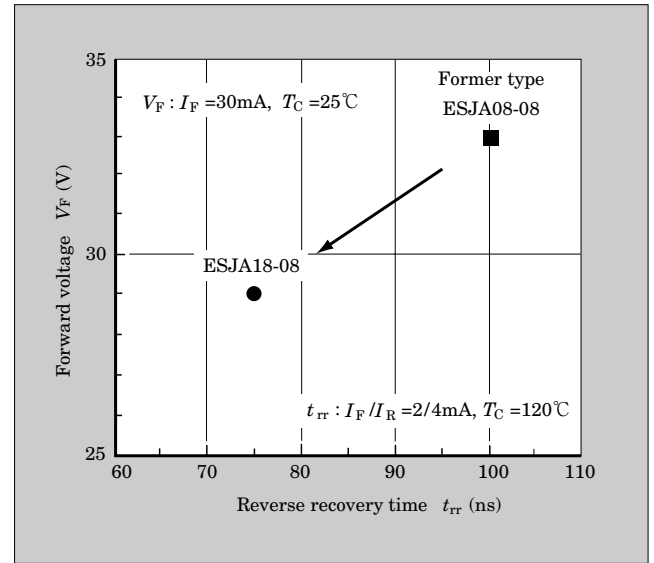
5.2 Forward voltage

Figure 9 shows reverse recovery time versus forward voltage for ESJA18-08 and ESJA08-08. As described above, there is a trade-off between forward voltage and reverse recovery time. The characteristics of this trade-off have been greatly improved.

5.3 Reverse characteristic

Due to the above improvements, avalanche breakdown voltage and reverse current at higher temperatures remain the same as those of the ESJA08-08.

Fig.9 Reverse recovery time versus forward voltage



5.4 Reverse surge voltage capability

The reverse surge voltage capability of the ESJA18-08 has been evaluated using a standard 5-layer, 5-diode type FBT (non-protecting resistance) and the aforementioned flash-over test circuit for CRTs. The result have been very favorable, with no degradation of FBT output even after more than 40,000 flash-over tests with a FBT high-voltage output of 30kV.

5.5 Summary

As described above, the ESJA18-08 diode has been developed with excellent high-speed switching characteristics, compatible with the demands for high reverse surge voltage capability required in most important market applications. The ESJA18-08 diode will also be suitable with the future technology for high resolution CRT monitors.

6. Conclusion

This paper has presented the ESJA18-08 high-speed high-voltage diode that was developed for large size and super high resolution CRT monitors. This high-speed, high-voltage diode will contribute to the development of larger sized and higher resolution CRT monitors. Based on these developed technologies, Fuji Electric will continue to provide improved devices and technology.



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