

Application Note

Fagor Electrónica Semiconductores

Fagor Electrónica Ultrafast Soft Recovery Diodes for High Speed Switching Applications

Abstract

Fagor Electrónica has developed a new series of ultrafast soft recovery diodes to meet the requirements of high frequency operation and power ratings. The best trade-off for leakage current, forward voltage drop (static parameters) and reverse recovery (dynamic parameter) have been achieved, with a typical recovery time as low as 15-20ns.

Fagor Electrónica FESx(D,G,J)ySR series reduce losses in the circuit minimizing the Electromagnetic Interferences.

SERIES NAME	PRODUCT RANGE		
	Peak Reverse Voltage VRM [V]	Output Current [A]	trr [nsg]
FESxDySR	200	1 ~ 3	< 25
FESxGySR	400	1 ~ 3	< 25
FESxJySR	600	1 ~ 3	< 50

Introduction

Ultrafast recovery rectifiers are nowadays playing a key role for high frequency applications where a fast and rugged switching performance is required. They are demanded as freewheeling and snubber components in most electronic circuits.

In order to reduce overall losses in the circuit and to prevent any failure mechanisms that might occur during the diode switching transients the most important features required for fast recovery diodes are:

1. - Low on-state voltage.
2. - Low leakage current.
3. - Low reverse recovery losses.
4. - Low noise.

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During the transition from the conduction state to the blocking state (turn-ON to turn-OFF) the current drops from I_F (Forward Current) to $I_R \approx \text{Zero}$ (Reverse Current). A change in the current polarity takes place during this process. A reverse maximum value is reached ($-I_{RM}$) (Fig.1).

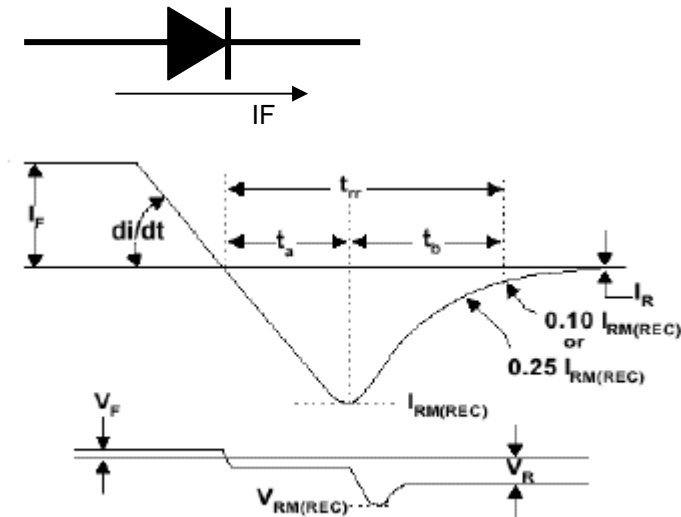


Figure 1

Because of the existence of parasitic LC in different parts of the electronic circuit, the way the I_{RM} to Zero current recovery occurs is responsible for Electromagnetic Interferences (EMI) generation.

Feature of Fagor Electrónica Ultrafast Rectifier Diodes

Fagor Electrónica Ultrafast Diodes (FESxySR series) are fabricated in a P+iN+ epitaxial structure with a top-glass junction termination (Fig.2).

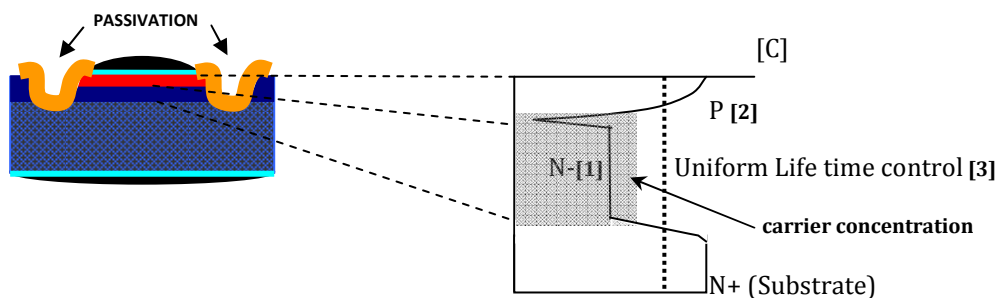


Figure 2

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Three are the design elements that play a major role in the control of the dynamic (switching) performance of the device:

- [1] Epitaxial layer thickness N_- ;
- [2] Base P concentration;
- [3] Life time killing control.

During the transition from ON-STATE to OFF-STATE a finite time is required to remove the excess of carriers before the diode will be able to block the voltage. This time is proportional to the thickness of the N- region [1] and the presence of recombination centres that are created by adding uniform lifetime killers [3]. Fagor Electrónica (FESxySR series) ultrafast diodes adopts platinum diffusion as lifetime killers because it is well established that for equal forward characteristics, the leakage current of platinum doped devices are much lower than for the gold doped devices at any temperature. Fig. 3 shows the typical "IR variation vs. temperature" curve for a **2A/200V Fagor Electrónica** ultrafast diode (FESxySR series).

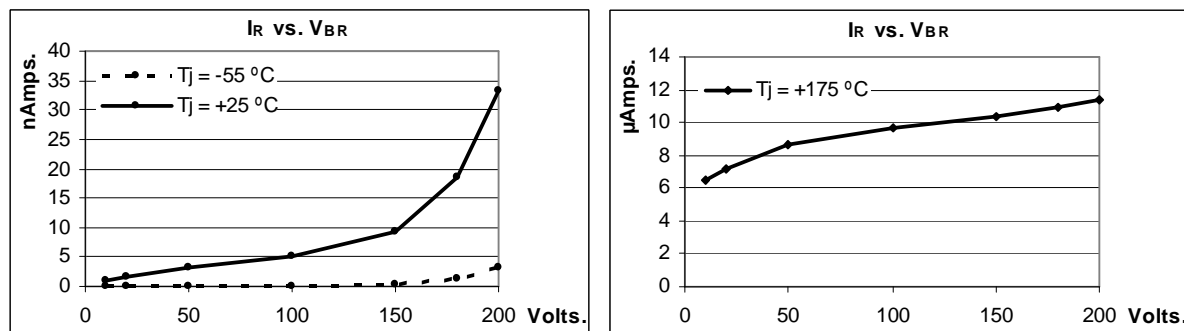


Figure 3

As long as the excess of carriers are at the end of the drift region, the PN- junction must be forward biased. Consequently the change in the voltage will be small from its conduction value (Fig.1). The shape and distribution of the stored charge in the drift region is a very important factor affecting the reverse recovery characteristics of the diode. For the control of the gradient for the excess carrier concentration the base P concentration [2] plays a major role.

At the end of "ta" time all the carriers have been removed and the junction becomes reverse biased. At this point, the diode voltage goes negative which change is proportional to dI/dt . The current will now evolve from $-IR$ to zero ("tb" time). If this dI/dt reverse recovery is large, the peak reverse **VRM(REC)** voltage is also high, causing failures when exceeding the blocking voltage capability. When the slope of the recovery is very fast or it shows a final ringing, noise immunity problems will be generated because of the emission of radio frequency.

Once the carriers have been removed, the depletion layer expands into the drift region and thus the diode is able to block the reverse voltage.

Fagor Electrónica Ultrafast Diodes (FESxySR series) have been developed integrating all the above exposed technological considerations. Figure 4 shows the reverse recovery current waveform for a **2A/200V Fagor Electrónica** diode compared to other ultra-fast conventional diodes from competitors.

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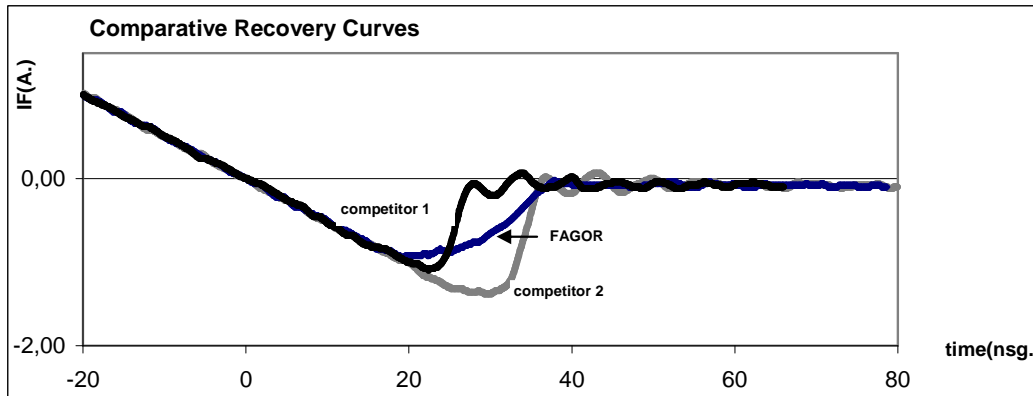


Figure 4

Fagor Electrónica diode presents a soft recovery curve with no oscillatory (ringing) behaviour.

Device Characterization

To carry out the design of any low on-state voltage, fast switching and soft recovery loss ultra-fast diode the above described technological considerations and other, are required to get the best trade-off of the electrical characteristics.

In order to select the most suitable device for the application circuit conditions, it will be necessary to understand the correlations for the more relevant electrical parameters.

Thus some experimental curves for the Fagor Electrónica Ultrafast Diodes (FESxySR series) will be presented.

ON-STATE VOLTAGE

Following illustration shows the "Forward Voltage versus trr" curve for a 2A/200V Fagor Electrónica diode.

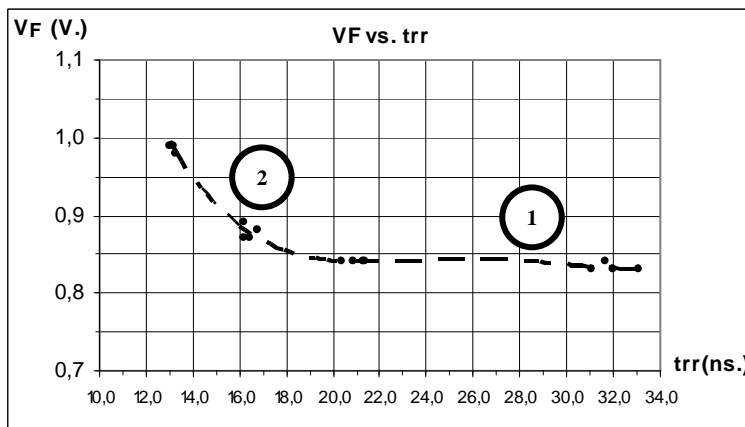


Figure 5

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As follows from the picture the “VF vs. trr” curve has two well established regimes. For high trr values (**REGIME 1**) the “VF vs. trr” relation is basically steady. As the trr value decreases it is reached a point where the “VF vs. trr” relation becomes exponential (**REGIME 2**); in such a way that the lower the trr the higher the VF.

For the (2A/200V) Fagor Electrónica Ultrafast diode this regime change takes place at a trr = 19 nsg.

REVERSE RECOVERY

The **Softness Factor (SF)** is defined as tb/ta (fig. 1). It is useful to define the softness degree of any recovery curve: the higher its value the softer the reverse recovery curve.

Following illustration shows experimental results for “**Softness Factor versus trr**”.

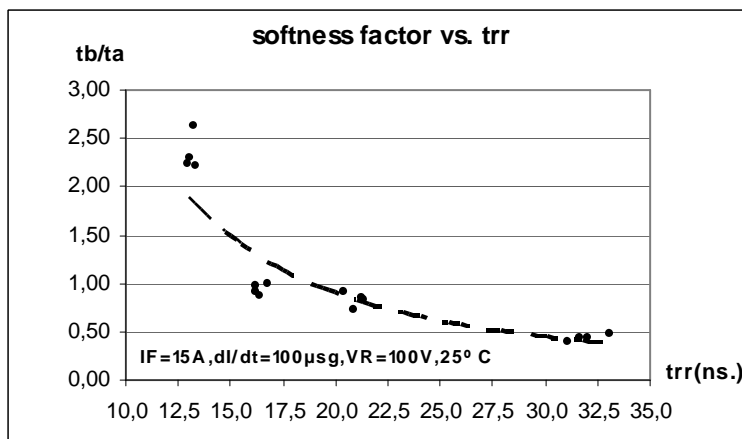
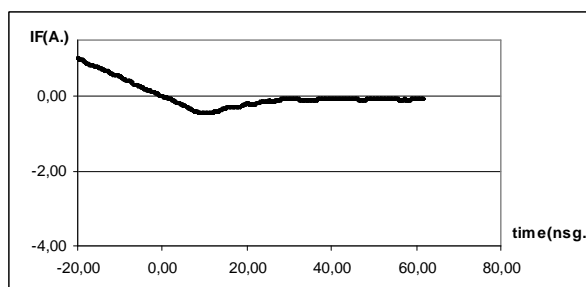


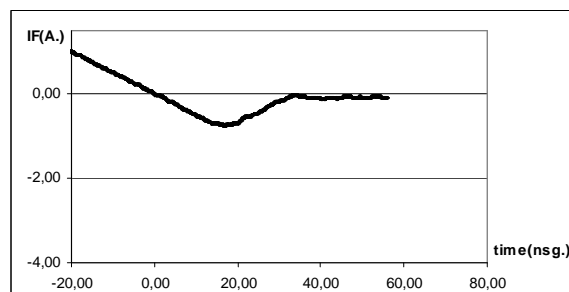
Figure 6

As the trr decreases the Softness Factor increases, indicating that the reverse recovery current will be softer.

Figure 7 collects some reverse recovery current waveforms corresponding to the numbered points from experimental curve in figure 6.



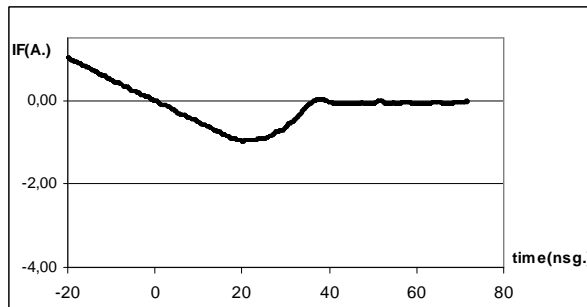
[1]. trr = 13 nsg. Softness Factor = 1.70



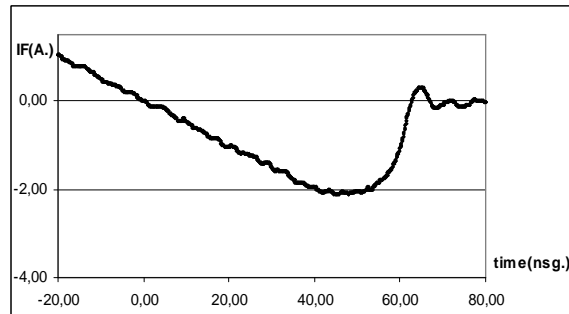
[2]. trr = 16 nsg. Softness Factor = 1.25

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[3]. $t_{rr} = 21 \text{ ns.g.}$ Softness Factor = 0.80



[4]. $t_{rr} = 24 \text{ ns.g.}$ Softness Factor = 0.65

Figure 7

TEMPERATURE CURVES

Following illustrations show the temperature dependency for both the t_{rr} and the Softness Factor.

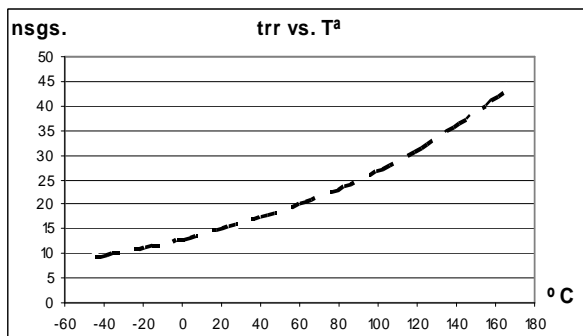


Figure 8a

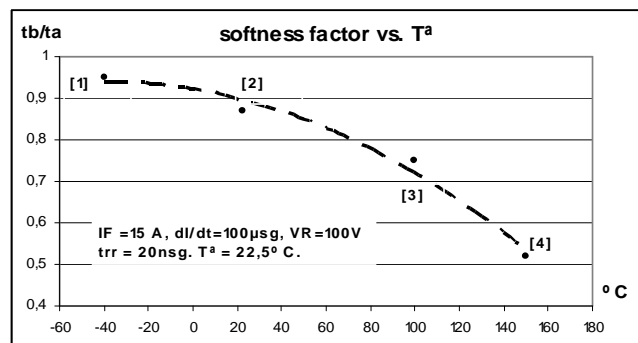
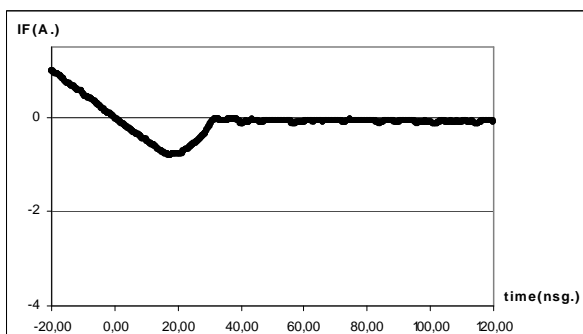


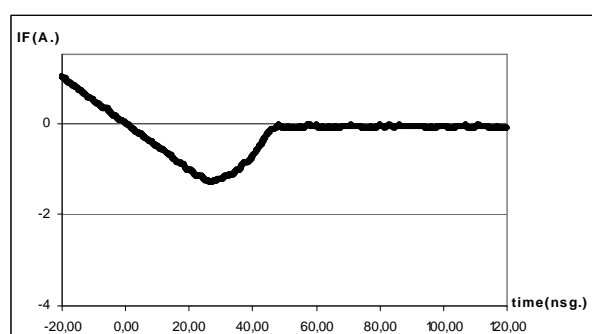
Figure 8b

The t_{rr} value increase as the temperature is increased, whereas the Softness Factor has an inverse dependency with temperature.

Figure 9 collects some reverse recovery current waveforms corresponding to the numbered points from experimental curve in figure 8b.



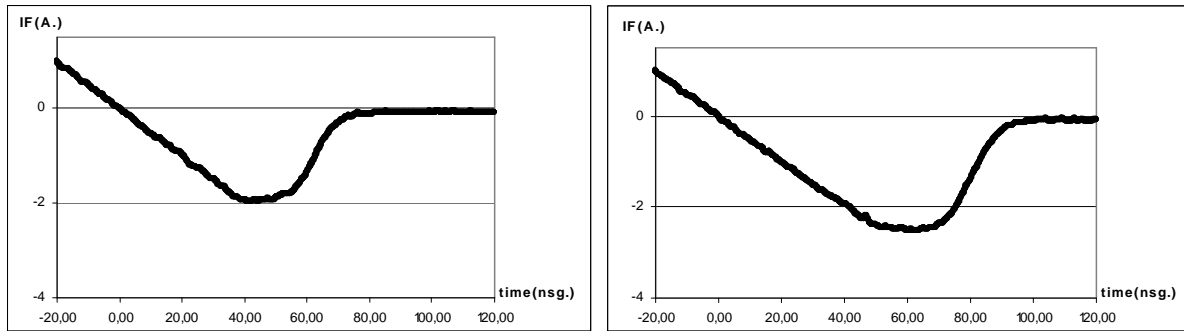
[1]. $Tª = -40° \text{ C.}$ $t_{rr} = 15 \text{ ns.g.}$ Softness Factor = 0.95



[2]. $Tª = +22.5° \text{ C.}$ $t_{rr} = 20 \text{ ns.g.}$ Softness Factor = 0.88

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[3]. $T^a = +100^{\circ}\text{C}$. $\text{trr} = 32 \text{ nsg}$. Softness Factor = 0.75

[4]. $T^a = +150^{\circ}\text{C}$. $\text{trr} = 44 \text{ nsg}$. Softness Factor = 0.53

Figure 9

It is remarkable that Fagor Electrónica (FESxySR series) ultrafast diodes are free of oscillatory behaviour at any range of operation temperature as followed from graphs above.

The forward voltage related to the temperature is graphed as follows (Figure 10).

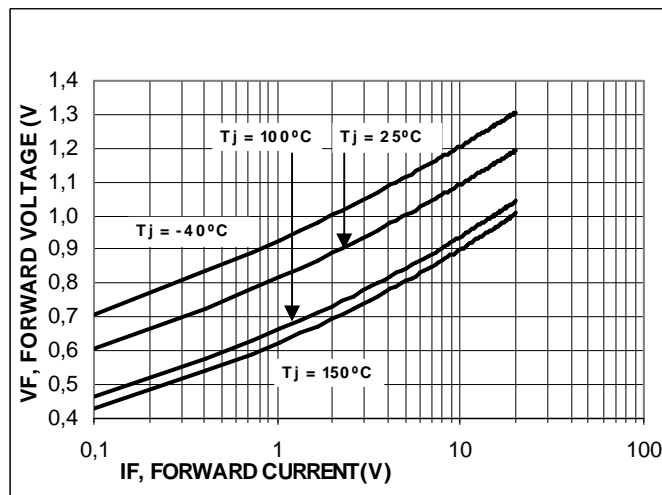


Figure 10

Conclusion

Fagor Electrónica has introduced a new family of soft recovery ultrafast diodes in the range of 200V-400V. This paper outlines the main design elements that have been considered in the control of dynamic performance of the device. Some (VF, trr), (Softness Factor, trr) experimental curves have been presented being useful to get the best trade-off of the characteristics required for the device: **low losses** and **low EMI** for industrial application.

Thus, Fagor Electrónica (FESxySR series) ultrafast diodes are able to offer the best trade-off for (**trr/ VF / Softness Factor**) in a band-gap of (**15-20 nsg. /0.84-0.86 Volts/ 0.90-1.50**) showing high strength to all the application temperatures.