Application Note

Central Semiconductor

Fast Recovery Time in a Rectifier Diode

Urfa Ajmal *- Associate Engineer, Product Development*

Introduction

Fast-recovery diodes (also called fast diodes or fast switching diodes) are defined as semiconductor devices with a short reverse recovery time. They have a shorter reverse recovery time than conventional diodes, making them more suitable for high-frequency rectification applications. They are used for high-frequency switching up to 100 kHz.

When a reverse voltage is applied, the diode will not withstand the voltage until it is reverse-biased. In reverse bias, current flows for a certain period. This time is known as the reverse recovery time (t_{rr}).

The fast-recovery diodes offer high-speed support and generally have a t_{rr} of approximately 50 to 100ns. Even among fast-recovery diodes, we have the ultrafast type, which is specifically designed for speed. This type offers an even smaller t_{rr} of approximately 25ns, with the V_F being quite large.

Typical Characteristics

Withstand voltage (V_{RM})	High voltages such as 600V and 800V
Forward voltage (V_F)	Approximately 1.3 to 3.6V
Reverse current (I_R)	Extremely small: several µA to tens of µA
Reverse recovery time (t_{rr})	Approximately ten of ns to 100ns
Application	Rectifying high voltage switching circuits

Advantages

Some of the advantages of a fast-recovery diode are:

- Low reverse recovery time
- High switching speed
- Low power loss

Applications

Some of the applications of fast-recovery diodes are:

- Power Factor Correction (PFC)
- UPS
- PV Inverter
- DC-DC converters and inverters
- EV Charging station
- Switching power supplies
- Welder
- Detect high-frequency RF waves
- Analog and digital communication circuits (for modulation purposes)
- Industrial and commercial electronics circuits

Implementing FRDs

With these applications in mind, Central is working on launching fast-recovery diodes (FRDs) with suppressed switching loss with low t_{rr} and a high working voltage (V_{RM}). These rectifier diodes are the correct choice for soft switched/resonant converters.

These devices are being specifically designed to improve efficiency of high-speed LLC output rectification stages of EV/HEV on-board battery chargers.

	CRU24715-600	CRU24730-600
Package	TO-247	TO-247
Forward current (I_F (AV))	15 A	30 A
V_F	2.3 V	2.3 V
I_R	100 µA	250 µA
t_{rr} IF=0.5A, IR=1A, IRR=0.25A	40 ns	45 ns
t_{rr} IF=1A, VR=30V, di/dt=300A/µs	30 ns	35 ns

Principle of a Fast Recovery Diode

Fast-recovery diodes are used for rectification purposes. They convert a low-frequency (sinusoidal) AC signal to a DC signal. Since frequency and period are inversely proportional, this means that the signal with a low frequency will take longer to complete the cycle.

Therefore, the diode normally has enough time to change state according to the positive and negative alternation of this signal.

Similarly, at a higher frequency, the signal will take minimum time to complete the cycle. In this case, a regular diode cannot be used because it takes longer to change state. So, we need a rectifier diode that is fast and has a low reverse recovery time, hence FRDs.

Relationship Between Forward Current (I_F) and Reverse Recovery Time (t_{rr})

When the diode is forward-biased, the current through the diode is forward current (I_F). A diode is designed so that current can only flow in one direction. It blocks current in reverse bias and provides current that flows in forward bias. When a diode switches from forward to reverse, current flows for some time (reverse recovery time, t_{rr}).

During this forward polarization state, electrons and holes pass through the junction and travel in opposite directions laterally. And under reverse polarization, electrons and holes cannot move to their sides and create a depletion layer. When a diode reverses, it takes some time for the electrons and holes to return to their side.

The time depends on the DC current. When the forward current is high, holes and electrons pass through the junction and enter the region from the opposite side. The higher the forward current, the higher the t_{rr} because it takes some time for the holes to return to the other side.

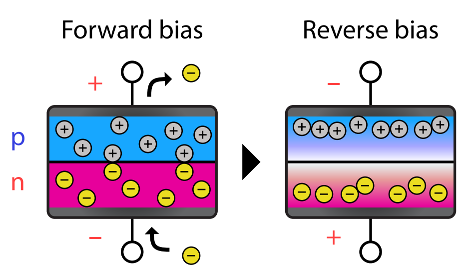

Figure 1: When the forward current is small

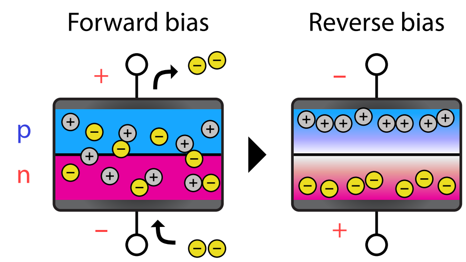

Figure 2: When the forward current is large

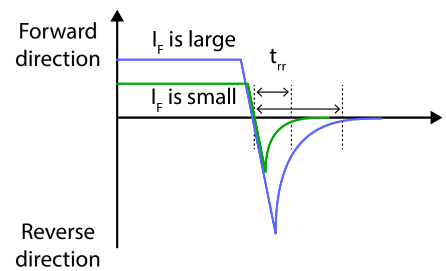

Figure 3: t_{rr} characteristic

In a diode, the n-layer is thick, and the holes take longer to recover. To reduce the reverse recovery time, traps are placed in the nth layer. Holes are trapped, reducing recovery time. To create a carrier trap, an electron beam or dispersed heavy metal is irradiated in a PN junction and it catches holes on the way back.

How FRDs improve t_{rr}

We can see from the first block in the diagram below that the n layer is thicker on the actual diode. That is why it takes time for the holes that have gone deep into the layer to come back. Whereas, in the second block of the diagram, the t_{rr} seems to be improved because it takes less time to go back, as the traps are set in the n layer and the holes are caught while they are in the n layer.

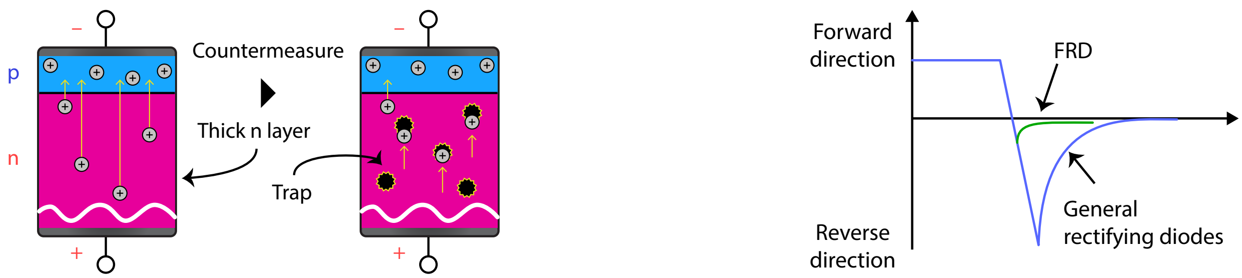

Figure 4: Demonstration of how FRD improves t_{rr}

Conclusion

As noted earlier, fast-recovery rectifier diodes are used for rectification purposes. Central Semiconductors is aware of the importance of this growing technology and is working on introducing these rectifier diodes with a fast recovery time. It is Central's goal to continue supporting such applications by manufacturing and designing the most efficient and advanced discrete semiconductors in the industry.

Central Semiconductor

145 Adams Avenue

Hauppauge, NY 11788, USA

1.631.435.1110