

White Paper

Schottky Diodes

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Schottky Diodes

Schottky diodes use a metal-semiconductor junction as opposed to the semiconductor-semiconductor junctions used in standard diodes. This configuration allows for lower forward bias voltage drops (0.15V - 0.45V vs. 0.5-0.7V) and faster switching times, making them ideal for power supply switching operations. Drawbacks for schottky diodes include much higher reverse bias leakage current ratings. Because p-n recombination is not a factor in switching delay time, only capacitance affects the reverse switching time.

These diodes are generally used to rectify voltages for power supply output. Their quick response time and low voltage consumption make them ideal for this purpose and it is assumed that they perform this function. As such, we will look primarily at the effects of temperature on forward bias voltage drop, capacitance, and reverse current leakage.

To provide a case study to the derating of schottky diodes, three parts were selected as examples

- 40L15CT International Rectifier
- MBR4015CTL ON Semiconductor
- STPS40L15CT ST Microelectronics

| Manufacturer | International Rectifier | ON Semi | ST Micro |
|------------------------------|-------------------------|--------------|--------------|
| Part Number | 40L15CT | MBR4015CTL | STP40L15CT |
| Junction Temp | -55C to 125C | -65C to 125C | -55C to 125C |
| Forward Voltage | 0.25V* | 0.34V** | 0.25V* |
| Working Peak Reverse Voltage | 15V | 15V | 15V |
| Working Forward Current | 40A | 40A | 40A |

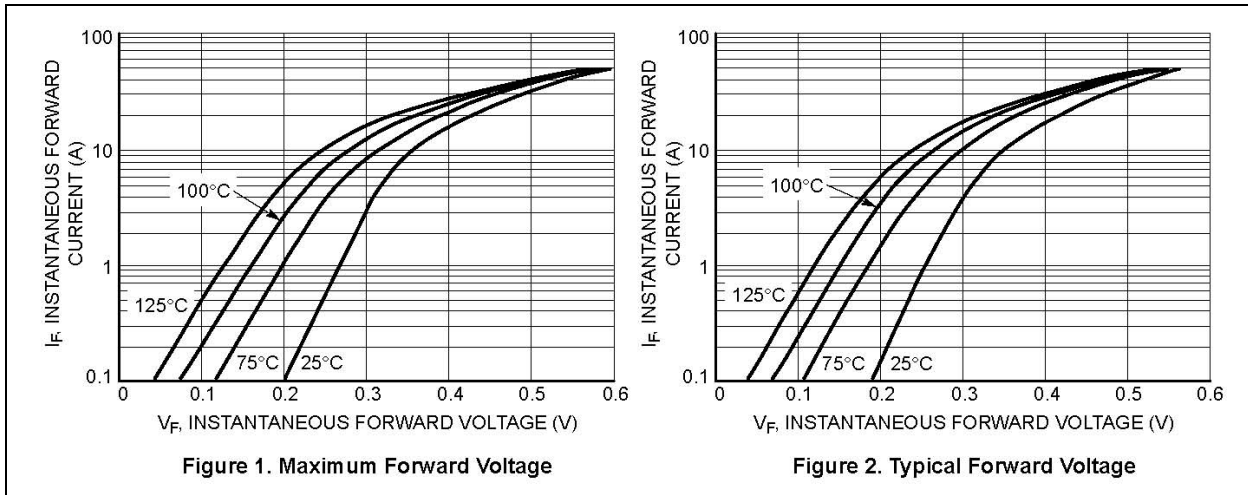
* 19A peak at Junction Temp. of 125°C

**20A peak at Case Temp of 125°C

1.1 Temperature vs. Forward Bias

Elevated temperature decreases forward voltage drop across schottky rectifiers at currents below about 50A. Above this point, elevated temperatures increase the amount of voltage used by the device.

As the rated maximum working current is 40A for all selected rectifiers, temperature increase will only be considered as decreasing the forward voltage drop throughout the working range of the rectifiers. Lower voltage usage by schottky rectifiers is generally desirable and so is not a concern when operating at elevated temperatures. Derating for forward current is not required until case temperature reaches 85°C, which is outside environmental specifications.

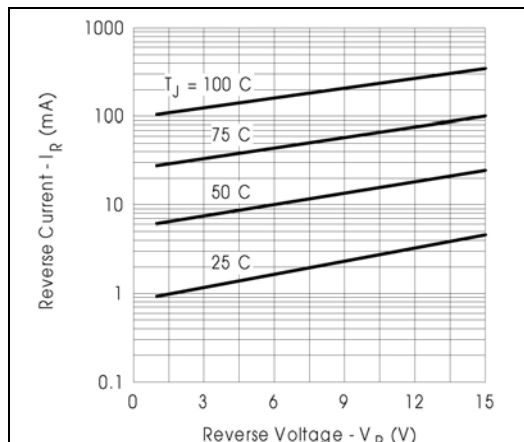


V_f vs. I_f at various junction temperatures from MBR4015CTL datasheet. This is typical of all three parts.¹

1.2 Temperature vs. Reverse Bias

Increasing temperature while maintaining a reverse bias of the rectifier diodes leads to an increase in reverse current through the diode. For every 25°C increase in junction temperature there is a corresponding increase in reverse current of an order of magnitude. Schottky diodes are generally mounted on heat sinks to mitigate these effects. Heat dissipation may become a factor, however, when ambient temperatures increase, leading to even higher reverse current and greater heat generation.

Heat dissipation will be critical, and dependent on ambient conditions local to the diodes, influenced mainly by overall ambient conditions and device proximity to other heat generating devices.



Reverse current vs. reverse voltage at various junction temperatures.²

¹ <http://onsemi.com>

² International Rectifier

1.3 Functional Parameters (Not Specified in Datasheet)

Junction capacitance is given only for ambient temperatures of 25°C, and is not shown as it varies with temperature. However, junction capacitance may increase as temperature increases. This may increase the switching time for the rectifiers, though not critically, as there is little to no p-n recombination to slow the time further. Thus, as the recovery time increases due to an increase in electrical capacitance, it will still be sufficiently short so as to preclude a thermal runaway condition.³ If the circuit is constructed with little tolerance with regard to switching time, this may become a problem, allowing reverse current to flow while the diodes reverse bias, leading to damage of sensitive devices downstream.

1.4 Electrical Overstress (Robustness)

Failure of schottky diodes during overstress conditions is usually a result of electrostatic discharge(ESD). Buildup of as little as 1000V – 1500V and the subsequent discharge are enough to damage these parts. Reverse bias is the most prevalent condition under which ESD takes place. The result of which is a shift in the I- E curve that varies in degree from slight to a complete short. As capacitance is not expected to increase by more than 5% at 85°C, the increased risk of charge buildup and ESD is considered negligible.

1.5 Wearout behavior

Schottky diode failure is seldom due to wearout mechanisms. This is especially the case with schottky diodes used on the output of power supplies, where failure is normally due to a single reverse current effect. Reliability studies have been published on SiC schottky's that indicate lifetime of >50yrs⁴. Due to the majority of failures due to electrical overstress, long term failure mechanisms of Schottky diodes are not known to have been historically significant.

1.6 Conclusion

Schottky diode failure as a result of increased temperature is almost entirely dependent on proper heat dissipation of the diode through its heat sink and can be mitigated by the placement of the diodes away from other heat generating devices. Assembly failure due to altered operating characteristics of the diode (ie greater reverse current) is more likely than direct failure of the diodes themselves.

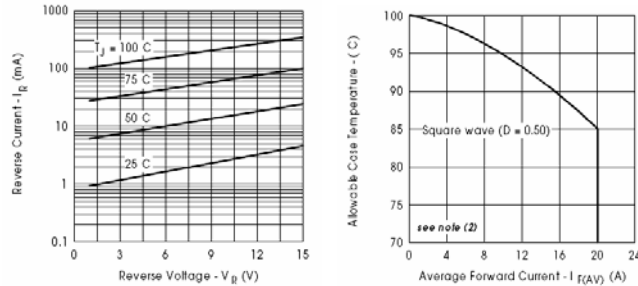
³ <http://www.irf.com/technical-info/design/tp/temp001.pdf>

⁴ Dr. Allan Ward, SiC Power Diode Reliability – March 2006
CPWR-RS03

Appendix

International Rectifier, 40L15CT

The listed device is rated for operation within a **junction** temperature range of -55°C to $+125^{\circ}\text{C}$.
Corollary: Some parametric performance is defined by **case** temperature (max. of 100°C)

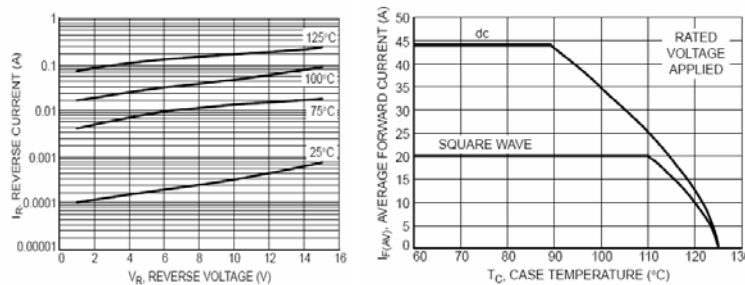


Performance issues: There are several parameters of concern with diodes, including reverse current, forward current, surge current, voltage drop behavior, junction capacitance, and power loss. The primary focus tends to be on maximum allowable forward current and leakage current in the reverse bias direction. Forward current is not a concern as derating is not required until the case temperature reaches 85°C , which is within environmental specifications. The reverse current does experience increase by orders of magnitude with increasing temperature and needs to be considered.

Reliability issues: Long-term degradation at the die-level is not expected to be an issue. Elevated temperature combined with repeated power cycling could drive fatigue at the die attach.

ON Semi, MBR4015CTL

The listed device is rated for operation within a **junction** temperature range of -65°C to $+125^{\circ}\text{C}$.
Corollary: Some parametric performance is defined by **case** temperature (max. of 125°C)



Performance issues: There are several parameters of concern with diodes, including reverse current, forward current, surge current, voltage drop behavior, junction capacitance, and power loss. The primary focus tends to be on maximum allowable forward current and leakage current in the reverse bias direction. Forward current is not a concern as derating is not required until the case temperature reaches 90°C , which is within environmental specifications. The reverse current does experience increase by orders of magnitude with increasing temperature and needs to be considered.

Reliability issues: Long-term degradation at the die-level is not expected to be an issue. Elevated temperature combined with repeated power cycling could drive fatigue at the die attach.

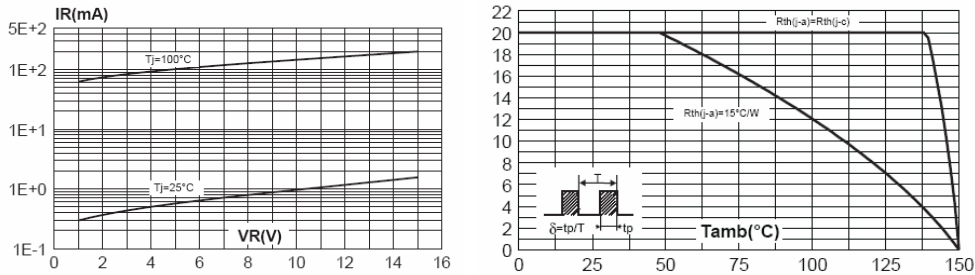
ST Micro, STP40L15CT

The listed device does not provide a temperature range. Several maximum temperatures are listed

Maximum **junction** temperature of +125°C on the first page of the specification

Maximum **junction** temperature of +150°C on some parametric charts

Maximum **ambient** temperature of +150°C for forward current



Performance issues: There are several parameters of concern with diodes, including reverse current, forward current, surge current, voltage drop behavior, junction capacitance, and power loss. The primary focus tends to be on maximum allowable forward current and leakage current in the reverse bias direction. Forward current may be a concern as derating may be required at ambient temperatures as low as 50°C. The reverse current does experience increase by orders of magnitude with increasing temperature and needs to be considered.

Reliability issues: Long-term degradation at the die-level is not expected to be an issue. Elevated temperature combined with repeated power cycling could drive fatigue at the die attach.

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