

National Aeronautics and Space Administration



Evaluation of Fast Switching Diode 1N4448 Over a Wide Temperature Range

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Scope

Electronic parts used in the design of power systems geared for space applications are often exposed to extreme temperatures and thermal cycling. Limited data exist on the performance and reliability of commercial-off-the-shelf (COTS) electronic parts at temperatures beyond the manufacturer’s specified operating temperature range. This report summarizes preliminary results obtained on the evaluation of automotive-grade, fast switching diodes over a wide temperature range and thermal cycling. The investigations were carried out to establish a baseline on functionality of these diodes and to determine suitability for use outside their recommended temperature limits.

Test Procedure

The COTS parts investigated in this work comprised of Diodes Incorporated surface mount, fast switching 1N4448WSF diodes. These automotive-grade diodes exhibit low leakage current and are qualified to AEC-Q101 (Automotive Electronics Council) standards for high reliability [1]. Table I shows some of the diode manufacturer’s specifications. Two batches of these diodes, for a total of 12, were investigated in this work. One batch consisted of 6 pristine units while the other comprised of 6 diodes that were subjected to an earlier life-testing at the Naval Surface Warfare Center in Crane, Indiana [2]. The diodes were examined in terms of their forward and reverse voltage-current (V/I) characteristics over a wide temperature range between -192 °C and +150 °C. Performance characterization, at specific test temperatures, was obtained using a Sony/Tektronix 370A programmable curve tracer and source measure units. Cold-restart capability of the diodes was also investigated. A temperature rate of change of 10 °C per minute was used, and a soak time of at 15 minutes was allowed at every test temperature. The effects of thermal cycling on the operation of these diodes were also investigated by subjecting the diodes to a total of 100 cycles between -192 °C and +150 °C at a temperature rate of 10 °C/minute. Following the thermal cycling, measurements of the diodes properties were retaken at various test temperatures.

Table I. Manufacturer’s specifications of 1N4448WSF diode [1].

Parameter	Symbol	
Forward Continuous Current (A)	I_{FM}	0.5
Non-repetitive Forward Surge Current (A)	I_{FSM}	0.5 - 4
Leakage Current (μA)	I_R	0.025 - 50
Forward Voltage (V)	V_F	0.62 - 1.25
Non-repetitive Peak Reverse Voltage (V)	V_{RM}	100
Peak Repetitive Reverse Voltage (V)	V_{RRM}	75
Reverse Recovery Time (ns)	t_{rr}	4.0
Power Dissipation (W)	P_D	0.4
Operating Temperature (°C)	T_J	-65 to +150
Package		SOD323F
Part Code		NSA153SHPD

One batch of diodes mounted on a 16 pin SIP-adaptor/surfboard is shown in Figure 1.



Figure 1. Diodes mounted on a test board.

Test Results

As indicated earlier, a total of 12 diodes were investigated in this work where half of them were pristine units and the others were subjected to life-testing. The results, though, revealed that all diodes, irrespective of batch lot, displayed similar trend in their behavior with temperature. Therefore, data pertaining to only one diode are presented.

Temperature Effects

The forward V/I characteristics of the 1N4448 diode at test temperatures of +150, +100, +50, +20, -50, -75, -100, -150, and -192 °C are shown in Figure 2. It can be seen that the diode maintained operation throughout this test temperature range. Its forward voltage, however, increased with decrease in temperature. For example, while the forward voltage had a value of about 0.7 V at room temperature, it increased to slightly over 1 V at the extreme cryogenic temperature of -192 °C. At the other extreme temperature, i.e. +150 °C, the trend is reversed as the voltage drop decreased to about 0.5 V. Figure 3 shows this dependency of the diode's forward voltage on temperature at a forward current of 5 mA.

The reverse V/I characteristics of the 1N4448 diode as a function of test temperatures are shown in Figure 4. The diode seemed to maintain low reverse current over the temperature range of -192 °C to +50 °C. At higher temperatures, however, it exhibited significant increase with temperature, notably at +150 °C, as shown in Figure 4. In addition the onset of the breakdown voltage in the reverse operation mode seemed to vary with temperature. At all test temperatures, the onset of breakdown voltage occurred at lower values when compared to its room temperature level. These changes were more dramatic at the test temperatures of -192, +100, and +150 °C, as shown in Figure 4.

Cold Re-Start

Cold-restart capability of the 1N4448 fast switching diodes was investigated by allowing the devices to soak at -192 °C for 20 minutes without electrical bias. Power was then applied to the device under test, and measurements were taken on the forward V/I

characteristics. All diodes did perform cold start at $-192\text{ }^{\circ}\text{C}$, and the results obtained were similar to those obtained earlier at that temperature.

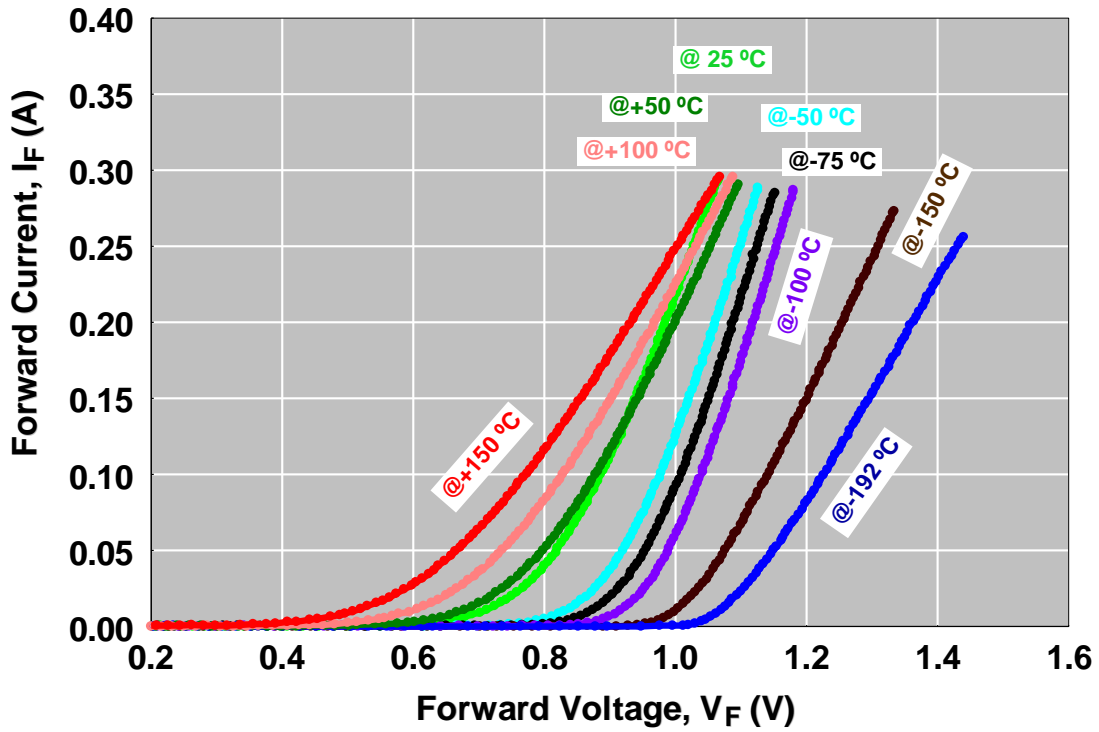


Figure 2. Forward V/I characteristics of 1N4148 diode versus temperature.

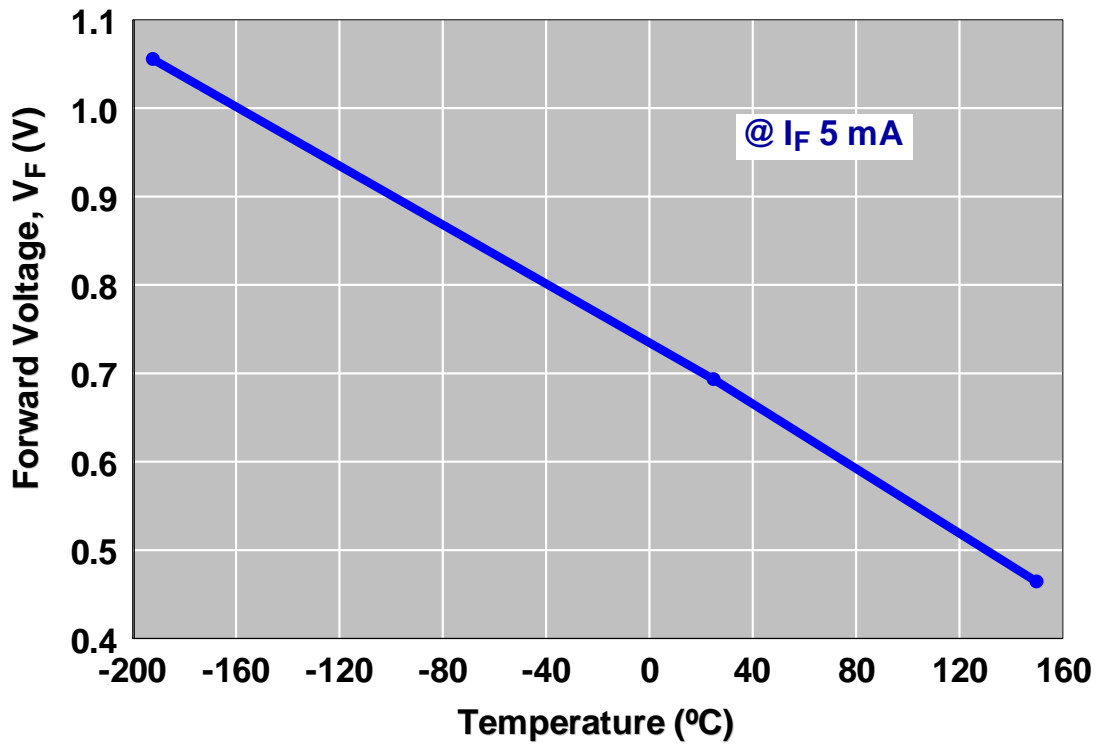


Figure 3. Diode's forward voltage as a function of temperature.

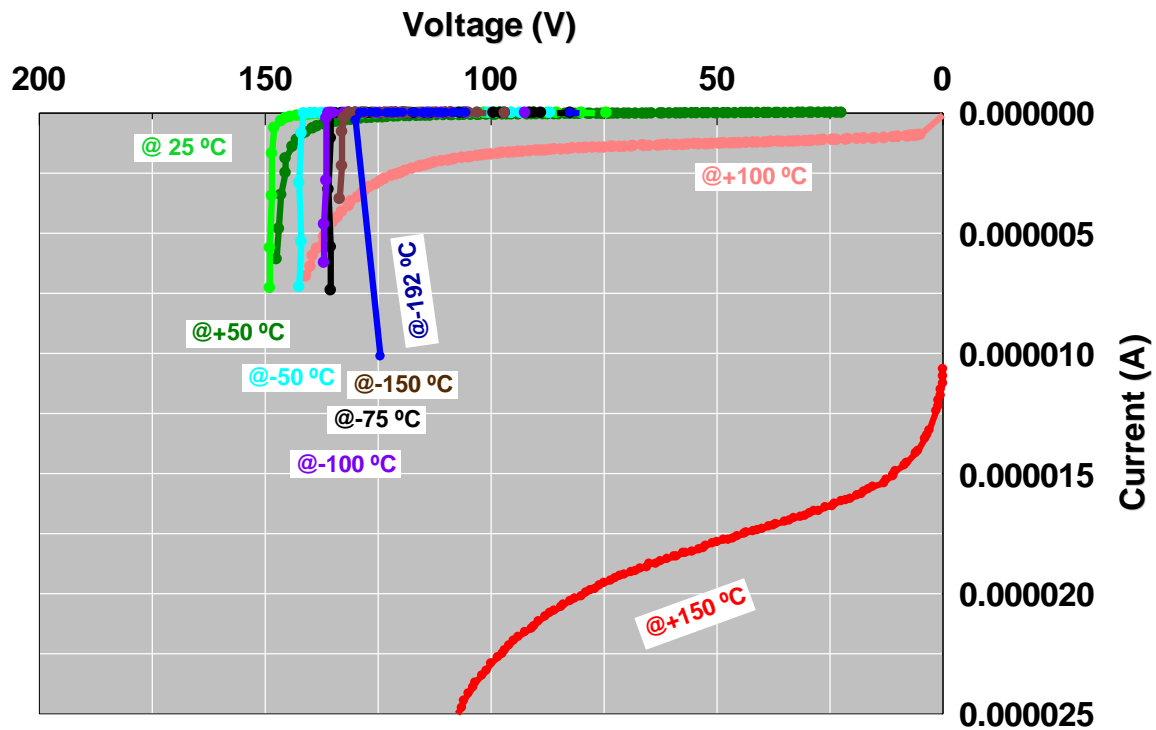


Figure 4. Reverse V/I characteristics of 1N4148 diode versus temperature.

Effects of Thermal Cycling

The effects of thermal cycling on the operation of the diodes were investigated by subjecting them to a total of 100 cycles between -192 °C and +150 °C at a temperature rate of 10 °C/minute. Post-cycling V/I characteristics of the diodes were then recorded at various test temperature. Comparison of the post-cycling data along to those obtained prior to cycling revealed that none of the devices under any significant change due to this cycling activity. For illustration purposes, the forward and reverse V/I characteristics for one of these diodes taken at the test temperatures of +20, -192, and +150 °C are shown, for both pre- and post-cycling conditions, in Figures 5 and 6, respectively. The diode's forward voltage, also for both pre- and post-cycling conditions taken at forward current of 5 mA, is illustrated over the whole test temperature range in Figure 7. This limited thermal cycling also appeared to have no effect on the structural integrity of these diodes as none underwent any structural deterioration or packaging damage.

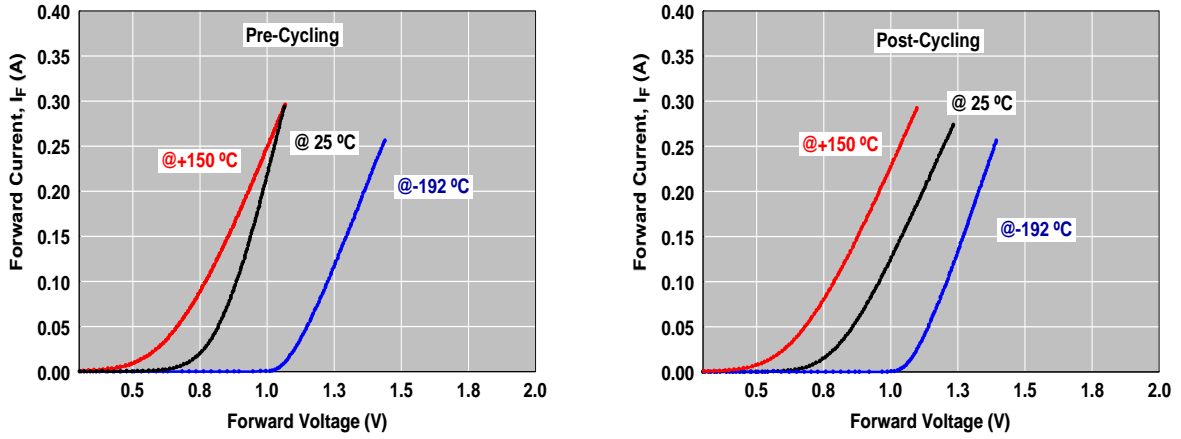


Figure 5. Pre- and post-cycling forward V/I characteristics of 1N4448 diode at selected temperatures.

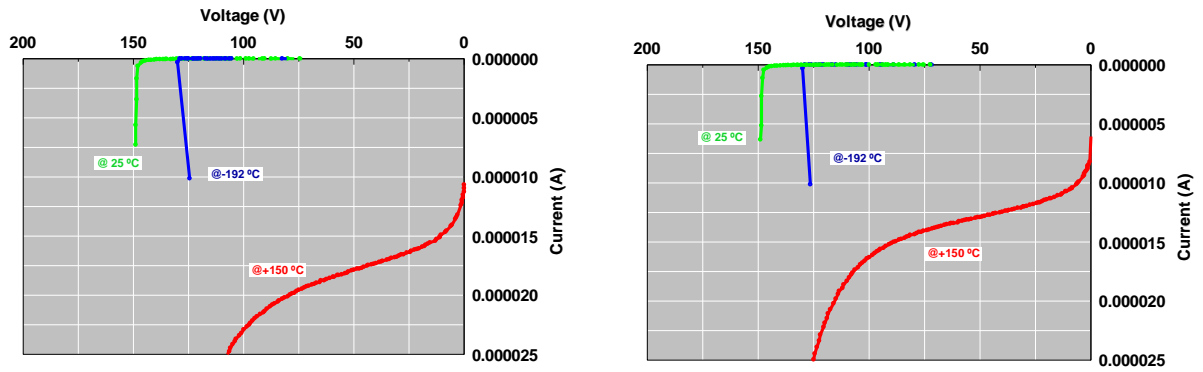


Figure 6. Pre- (left) and post-cycling (right) reverse V/I characteristics of 1N4448 diode at selected temperatures.

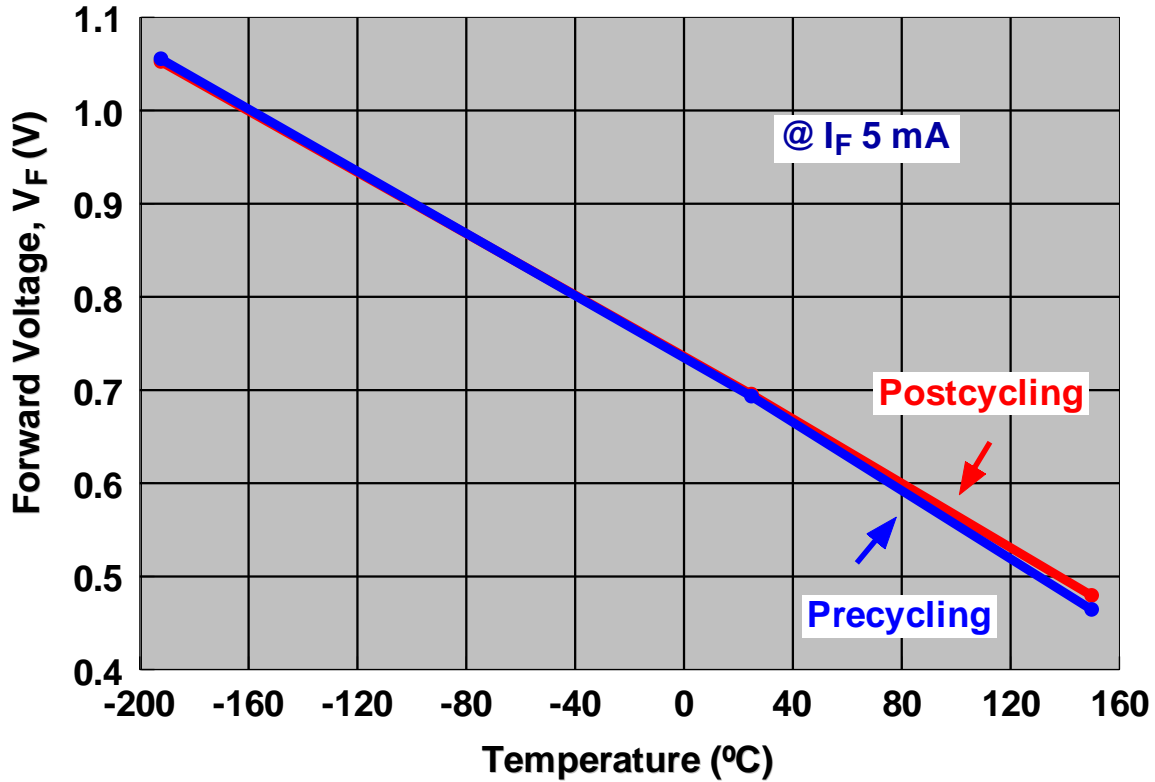


Figure 7. Pre- and post-cycling diode's forward voltage as a function of temperature.

Conclusions

Two batches of automotive-grade, fast switching diodes, Diodes Inc. 1N4448WSF diodes, were evaluated for operation under extreme temperatures extending beyond their specified low temperature range. While one batch consisted of 6 pristine units, the other comprised of 6 diodes that were previously subjected to life-testing. Performance of all diodes were examined in terms of their forward and reverse voltage-current (V/I) characteristics over the wide temperature range of -192°C to $+150^{\circ}\text{C}$. Cold-restart capability of the diodes as well as the effects of thermal cycling on their operation were also investigated. All diodes, from either batch, were able to maintain operation between -192°C and $+150^{\circ}\text{C}$ with minimal changes in their characteristics. While the diode forward voltage exhibited inverse dependency on test temperature, the temperature-induced changes mainly consisted of increase in leakage current at high temperatures, and a reduction in the onset of the breakdown voltage in the reverse operation; most notably at the very extreme high and low temperatures. Subjecting the diodes to limited thermal cycling produced no effect on their characteristics, and all devices were able to cold start at -192°C . The diode's plastic packaging was also not affected by either the short extreme temperature exposure or the limited thermal cycling. These preliminary results indicate that this surface-mount fast switching diode has the potential for use in cryogenic temperature region beyond its rating. Further testing under long term cycling is required to fully establish the reliability of these devices and to determine their suitability for extended use in extreme temperature environments.

References

- [1]. Diodes Incorporated, “1N4448WSF Surface Mount Fast Switching Diode” Document Number: DS35380 Rev.3-2, August 2011.
http://www.diodes.com/catalog/Small_Signal_Switching_Diodes_5/1N4448WSF_8619
- [2]. Results are being documented in a test report.

Acknowledgements

This work was performed in support of the NASA Electronic Parts and Packaging (NEPP) Program. Guidance and funding provided by the Program’s co-managers Kenneth LaBel and Michael Sampson are greatly appreciated. Part of this effort was done at the NASA Glenn Research Center under GESS-3 Contract # NNC12BA01B.