Application Report
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A Short Protection Method for Tantalum Capacitors Using CSD16327Q3 in Enterprise SSDs

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ABSTRACT

A discrete capacitor-based voltage hold-up circuit employs a bank of tantalum capacitors connected in parallel, and this application report introduces a short protection method of tantalum capacitors for high-reliability applications where a tantalum capacitor failing as short circuit will disrupt overall system performance. By applying this short protection method to backup power systems in enterprise SSDs, it would significantly improve the system reliability, and this report shows how well the initial design tests met the goals to resolve the tantalum capacitor short-circuit fault using the CSD16327Q3.

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Trademarks

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1 Introduction

Enterprise SSDs including server and datacenter SSDs rely on power failure function generating an early warning signal to SSD controller, and a hold-up circuit is implemented to protect against loss of data upon power failures. The hold-up time is the amount of time that the system can continue to run without resetting or rebooting during a power interruption, and a bank of discrete tantalum capacitors can be used for the proper hold-up time.

Figure 1 shows the simplified application circuit for the hold-up function in enterprise SSDs, and a boost converter is used for charging a bank of discrete tantalum capacitors as the energy storage. These tantalum capacitors provide a higher temperature operating range with respect to super capacitors, and as a result of this reason, a discrete tantalum capacitor based hold-up circuit is more able to meet the demands of enterprise SSD environments.

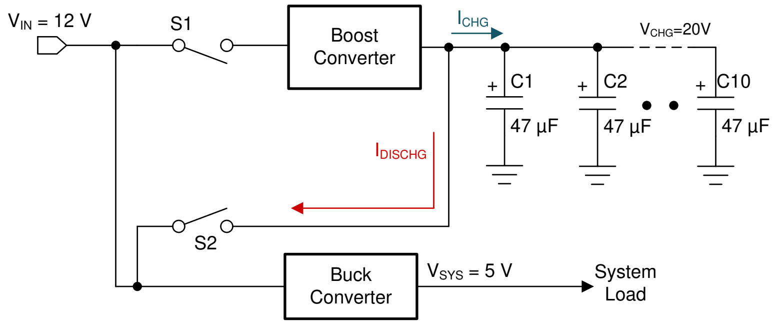

Figure 1. Simplified Application Circuit for the Hold-up Function

The output charging voltage (V_{CHG}) is usually 20 V from 12-V input voltage rail, and a boost converter is widely adopted because of its high efficiency. Hold-up time requirement is a special requirement for enterprise SSDs, and it requires the system to provide the output voltage within regulation for generally 10 ms to approximately 30 ms after loss of 12-V input at full load condition.

However, a short-circuit failure with tantalum capacitors from C1 to C10 could be a serious issue of this solution, and the tantalum capacitor short-circuit fault having zero-ohm resistance can be found in enterprise SSDs during the normal operation. In most situations the only serious damage is done to the tantalum capacitor, but in the case of a very low resistance it could load other parts of the circuit and cause them to fail. By having the tantalum capacitor short-circuited, the voltage thereof is zero, so that this element is not operational in the circuit.

2 Short Protection Method for Better System Reliability

Figure 2 shows the simplified application circuit using CSD16327Q3, and 10 CSD16327Q3s from M1 to M10 are used for protecting each capacitor rail from C1 to C10. In normal operation, all the external switches from M1 to M10 are turned on and controlled by MCU-controlled the gate signals, and the boost converter regulates the 20-V output. If one of the tantalum capacitors (C10 for an example) has the short-circuit fault as Figure 2 shows, Overcurrent Protection (OCP) and Undervoltage Protection (UVP) will be triggered on the system, and the output of the boost converter will go down to ground quickly with high peak current during a short period of time.

If this situation happens, the hold-up circuit in enterprise SSD system does not work properly, and the system goes into diagnostic mode turning off the external switch (S1) immediately to disable the output of the boost converter in this approach. Since the boost converter is turned off due to the capacitor short-circuit fault, an MCU tries to turn on S1 and M1 again after 4 ms as the first step in diagnostic mode. This is to verify each tantalum capacitor rail one by one, whether it has the capacitor short-circuited or not.

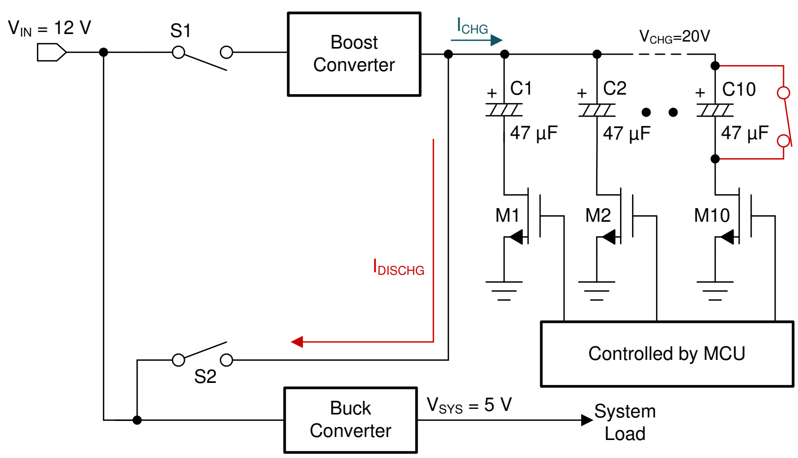

Figure 2. Simplified Schematic for Better Reliability Using CSD16327Q3

Figure 3 shows the flow chart of this approach. If the output of the boost converter increases properly up to 20 V turning on S1 and M1, the MCU keeps M1 turning on continuously and will try to turn on M2 as the next step. If the output of the boost converter still works properly with M1 and M2, the MCU is continuously trying to turn on the next MOSFETs one by one from M3 to M10 updating the status. Since C10 is considered as the short-circuit fault component, the output of the boost converter goes down to ground immediately when M10 is turned on. In this case, the MCU turns off S1 for 4 ms while M10 is turned off permanently. After 4 ms, S1 and the external MOSFETs (CSD16327Q3) from M1 to M9 will be turned on all together as the next step, and the boost output goes up to 20 V without fail since there is no capacitor short-circuit fault from C1 to C9.

As the same process, if C1 is a short-circuited capacitor, OCP and UVP will be triggered again quickly, and the boost converter does not work properly. If the output of the boost converter does not increase using C1 and M1, the MCU turns off S1 for 4 ms while M1 is turned off permanently. After 4 ms, S1 and M2 will be turned on as the next step. If the output of the boost converter increases properly up to 20 V with M2, the MCU keeps M2 turning on and continues to turn on the next MOSFETs from M3 to M10 one by one to identify the rail of the shorted capacitor.

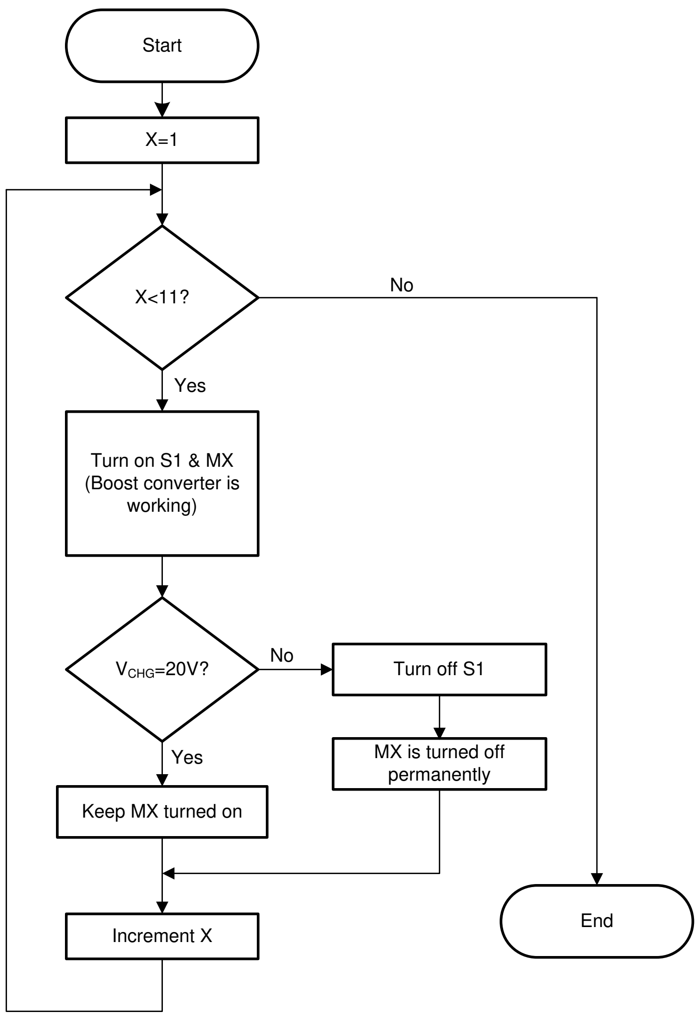

Figure 3. Short-Circuit Fault Protection Flow Chart

Since one of tantalum capacitor rails is disabled due to the short-circuit fault, the hold-up time will be reduced by 10%. However, this is an acceptable result in terms of better reliability and the costs compared to the real repair of enterprise SSDs since the time to repair the short-circuit fault is the sum of the time required for evacuation, diagnosis, repair, inspection, and return with assigning engineering resources.

3 Experimental Results

To verify the operation and performance of the proposed application method, the CSD16327Q3 is used for the external switches from M1 to M10. Figure 4 shows the output of the boost convert and the current of M10 when C10 has the short-circuit fault, and OCP and UVP will be triggered in this case.

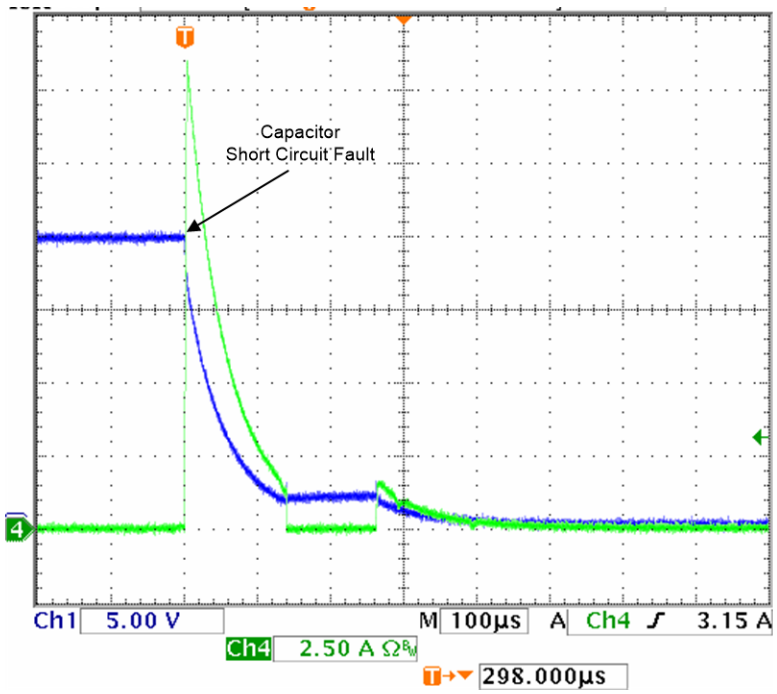

Figure 4. Capacitor Short-Circuit Fault

Figure 5 shows the re-start waveform of the boost converter after the capacitor short-circuit fault occurs at C10. Since M10 is turned off in this case, the rest of external MOSFETs from M1 to M9 is turned on, and the boost converter is working properly regulating 20-V output as Figure 5 shows.

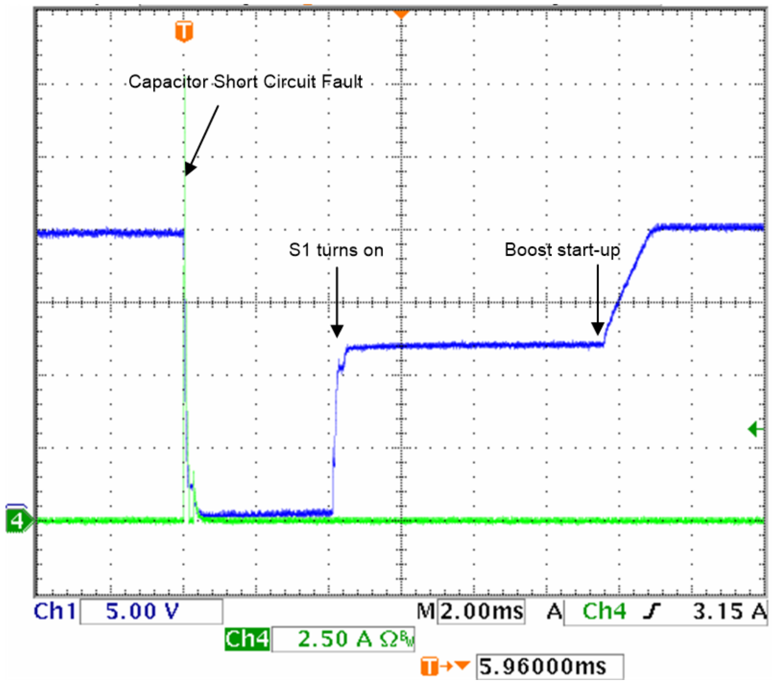

Figure 5. Start-up After Short-Circuit Fault

4 Conclusion

A short-circuit protection method for tantalum capacitors using the CSD16327Q3 device is described in this application report. By applying this short protection method to the backup power system in enterprise SSDs, it significantly improves the system reliability and reduces the maintenance costs compared to the real repair of the system. The CSD16327Q3 has been designed to minimize power losses with low $R_{DS(on)}$, and the operation of the CSD16327Q3 for this application is in the safe operating area in the data sheet. As it has been confirmed with the actual application case using 10 tantalum capacitors in parallel for the hold-up function, the solution operates properly, and it is suitable for the high reliability backup power in enterprise SSDs.

5 References

- Texas Instruments, *CSD16327Q3 25-V N-Channel NexFET™ Power MOSFET Data Sheet*