Pulsed-laser Test Report of the MSK5059RH Switching Regulator

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I. Introduction

The purpose of this test is to examine the pulsed-laser-induced single event effects (SEE) susceptibility of the MSK5059RH step down switching voltage regulator from M. S. Kennedy Corporation. The test was conducted at the Naval Research Laboratory.

II. Device Description

The MSK5059RH is a radiation hardened 500 KHz switching regulator controller capable of delivering up to 4.5A of current to the load. The part is packaged from the RH1959 die fabricated by Linear Technology, Inc. The output voltage is adjustable down to 1.21 V. Typical applications include point of load DC/DC converters for satellite power supplies, microprocessors, FPGAs, and ASICS. Table I displays the part and test information. Figure 1 shows the pin configurations for the device. The device datasheet can be downloaded from the web link in ref [1].

Table I. Test and part information.

Generic Part Number	MSK5059RH
Package Marking	MSK 5059RHG Be0 51651 USA
Manufacturer	M. S. Kennedy Corp./Linear Tech. die
Lot Date Code (LDC)	To be determined
Quantity tested	1
Part Function	Step down switching regulator
Part Technology	BIPH400 4 µm high speed bipolar
Package Style	Hermetically sealed flat-16
Test Equipment	Power supply, digital oscilloscope, multimeter, and computer

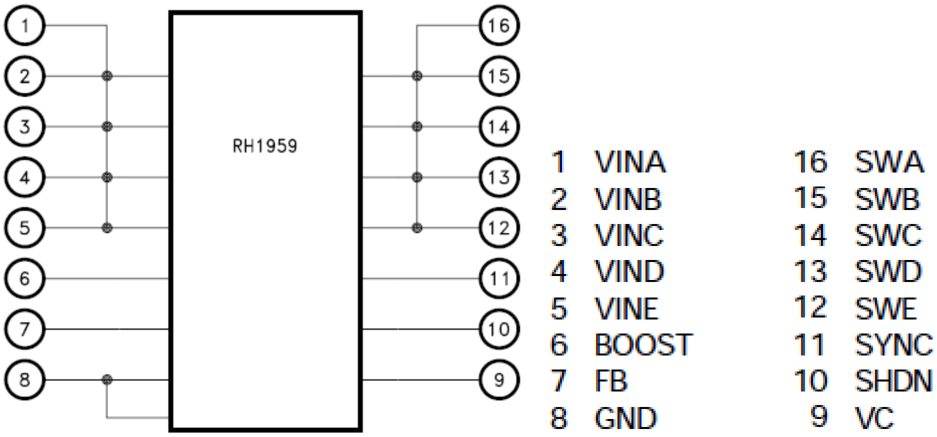

Figure 1. Pin configuration for the MSK5059RH.

III. Test Facility

The testing was conducted at the Naval Research Laboratory with a YLF laser. The laser beam characteristics are listed in Table II below.

Table II. Laser characteristics.

Wave Length	590 nm
1/e penetration depth	2 µm
Beam diameter	~ 1.7 µm

IV. Test Methods

Figure 2 shows the circuit schematic diagram for the application circuit. The evaluation boards were provided by M.S. Kennedy. Figure 3 shows a photograph of the evaluation board, with the device under test (DUT) identified. The input voltage (V_{in}) was set around 5 V. The output voltage (V_{out}) is fixed at 3.3 or 1.8 V. We evaluated SETs with various output loads, from 0.2 to 4 A, using an electronic load. We also compared the SET response with physical resistors.

Figure 4 shows a schematic of the test setup. The oscilloscope is connected directly at the device output terminals on the evaluation board to monitor SETs. A LabVIEW program captured and recorded the voltage transients.

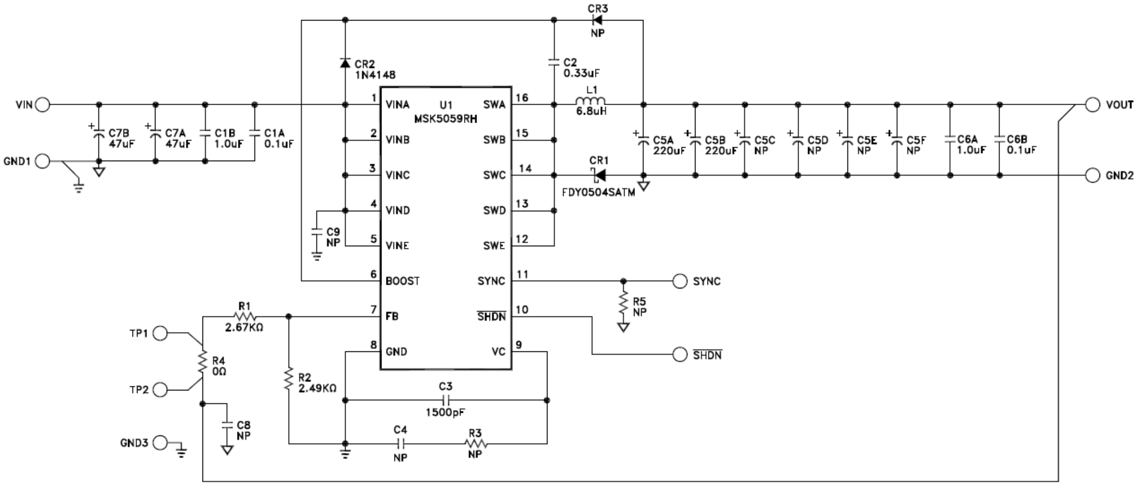

Figure 2. Application circuit diagram.

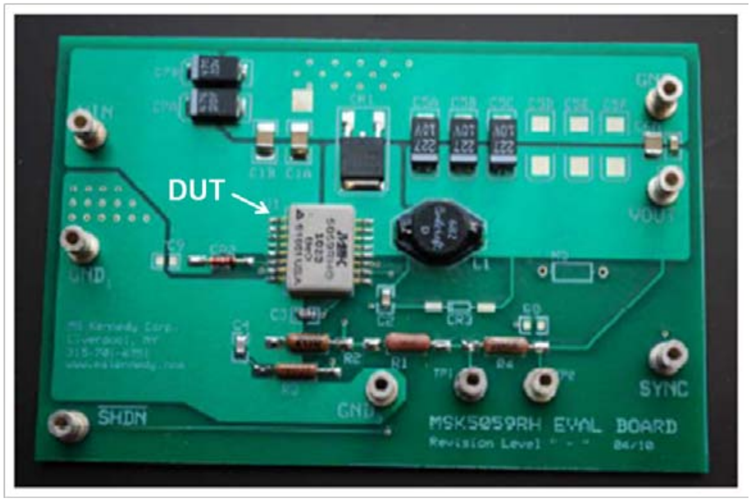

Figure 3. Photograph of the evaluation board.

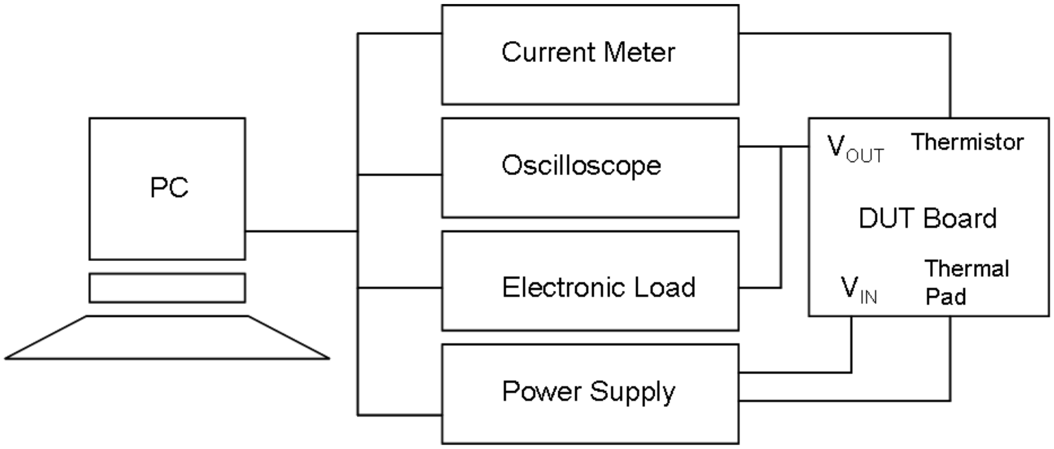

Figure 4. Block diagram of the testing setup.

Test Conditions

Test Temperature:	Room temperature
Operating Frequency:	DC (internally fixed at 500 kHz)
Power Supply:	V_{in} = 5 V
Output Voltage:	V_{out} = 3.3 or 1.8 V
Output Load:	I_{out} = 0.2 to 4 A
Angles of Incidence:	0^o (normal)
Parameters:	1) Input supply voltage 2) Input supply current 3) Output current 4) Output voltage

V. Results

We identified one area on the die that showed sensitivity to pulsed-laser. The most significant transients caused output voltage dropouts. The duration of the dropout depends on the laser pulse frequency. Figure 5 shows SETs with the part operating at V_{out} = 3.3 V output and I_{out} = 1 A load, and a laser frequency of 1 Hz. Figure 6 shows SETs at a laser frequency of 10 Hz. The SETs showed frequency dependence on the order of 1 Hz and 10 Hz, respectively. The results indicate that the output shuts “off” or turns “on” following each laser pulse strike. The input supply current also decreased following a pulsed-laser strike, as shown in Figure 7 for a run with laser frequency of 1 Hz.

The SET magnitudes were independent of the output load. We found output voltage dropouts with various output loads ranging from 0.2 A to 4 A. However, with the device operating with an output load of 4 A, the output remained “off” following a pulsed laser strike. This is unlike the behavior with the device operating at smaller output loads, where the output voltage oscillates corresponding to each successive laser pulse. We believe the behavior at 4 A is caused by saturation of the electronic load tripping the foldback current limit feature of the DUT.

The SET slew rate, from the trailing edge, showed dependence on the output load. Figure 8 shows examples of SETs with the device operating at V_{out} = 1.8 V, I_{out} = 0.2 A, 1 A and 0.2 A. The slew rate of the falling edge increases with increasing output load.

We also investigated the SET characteristics with an electronic load vs. physical resistors. Figure 9 shows SETs with the device operating from an electronic load of 2 A, and with a physical resistor of 1Ω (equivalent output current of 1.8 A). The SET from the physical load showed a more gradual and logarithmic decay relative to the SET from the electronic load.

We determined that the laser threshold energy for the dropout events was approximately between 55 to 110 pJ. The equivalent LET values, as extrapolated from empirical data, are approximately 165 to 330 MeV·cm^2/mg. These energy/LET upset threshold values are relatively high for space applications. The probability for ions of such high LET values to strike the device in space is extremely low. The output dropouts observed here may also be similar to the event observed during a previous heavy-ion test, as shown in Figure 10. The dropout event during the heavy-ion test occurred during a run with an effective LET of 124 MeV·cm^2/mg [2].

The sensitive location is occupied by a junction capacitor, which lies across the collector-base region of an NPN transistor. The photocurrent from the pulsed-laser is most likely amplified through the NPN transistor gain, thereby shutting down the reference voltage.

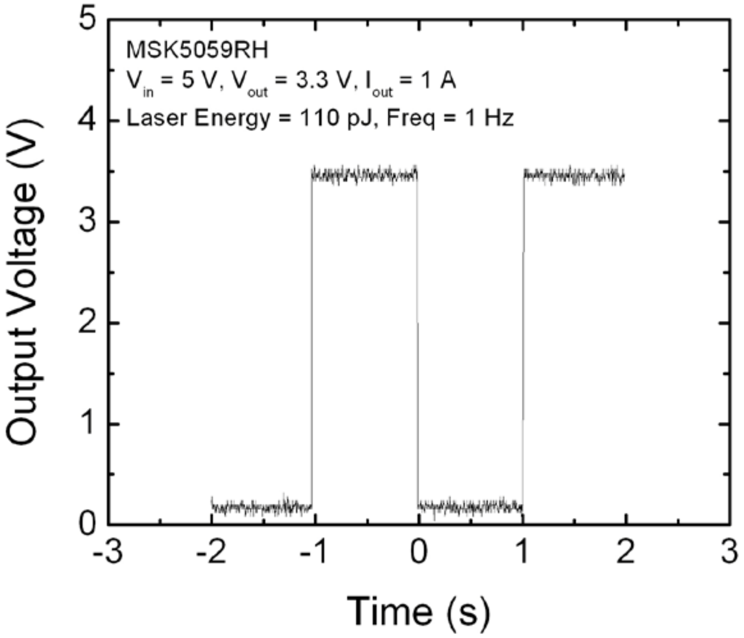

Figure 5. Pulsed laser-induced SET for the MSK5059RH operating with V_{in} = 5 V, V_{out} = 3.3 V, and I_{out} = 1A, and laser energy = 110 pJ and laser pulse frequency = 1 Hz.

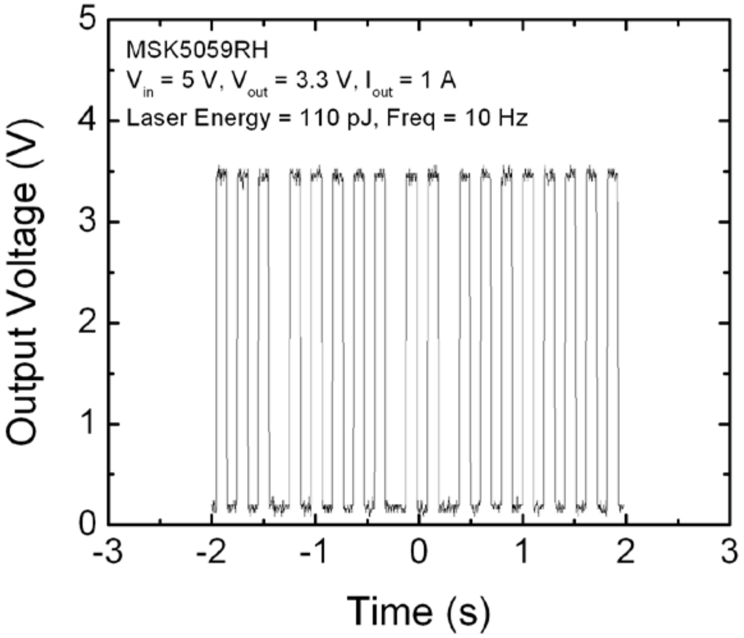

Figure 6. Pulsed laser-induced SET for the MSK5059RH operating with V_{in} = 5 V, V_{out} = 3.3 V, and I_{out} = 1A, and laser energy = 110 pJ and laser pulse frequency = 10 Hz.

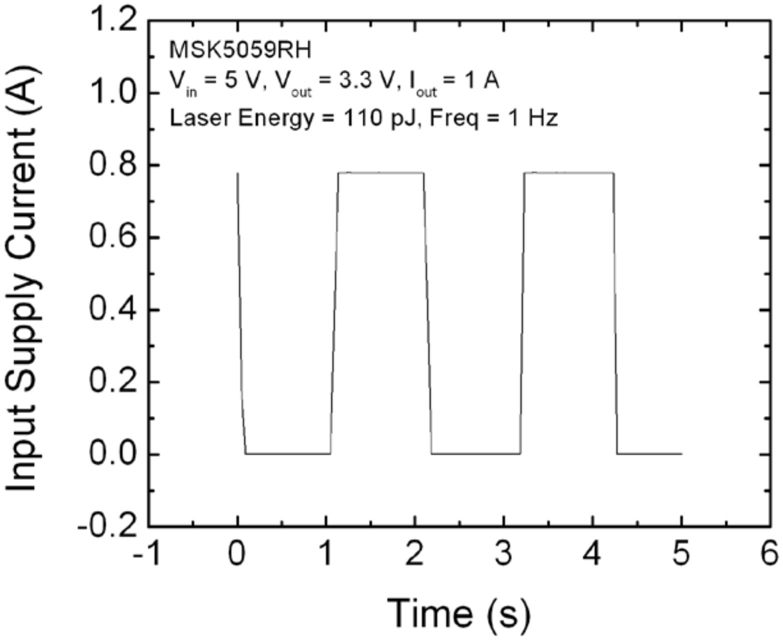

Figure 7. The input supply current for the MSK5059RH operating with V_{in} = 5 V, V_{out} = 3.3 V, and I_{out} = 1A, during a run with laser energy = 110 pJ and laser pulse frequency = 1 Hz.

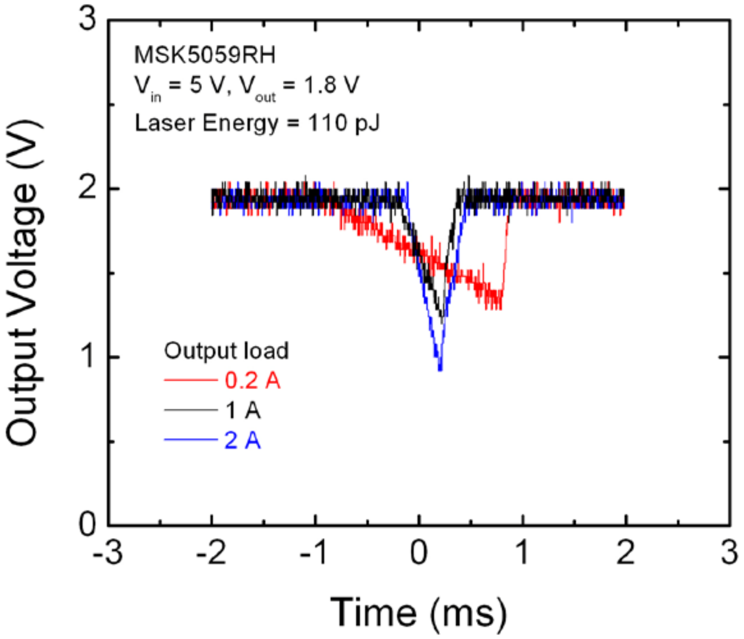

Figure 8. Pulsed laser-induced SETs for the MSK5059RH operating with V_{in} = 5 V, V_{out} = 1.8 V, and I_{out} = 0.2 and 2 A, and laser energy = 110 pJ and laser pulse frequency = 100 Hz.

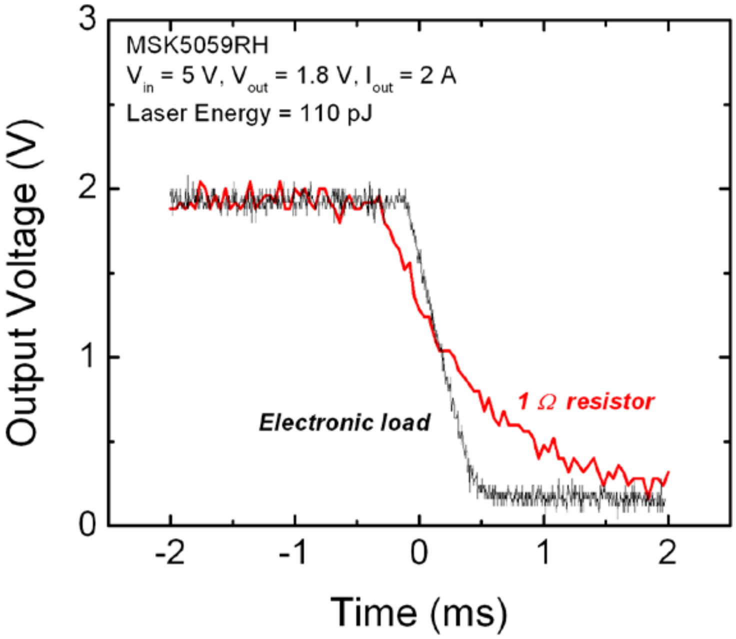

Figure 9. Pulsed laser-induced SETs for the MSK5059RH operating with V_{in} = 5 V, V_{out} = 1.8 V, and I_{out} = 2 A (physical 1 Ω resistor vs. electronic load), and laser energy = 110 pJ and laser pulse frequency = 100 Hz.

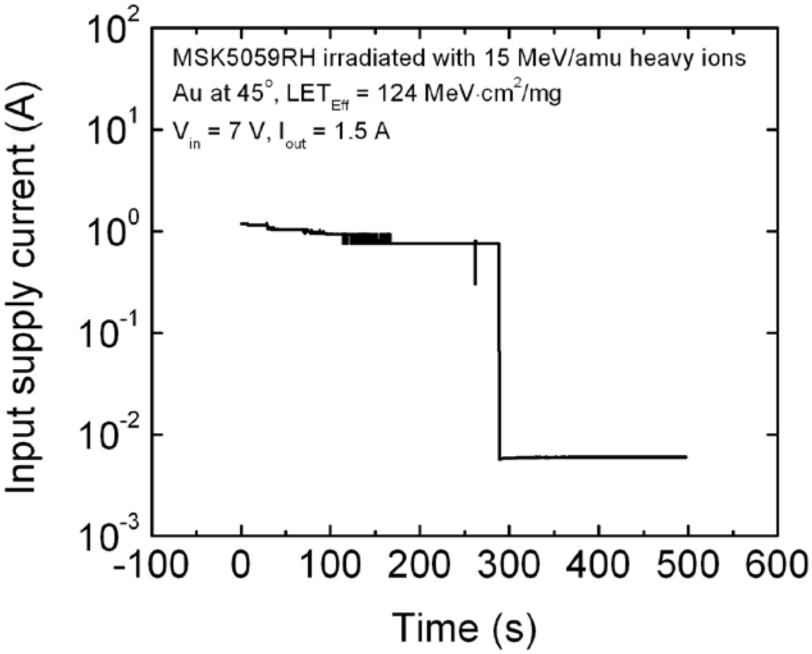

Figure 10. Input supply current vs. time for the MSK5059RH, operating with V_{in} = 7 V and I_{out} = 1.5 A, irradiated with Au at 45^{o}, with an effective LET of 124 MeV·cm^{2}/mg, for 15 MeV/amu tuned heavy-ions (after [2]).

VI. Conclusion

We have examined the SEE susceptibility for the MSK5059RH switching regulator with pulsed-laser irradiation. We identified one area on the die that is sensitive to device functional interrupts in the form of output voltage dropouts. The voltage dropouts occurred for various output loads ranging from 0.2 to 4 A, with an output voltage of 1.8 and 3.3 V. The laser energy threshold for the dropout events lies approximately between 55 and 110 pJ. These energy levels approximately correspond to heavy-ion LET values of 165 to 330 MeV·cm^2/mg. The relatively high LET thresholds are probabilistically not a concern for most space applications.

However the heavy-ion beams have greater penetration range relative to the pulsed-laser beam. So pulsed-laser may not deposit sufficient charges in certain sensitive volumes. Therefore, an additional heavy-ion test may provide a more comprehensive evaluation of the device's SET susceptibility.

VII. Reference

1. MSK5059RH data sheet, "http://www.mskennedy.com/documents/5059RHrc.pdf."
2. NASA test report, "http://radhome.gsfc.nasa.gov/radhome/papers/T120510_MSK5059RH.pdf."