

Heavy ion Single Event Effects test of Switching regulator LM2651 from National Semiconductor

Test Report

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1 Introduction

This report gives heavy ion SEE test data on the switching regulator LM2651 from National Semiconductor. This work has been performed in the frame of the ST5 project.

2 Tested Devices

The tested devices are described in Table 1.

Type	LM2651MTC-ADJ
Manufacturer	National Semiconductors
Function	1.5A high efficiency synchronous switching regulator
Package	TSSOP 16
Package marking	M14 AD 2651MTC-ADJ
Die Marking	See Figure 1
Previous SEE testing	No data available

Table 1: description of the tested devices.

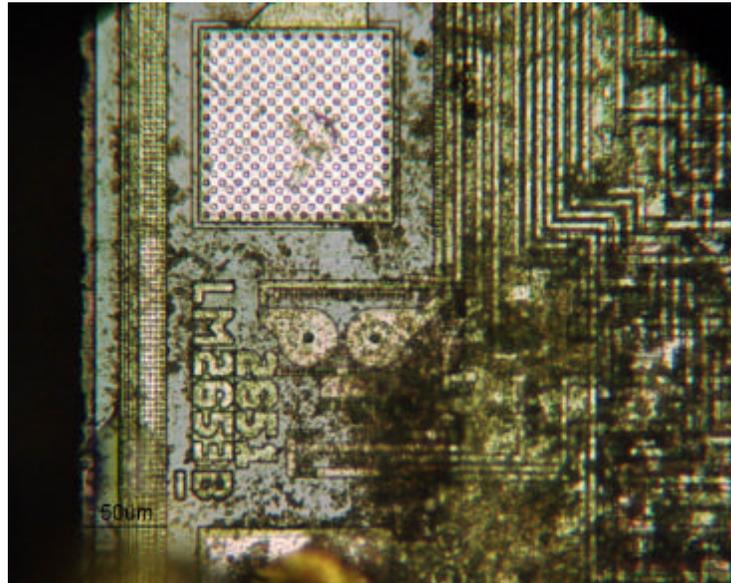


Figure 1: die marking

3 Test description

3.1 Irradiation facility

The tests have been performed at the Brookhaven National Laboratories in March 2002. The ion beams used are described in Table 2.

Ion	Energy (MeV)	Average flux (#/cm²-s)	Range (mm)	LET (MeVcm²/mg)
Cl-35	210	~1E+04	63	11.4
Br-81	280	~2E+04	36	37.4
Ni-58	266	~2E+04	42	26.6

Table 2: Ions used at BNL.

3.2 Test set-up

Figure 2 shows the bias circuitry. The part has been biased with a 10V input voltage. The output voltage has been adjusted to 2.5V. An oscilloscope monitors the device output. As soon as the device output deviates of 500 mV from the nominal output voltage, an output is counted. Three different load conditions have been investigated:

- no load
- Iload=130 mA (40% of maximum load)
- Iload=210 mA (60% of maximum load)

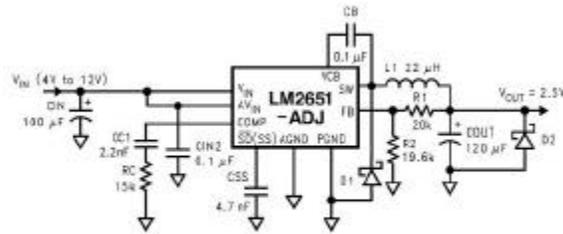


Figure 2: Bias schematics

4 Test results

The test results are presented in Table 3. Three different types of events have been observed:

- Transients: the output goes up to +Vin or down to GND during tens of microseconds.
- The part output is locked at the power supply voltage rail (Vout=8.2V), a power cycling is necessary to recover the part functionality.
- Part failure.

The part is more sensitive to transients without load, but the functional failures occurred with a load.

Cross section curves are shown in Figure 3. The transient LET threshold is about 5 MeVcm²/mg. The transient cross section at saturation is about 1.5E-04 cm²/device. The failure LET threshold is about 25 meVcm²/mg. The failure cross section at saturation is about 2.5E-06 cm²/device. On two parts (SN1 and SN2) the output voltage is at 0 V after the failure. On SN3, the output voltage is equal to +Vin (10V) after the failure. On SN1 and SN3 the failure occurred at the bonding of one of the output power MOSFET as shown in Figure 4.

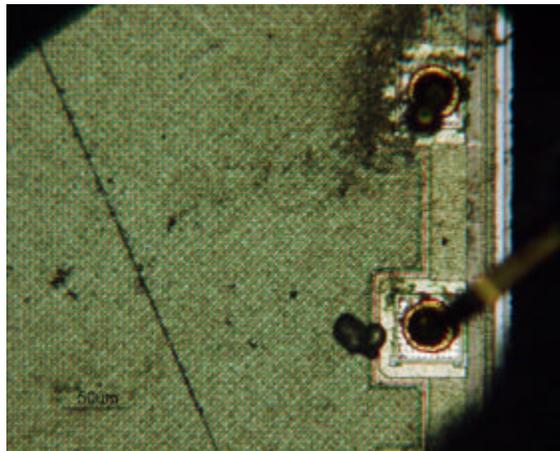


Figure 4: SN1, output MOSFET after the failure

run #	SN #	Iload (mA)	eff. LET (MeVcm ² /mg)	eff. Fluence (#/cm ²)	failure	SET	lockout	Cross section failure (cm ² /dev)	Cross section SET (cm ² /dev)	Cross section lockout (cm ² /dev)
149	1	0	26.55	1.00E+06		1		0.00E+00	1.00E-06	0.00E+00
150	1	0	26.55	3.10E+05			1	0.00E+00	0.00E+00	3.23E-06
151	1	0	26.55	2.50E+05			1	0.00E+00	0.00E+00	4.00E-06
152	1	0	26.55	2.13E+05		30	1	0.00E+00	1.41E-04	4.69E-06
153	1	0	26.55	3.92E+05		11	1	0.00E+00	2.81E-05	2.55E-06
154	1	0	26.55	1.05E+06				0.00E+00	0.00E+00	0.00E+00
155	1	0	26.55	2.20E+05		14	1	0.00E+00	6.36E-05	4.55E-06
156	1	0	26.55	4.70E+05		9	1	0.00E+00	1.91E-05	2.13E-06
157	1	210	26.55	2.60E+04		2		0.00E+00	7.69E-05	0.00E+00
158	1	210	26.55	1.00E+06		3		0.00E+00	3.00E-06	0.00E+00
159	1	210	26.55	1.00E+06		3		0.00E+00	3.00E-06	0.00E+00
160	1	210	26.55	1.00E+06		2		0.00E+00	2.00E-06	0.00E+00
161	1	130	26.55	1.00E+06		6		0.00E+00	6.00E-06	0.00E+00
162	1	130	26.55	1.00E+06		4		0.00E+00	4.00E-06	0.00E+00
163	1	130	26.55	1.00E+06		2		0.00E+00	2.00E-06	0.00E+00
164	2	130	26.55	1.00E+06		3		0.00E+00	3.00E-06	0.00E+00
165	2	130	26.55	1.00E+06		1		0.00E+00	1.00E-06	0.00E+00
166	2	130	26.55	1.00E+06		4		0.00E+00	4.00E-06	0.00E+00
167	2	130	37.55	1.00E+06		10		0.00E+00	1.00E-05	0.00E+00
168	2	130	37.55	1.00E+06		3		0.00E+00	3.00E-06	0.00E+00
169	2	130	53.10	5.00E+05	1	44		2.00E-06	8.80E-05	0.00E+00
170	3	130	26.55	1.00E+06		0		0.00E+00	0.00E+00	0.00E+00
171	3	130	26.55	1.00E+06		1		0.00E+00	1.00E-06	0.00E+00
172	3	130	26.55	8.00E+06		7		0.00E+00	8.75E-07	0.00E+00
173	3	210	26.55	5.00E+06		5		0.00E+00	1.00E-06	0.00E+00
174	3	210	26.55	5.00E+06		2		0.00E+00	4.00E-07	0.00E+00
175	3	0	26.55	6.99E+05		42		0.00E+00	6.01E-05	0.00E+00
176	3	0	26.55	1.20E+06		81		0.00E+00	6.75E-05	0.00E+00
177	3	0	37.55	1.07E+06		113	1	0.00E+00	1.06E-04	9.35E-07
178	3	130	37.55	3.70E+06	1	2		2.70E-07	5.41E-07	0.00E+00
179	1	0	11.40	5.00E+06		100		0.00E+00	2.00E-05	0.00E+00
180	1	0	11.40	5.00E+06		22		0.00E+00	4.40E-06	0.00E+00
181	1	0	17.74	5.00E+06		17		0.00E+00	3.40E-06	0.00E+00
182	1	0	22.80	5.00E+06		131		0.00E+00	2.62E-05	0.00E+00
183	1	0	37.40	2.00E+06		225	1	0.00E+00	1.13E-04	5.00E-07
184	1	210	37.40	1.60E+06	1	95		6.25E-07	5.94E-05	0.00E+00

Table 3: test results

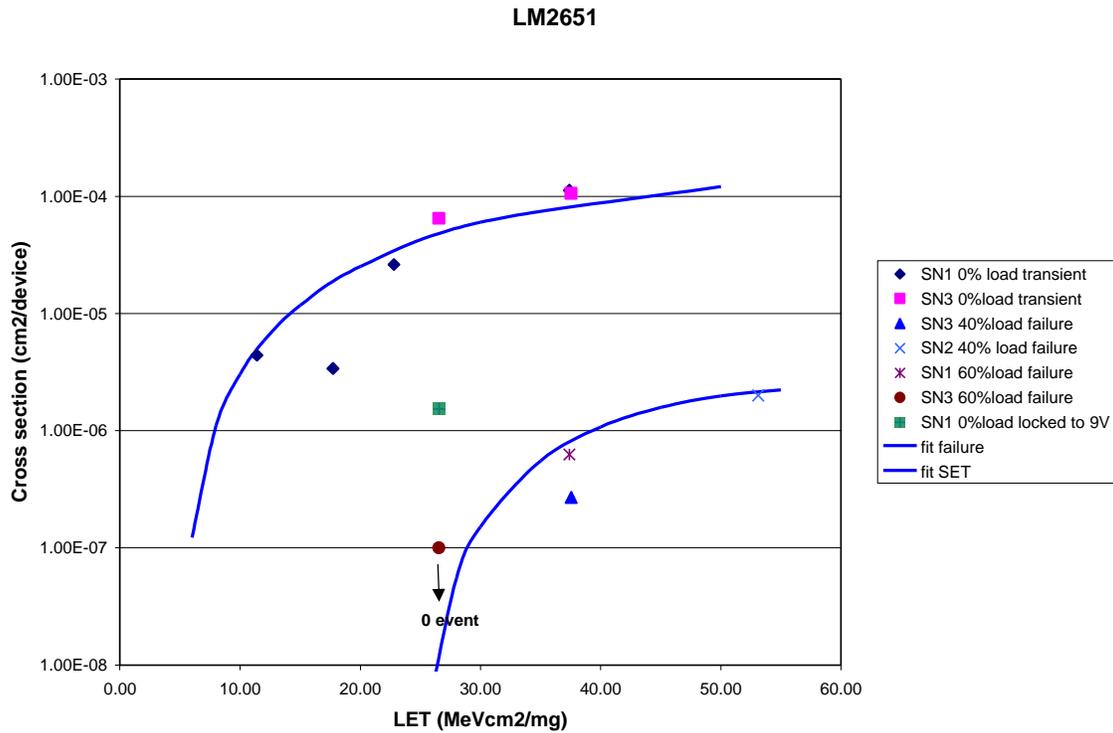


Figure 3: cross section.

A worst-case estimation of the transient and failure rates in the ST5 environment have been performed for the worst-case environment conditions (Galactic Cosmic Rays at solar minimum) and with conservative estimates of the part geometry (thickness of the sensitive volume = 2 μ m). The results are a transient rate of 6E-3 transients/device-day and a failure rate of 2E-7 failures/device-day.

5 Conclusions

The test results show that the switching regulator is sensitive to destructive events. This sensitivity is low. The failure event rate is quasi negligible for the three months ST5 mission. The part is also sensitive to transients, the transient rate is not negligible and a transient is probable during the 3 months ST5 mission. In some cases, the device output is locked to the power supply voltage rail. When the part is locked a power cycling is necessary to recover functionality.