Heavy ion Single Event Effects test of 4A Adjustable Switching regulator MSK5042 from M. S. Kennedy

Test Report

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1 Introduction

This report gives heavy ion SEE test data on the switching regulator MSK5042 from National Semiconductor. This work has been performed in the frame of the ST5 project.
Previous testing in March 2002 showed a Single Event Burnout (SEB) sensitivity of the device power MOSFETs for an input voltage of 30V (maximum device input voltage). This previous test was also performed at a low load condition (Iout < 400 mA) and a 2.5V output voltage.
This new test has been performed in the worst case ST5 bias condition (Vin=8.5V, Iout=1.5A, Vout=5V). Other inputs conditions and load conditions have also been tested.

2 Tested Devices

The tested devices are described in Table 1. A picture of the part is shown in Figure 1.

Type	**MSK5042**
Manufacturer	M. S. Kennedy
Function	4A adjustable switching regulator
Package	44 pin metal package
Package marking	MSK 5042 0204 51651 USA
Previous SEE testing	Previous testing in March 2002 showed a Single Event Burnout (SEB) sensitivity of the device power MOSFETs for the device maximum input voltage of 30V at a LET of 37 MeVcm^2/mg.

Table 1: description of the tested devices.

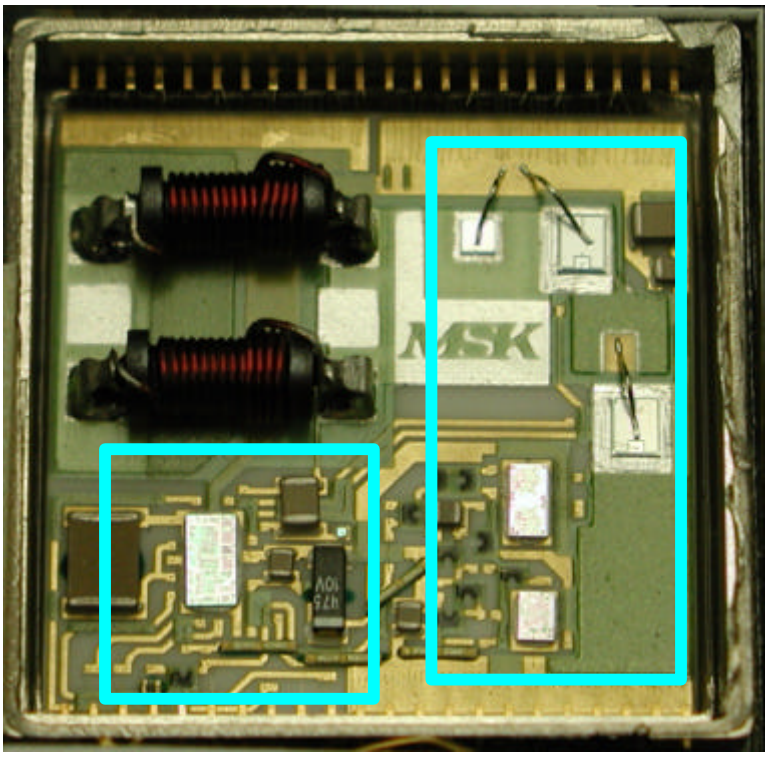

Figure 1: MSK5042

3 Test description

3.1 Irradiation facility

The tests have been performed at the Brookhaven National Laboratories in June 2002. The ion beams used are described in Table 2. The MAX797 controller has been irradiated alone, then the other active parts (REF43 voltage reference, AD822 operational amplifier and the two IRLC034N 60VN channel MOSFETs) have been irradiated together. The two different irradiation areas are shown in Figure 1.

Ion	Energy (MeV)	Average flux (#/cm^2-s)	Range (mm)	LET (MeVcm^2/mg)
C-12	99	~1E+04	184	1.45
F-19	140	~5E+04	77	3.4
Cl-35	210	~1E+04	63	11.4
Br-81	278	~5E+04	36	37.5
I-127	320	~1.5E+03	31	59.7

Table 2: Ions used at BNL.

3.2 Test set-up

Figure 2 shows the bias circuitry. The output voltage has been adjusted to 5V. An oscilloscope monitors the device output. As soon as the device output deviates of 500 mV from the nominal output voltage, an event is counted.

Most of the tests have been performed for an input voltage of 8.5V and an output current of 1.5A. This represents the worst case ST5 application (maximum input voltage and maximum output current). Different input voltages and load conditions have also been tested.

The input current was also monitored during the experiments to check for Single Event Latchup. The Latchup detection threshold was set to 2A. As soon as the input current is higher than 2A, the input voltage is shutdown and a latchup event is counted. Table 3 gives the typical measured input current for the different test conditions.

Vin (V)	Iout (A)	Icc (A)
8.5	0.5	0.4
8.5	1.0	0.8
8.5	**1.5**	**1.2**
8.5	2.0	1.7
12.0	0.3	0.2
12.0	0.5	0.3
12.0	0.8	0.4
12.0	1.0	0.6
12.0	1.5	0.9
12.0	2.5	1.5

Table 3: Typical input current for the different input and load test conditions.

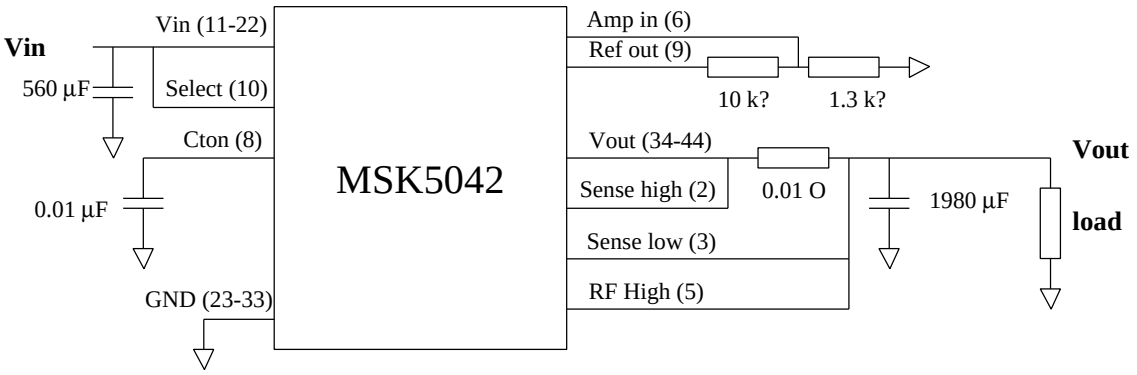

Figure 2: Bias schematics

4 Test results

The test results are presented in Table 4. For the different tested conditions, when the MOSFET and linear devices is irradiated no sensitivity to any event (SEB, SET) has been found. When the mAX797 controller was irradiated, different types of events have been seen:

- output voltage lockout for high load conditions (Iout>1A)
- output oscillations for medium load conditions (Iout ~ 1A)
- output transients for low load conditions (Iout < 750mA)

The part recovers from lockout or oscillation conditions when the load is disconnected without power cycling the device. The devices recovers also after a power cycling, but it takes a longer time because of the large input and output capacitors used in the applications.

The cross section curve is shown in Figure 3.

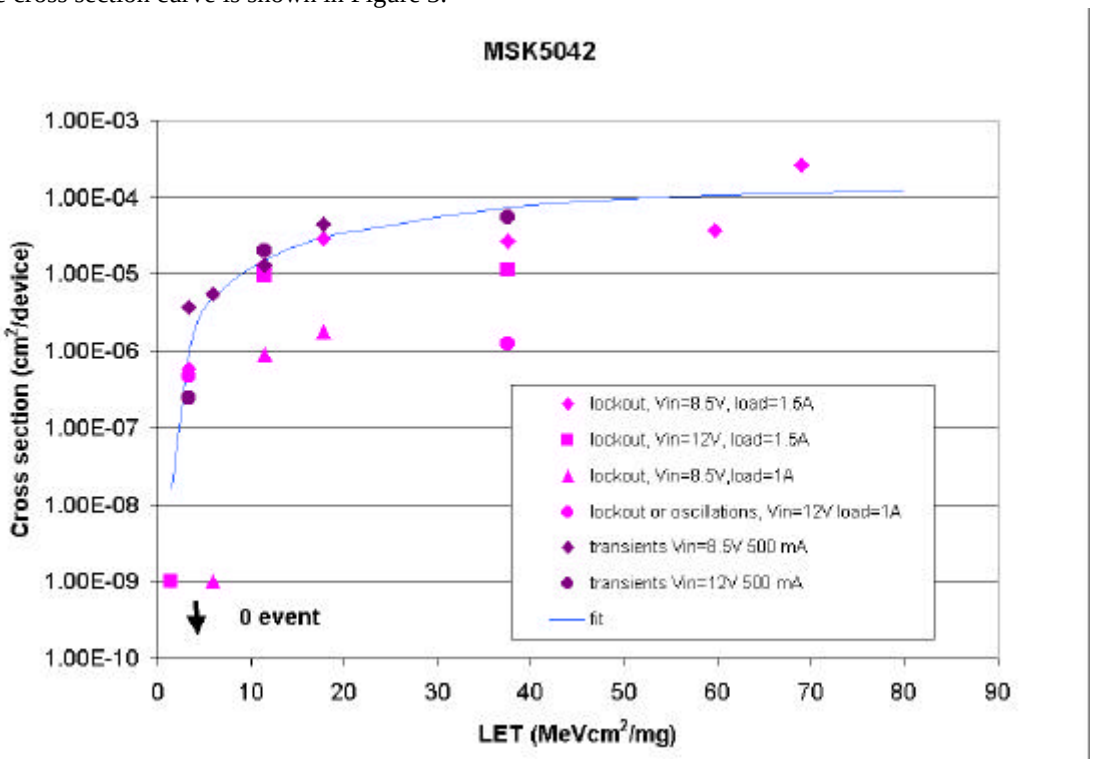

Figure 3: Cross section curve.

Run #	SN #	irradiated area	Vin (V)	Iout (A)	tilt	eff. LET (MeVcm2/mg)	eff. Fluence (#/cm2)	SEL/ SEB	SET	SEFI	Xsec SET	Xsec SEFI	comment
2	290	controller	8.5	1.5	0	37.47	4.10E+04	0	0	1	0.00E+00	2.44E-05	output dropped to 0
3	290	controller	8.5	1.5	0	37.47	3.24E+04	0	0	1	0.00E+00	3.09E-05	output dropped to 0
4	290	linear+MOSFET	8.5	1.5	0	37.47	1.00E+07	0	0	0	0.00E+00	0.00E+00	
5	290	linear+MOSFET	8.5	2.0	0	37.47	1.00E+07	0	0	0	0.00E+00	0.00E+00	
6	290	linear+MOSFET	8.5	1.0	0	37.47	1.00E+07	0	0	0	0.00E+00	0.00E+00	
7	290	linear+MOSFET	12.0	1.5	0	37.47	1.00E+07	0	0	0	0.00E+00	0.00E+00	
8	290	controller	12.0	1.5	0	37.47	9.95E+04	0	0	1	0.00E+00	1.01E-05	output dropped to 0
9	316	controller	12.0	1.5	0	37.47	6.54E+04	0	0	1	0.00E+00	1.53E-05	output dropped to 0
10	316	controller	12.0	0.5	0	37.47	4.88E+06	0	352	1	7.21E-05	2.05E-07	
12	316	controller	12.0	1.0	0	37.47	8.99E+05	0	0	0	0.00E+00	0.00E+00	output oscillates
13	316	controller	12.0	0.5	0	37.47	2.38E+05	0	15	0	6.30E-05	0.00E+00	
14	316	controller	12.0	0.8	0	37.47	1.37E+05	0	106	0	7.74E-04	0.00E+00	
15	316	controller	12.0	1.0	0	37.47	9.40E+04	0	0	1	0.00E+00	1.06E-05	output oscillates
16	316	linear+MOSFET	12.0	1.5	0	37.47	1.00E+07	0	0	0	0.00E+00	0.00E+00	
17	316	controller	12.0	1.0	0	37.47	6.00E+05	0	0	1	0.00E+00	1.67E-06	output oscillates (6Hz frequency)
18	293	controller	12.0	1.5	0	37.47	9.83E+04	0	0	1	0.00E+00	1.02E-05	output dropped to 0
19	293	controller	12.0	0.5	0	37.47	1.50E+06	0	0	1	0.00E+00	6.67E-07	output oscillates and then dropped to 0
20	293	controller	12.0	0.3	0	37.47	5.00E+06	0	0	0	0.00E+00	0.00E+00	
21	293	controller	12.0	0.3	0	37.47	1.64E+06	0	97	0	5.91E-05	0.00E+00	
22	293	controller	12.0	0.5	0	37.47	1.48E+06	0	107	0	7.23E-05	0.00E+00	
23	293	linear+MOSFET	12.0	1.5	0	37.47	1.00E+07	0	0	0	0.00E+00	0.00E+00	
24	293	linear+MOSFET	12.0	1.5	0	11.44	5.30E+05	0	0	0	0.00E+00	0.00E+00	
25	293	controller	12.0	1.5	0	11.44	2.46E+05	0	0	1	0.00E+00	4.07E-06	output dropped to 0
26	293	controller	12.0	1.5	0	11.44	3.11E+04	0	0	1	0.00E+00	3.22E-05	output dropped to 0
27	293	controller	12.0	1.5	0	11.44	3.60E+04	0	0	1	0.00E+00	2.78E-05	output dropped to 0
28	293	controller	12.0	0.5	0	11.44	2.44E+06	0	50	0	2.05E-05	0.00E+00	
29	293	controller	12.0	1.0	0	11.44	8.13E+04	0	0	1	0.00E+00	1.23E-05	output dropped to 0
30	293	controller	8.5	1.0	0	11.44	3.13E+06	0	52	0	1.66E-05	0.00E+00	
31	293	controller	8.5	1.5	0	11.44	6.90E+04	0	0	1	0.00E+00	1.45E-05	output dropped to 0
32	293	controller	8.5	1.5	50	17.80	4.20E+04	0	0	1	0.00E+00	2.38E-05	output dropped to 0
33	293	controller	8.5	1.0	50	17.80	8.60E+05	1	36	0	4.19E-05	0.00E+00	current spike, SEL?
34	293	controller	8.5	1.0	50	17.80	2.14E+05	1	7	0	3.27E-05	0.00E+00	current spike, SEL?
35	316	controller	8.5	1.5	0	11.44	1.55E+05	0	0	1	0.00E+00	6.45E-06	output dropped to 0
36	316	controller	8.5	1.0	0	11.44	4.90E+04	0	0	1	0.00E+00	2.04E-05	output dropped to 0
37	316	controller	8.5	1.0	0	11.44	1.02E+05	0	0	1	0.00E+00	9.80E-06	output dropped to 0
38	316	controller	8.5	0.5	0	11.44	2.48E+06	0	28	0	1.13E-05	0.00E+00	
39	316	controller	8.5	0.5	50	17.80	1.25E+06	0	54	0	4.32E-05	0.00E+00	
40	316	controller	8.5	1.5	50	17.80	2.91E+04	0	0	1	0.00E+00	3.44E-05	output dropped to 0
41	316	controller	8.5	1.0	50	17.80	2.38E+04	0	0	1	0.00E+00	4.20E-05	output dropped to 0
42	290	controller	8.5	1.5	0	11.44	2.74E+04	0	0	1	0.00E+00	3.65E-05	output dropped to 0
43	290	controller	8.5	1.0	0	11.44	3.85E+04	0	0	1	0.00E+00	2.60E-05	output dropped to 0
44	290	controller	8.5	0.5	0	11.44	1.88E+06	0	30	0	1.60E-05	0.00E+00	
45	290	controller	8.5	0.5	50	17.80	3.11E+04	0	1	0	3.22E-05	0.00E+00	
46	290	controller	8.5	0.5	50	17.80	1.22E+06	0	58	0	4.75E-05	0.00E+00	
47	290	controller	8.5	1.5	50	17.80	3.31E+04	0	0	1	0.00E+00	3.02E-05	output dropped to 0
48	290	controller	8.5	1.0	50	17.80	2.90E+04	0	0	1	0.00E+00	3.45E-05	output dropped to 0
49	290	controller	8.5	1.5	0	3.38	1.25E+06	0	0	1	0.00E+00	8.00E-07	output dropped to 0
50	290	controller	8.5	1.0	0	3.38	1.00E+07	0	46	0	4.60E-06	0.00E+00	
51	290	controller	8.5	0.5	0	3.38	6.00E+06	0	22	0	3.67E-06	0.00E+00	
52	290	controller	8.5	0.5	55	5.89	3.70E+06	0	20	0	5.41E-06	0.00E+00	

Table 4: Test results (1/2)

Run #	SN #	irradiated area	Vin (V)	Iout (A)	tilt	eff. LET (MeVcm2/mg)	eff. Fluence (#/cm2)	SEL/ SEB	SET	SEFI	Xsec SET	Xsec SEFI	comment
53	290	controller	8.5	1.5	55	5.89	2.25E+05	0	0	1	0.00E+00	4.44E-06	output dropped to 0
54	290	controller	8.5	1.0	55	5.89	4.99E+06	0	18	0	3.61E-06	0.00E+00	
55	290	controller	12.0	1.0	0	3.38	1.90E+06	0	0	1	0.00E+00	5.26E-07	output oscillates
56	316	controller	8.5	1.5	0	3.38	3.74E+06	0	0	1	0.00E+00	2.67E-07	output dropped to 0
57	316	controller	8.5	1.0	0	3.38	1.00E+07	0	0	0	0.00E+00	0.00E+00	
58	316	controller	12.0	1.0	0	3.38	2.50E+06	0	0	1	0.00E+00	4.00E-07	output oscillates
59	316	controller	12.0	0.5	0	3.38	1.00E+07	0	3	0	3.00E-07	0.00E+00	
60	293	controller	8.5	1.5	0	3.38	2.30E+05	0	0	1	0.00E+00	4.35E-06	output dropped to 0
61	293	controller	8.5	1.0	0	3.38	1.00E+07	0	0	0	0.00E+00	0.00E+00	
62	293	controller	12.0	1.0	0	3.38	2.06E+06	0	0	1	0.00E+00	4.85E-07	output dropped to 0
63	293	controller	12.0	0.5	0	3.38	1.00E+07	0	2	0	2.00E-07	0.00E+00	
64	293	linear+MOSFET	8.5	1.5	0	59.70	1.00E+07	0	0	0	0.00E+00	0.00E+00	
65	293	linear+MOSFET	12.0	1.5	0	59.70	1.00E+07	0	0	0	0.00E+00	0.00E+00	
66	293	linear+MOSFET	12.0	2.5	0	59.70	1.00E+07	0	0	0	0.00E+00	0.00E+00	
67	293	linear+MOSFET	12.0	0.5	0	59.70	1.00E+07	0	0	0	0.00E+00	0.00E+00	
68	290	linear+MOSFET	12.0	1.5	0	59.70	1.00E+07	0	0	0	0.00E+00	0.00E+00	
69	290	controller	8.5	1.5	0	59.70	2.08E+04	0	0	1	0.00E+00	4.81E-05	output dropped to 0
70	290	controller	8.5	1.5	30	68.94	2.30E+03	0	0	1	0.00E+00	4.35E-04	output dropped to 0
71	290	controller	8.5	1.5	30	68.94	5.25E+03	0	0	1	0.00E+00	1.90E-04	output dropped to 0
72	290	controller	8.5	1.5	0	59.70	3.35E+04	0	0	1	0.00E+00	2.99E-05	output dropped to 0
73	290	controller	8.5	1.5	0	1.45	1.00E+07	0	0	0	0.00E+00	0.00E+00	
74	290	controller	12.0	1.5	0	1.45	4.85E+06	0	0	0	0.00E+00	0.00E+00	

Table 4: test results (2/2)

Figure 4 shows an example of a lockout, Figure 5 shows an example of oscillation, and Figure 6 shows a typical transient.

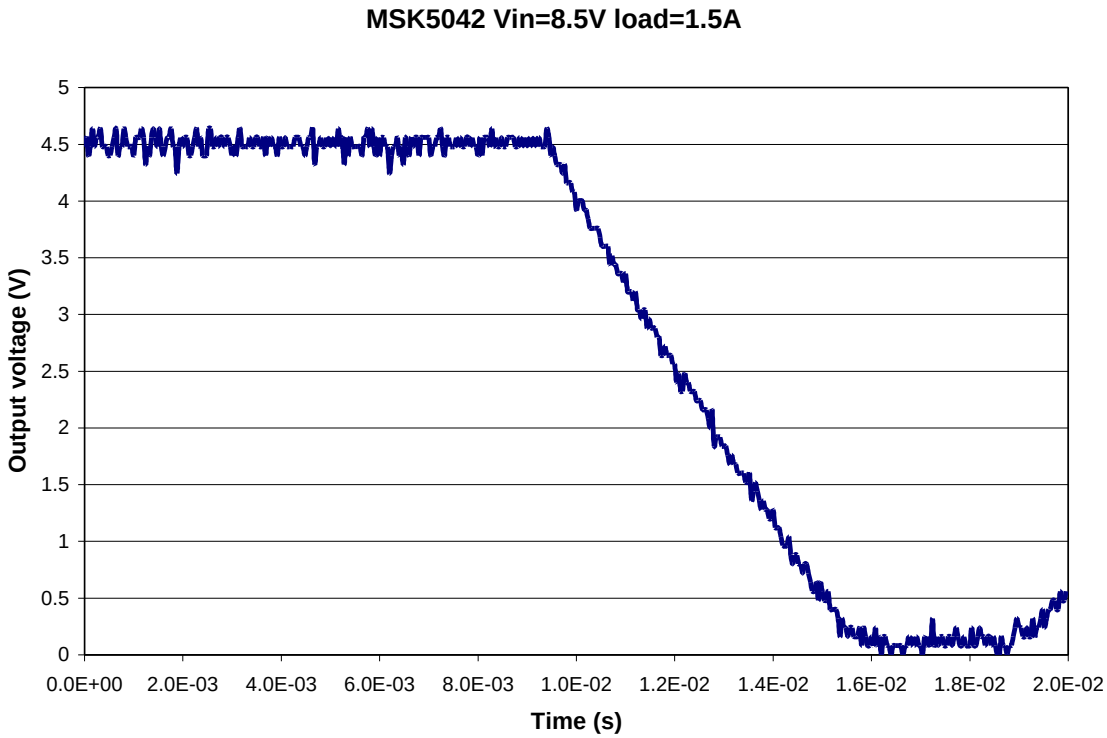

Figure 4: example of a lockout.

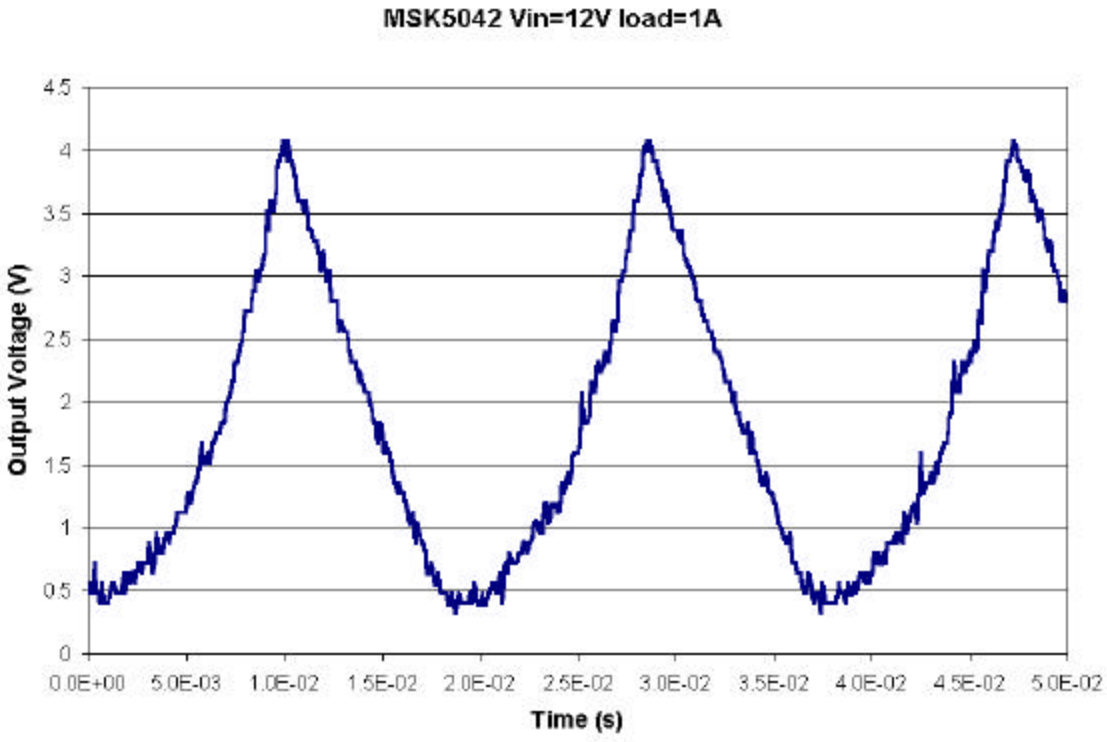

Figure 5: example of oscillations.

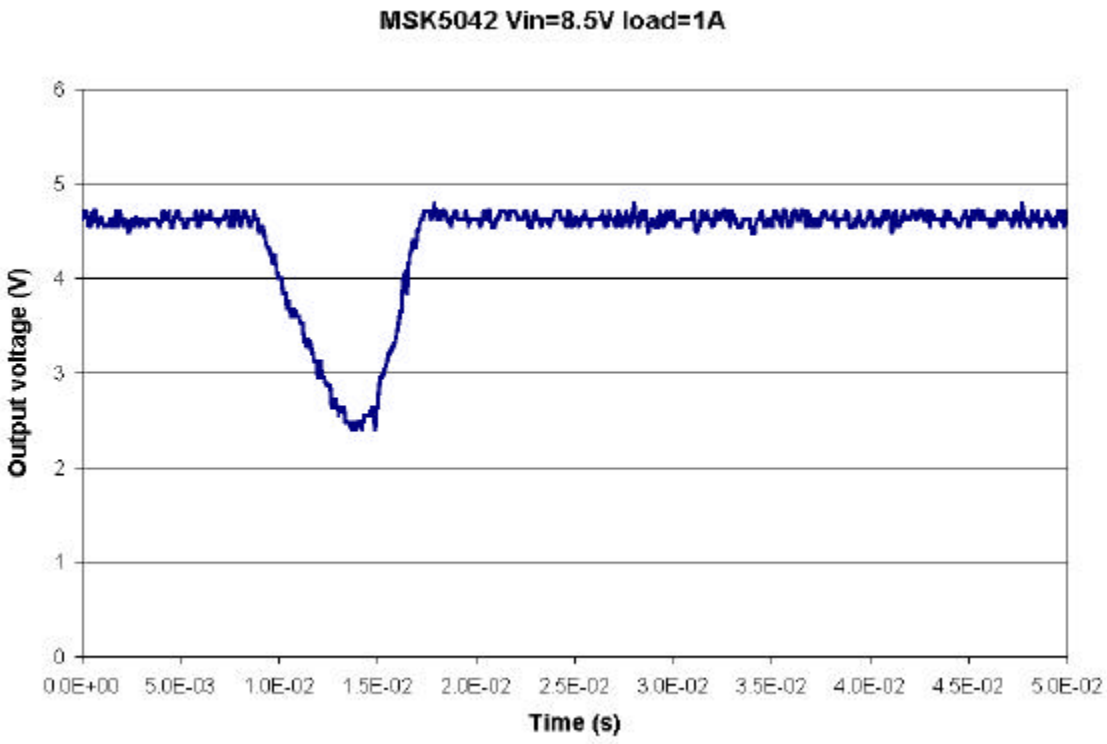

Figure 6: example of a typical transient.

The event rates have been calculated for the ST5 worst case background environment (GCR solar minimum), and the Solar Particle Event (SPE) worst day model of CREME96. The results are shown in Table 5.

	Event rate (event/device-day)
GCR solar minimum	0.05
SPE worst day	0.9

Table 5: Event rates on ST5

5 Conclusions

The part is sensitive to lockout or oscillations conditions for high load applications and transients for low load applications. The risk of such events is high, several events are expected during the 3 months ST5 mission, and one event is expected during a Solar Particle Event. Therefore the designs needs to be able to recover from a lockout condition for high load applications. And for low load applications, the designs have to be tolerant to transients of about 5 ms duration.