Transient SEU Characterisation of Analog IC's for ESA's Satellite

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Abstract

Data analysis of four self switch-off power supply events in the SOHO satellite pointed strongly in the direction of being Cosmic Ray or Proton induced. Further analysis of the relevant power supply schematics identified a number of analog IC's capable of causing or contributing to such events. This paper concentrates on the testing aspects of these analog IC's and presents the results of a Single Event Effects (SEEs) test program. Ground testing, simulating the flight conditions, were carried out at both heavy ion and proton accelerators.

I. INTRODUCTION

The SOHO (Solar and Heliospheric Observatory) satellite orbiting at the Lagrangian point L1 about 1.5 million Km from the earth, is a ESA/NASA scientific satellite. During three years of successful operations, SOHO experienced four power supply switch-off, two in the service module and two in the payload module, all recoverable. Even though SOHO operates in a relative quiet environment regarding Galactic Cosmic Rays, these four events were believed to originate from space radiation as Single Event Upset (SEU) in one or more of the following analog semiconductors IC's:

LM/PM139 Quad Voltage Comparator
UC1707J Dual Channel Power Driver
UC1842J Current Mode PWM Controller
RH1078 Dual, Single Supply, Precision Op Amp

However, lacking detailed knowledge of these components SEU behaviour, a major ground test program was put together. This program, funded by ESA's next scientific satellite XMM (X-Ray Multi-Mirror), had high priority, as several of SOHOs PS designs are re-used in XMM.

II. DEVICES TESTED

Flight lot devices, as detailed as ID 1 to 4 in Table 1, were characterised during this ground test program. In addition to these four types, LM139 devices from National Semiconductor and LM339 devices from SGS Thomson, were also included for comparison.

The four self switch-off events happened in power supplies using the following IC's:

a) – ACU PSU	PM139, UC1707J and UC1842J
b) – CDMU PCCS	PM139 and UC1707J
c) – LASCO PSU	PM139 and UC1707J
d) – VIRGO PSU	PM139

So overall, six device types were ground SEU characterised using various SOHO/XMM designs and operating conditions, during heavy ion and proton accelerator testing.

III. TEST CONDITIONS & RESULTS

Where available, SOHO/XMM flight conditions were used during these ground SEU tests carried out at the Heavy Ion Irradiation Facility at Cyclone, UCL, Belgium and at the Proton Irradiation Facility, PSI, Switzerland.

Test condition were used as follows;

LM/PM139 Quad Voltage Comparator

Test Conditions:

Two test configurations were used, one representing the VIRGO design with VDD = 10.0 V and Cond. 1) input levels of Ref. V = 300 mV and Line V = 290 mV, and Cond. 2) Ref. V = 300 mV and Line V = 250 mV, see Figure 1 (*not inc. here*). SEU was monitored and counted at three locations:

Table 1. Anolog IC identification chart.

SOHO/XMM FLIGHT LOT DEVICES - SEE TESTED 1998

ID s/n	DEVICE	MANUFACTURER MARKING/DATE CODE	DIE MARKING	DIE mm²	PACKAGE	FUNCTION
1	UC1707J	Unitrode SIC01-01002B OC9145	BIPOLAR 1707 SMG U84	5.56	CERDIP DIL-16C	Dual Channel Power Driver
2	UC1842J	Unitrode SIC01-00902B OC9146	BIPOLAR 1842 U85	4.20	CERDIP DIL-8C	Current Mode PWM Controller
3	RH1078	Linear Technology XMIG0067 01BR 9638A	BIPOLAR M 1987	5.51	CERDIP DIL-8C	Dual, Single Supply, Precision Op Amp
4	PM139	Analog Devices/PMI JM38510/11201SCA 9524A	BIPOLAR 3003Y 1987	1.50	CERDIP DIL-14C	Quad Voltage Comparator
5	LM139J	National Semiconductor LM139J B9718AB	BIPOLAR 1901F	1.32	CERDIP DIL-14C	Quad Voltage Comparator
6	LM339	SGS Thomson LM339D1 9836	BIPOLAR 0339 ST 1993	1.82	Side-B DIL14C	Quad Voltage Comparator

a) at the output of the latch F01, b) at the output of the comparator F02 and c) at L01 to verify a permanent latch (delay period of 100 ms). In addition tests were carried out with a de-coupling capacitor of 1 nF on the base of T02, thus filtering the transient puls.

The comparator condition with VDD = 10.0 V used input levels of: Cond. 1) VI1 = 100 mV and VI2 = 50 mV, Cond. 2) VI1 = 7.10 V and VI2 = 7.05 V, and Cond. 3) VI1 = 1.05 V and VI2 = 50 mV, see Figure 2. The output comparator fixed at 10.0 V uses threshold levels of a) large errors = amplitudes of > 8.0 V and b) small errors = amplitudes of > 2.0 V.

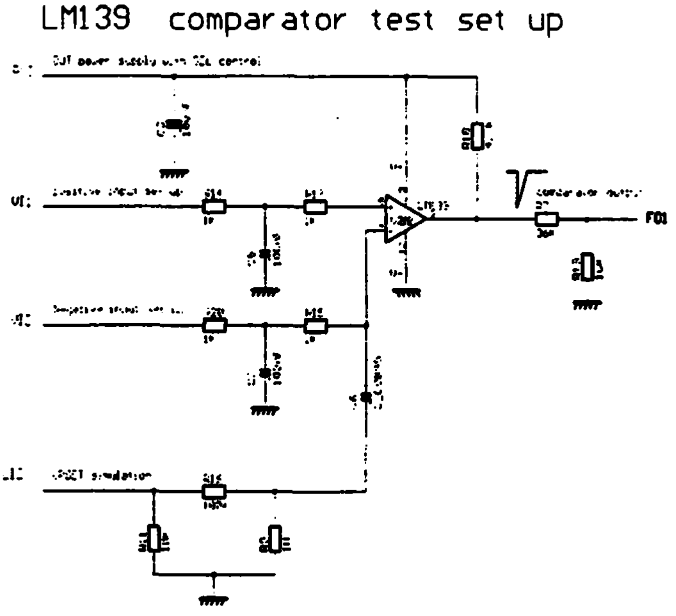

Figure 2 LM139 - Comparator test schematic.

Similarly, Figure 1 and other test conditions inc. schematics will be included for the other three device types.

Heavy Ion Results LM139, NS:

Heavy ion transient SEU results for the two test conditions are shown in Figure 3. These NS results are presented for the VIRGO condition and for comparator conditions Cond. 1 and Cond. 2.

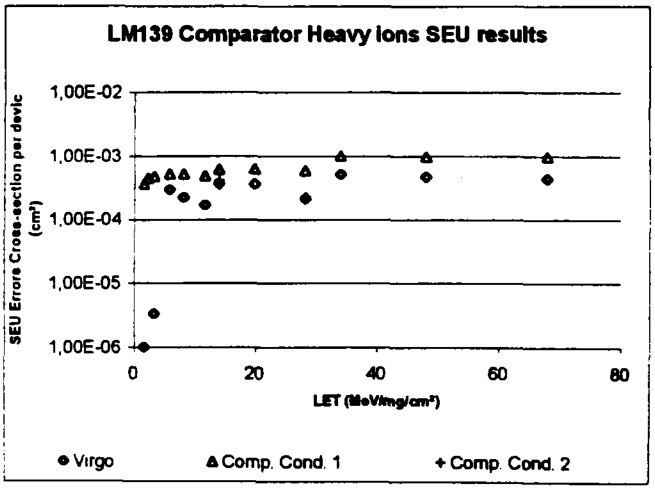

Figure 3. Heavy ion transient SEU results for NS LM139.

Proton Results LM139, NS:

One transient SEU was measured at 300 MeV at a fluence of 1.0E11 protons/cm² for the VIRGO testing. Comparator testing showed transient SEU sensitivities as follows: Cond. 1, see Figure 4, Cond. 2, two SEUs at 300 MeV for a fluence of 1.2E11 protons/cm² and Cond. 3, no errors for 300 MeV and a fluence of 1.2E11 protons/cm². Obviously here, the SEU rate strongly depend on input levels.

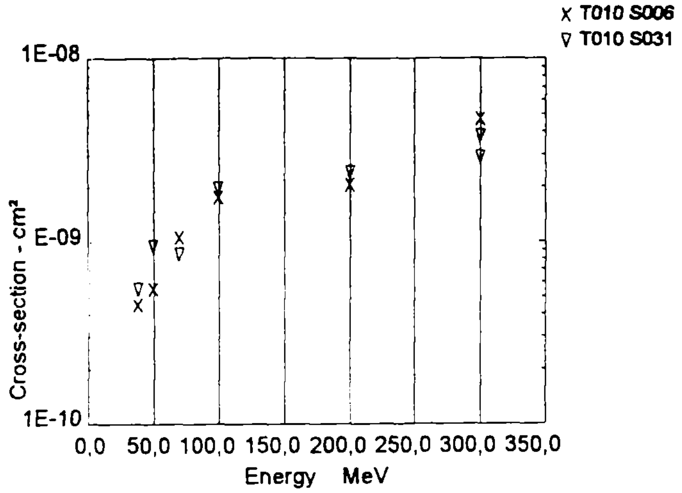

Figure 4. Proton transient SEU results for NS LM139, Test Cond. 1.

The envelope of comperator waveforms as recorded by the scope can be seen in Figure 5. Typical waveforms are rail to rail and up to 2 microseconds.

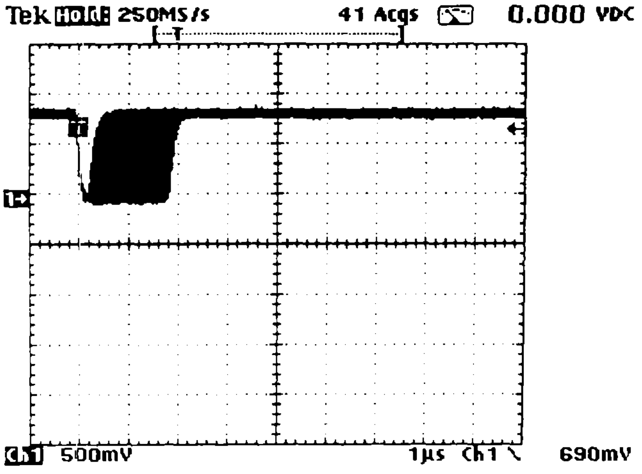

Figure 5. LM139 NS, transient envelope of heavy ion SEUs. (5V/div - 1us/div)

Only these examples of SEU results will be inc. here as we at present have 14 graphs, 18 tables and 16 scope records to select from (most relevant will be selected).

IV. CONCLUSIONS

All device types tested here showed transient SEU to levels far higher than expected. Earlier papers indicated this high rate but did not sufficiently cover all aspect of ground testing. Obviously relevant devices and test conditions are mandatory if accurate transient SEU characterisation have to be carried out. However, in the end it is the circuit design which is the weak point if it allows a 2 microsecond spike to switch a latch, responsible for the "off" condition of a power supply. As also shown here, often a filter capacitor of 1 to 100 nF in the design could improve the situation! Finally, apart from creating transient SEU's, non-of the tested types showed any other defects or errors stopping them for being used in space projects.

V. REFERENCES

Several references will be included in the final paper (Nichels, Koga, Johnson etc).