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ESA-QCA0006S-C

RADIATION TEST REPORT

Heavy Ions Testing of

LM339

Quad Voltage Comparator

from SGS Thomson

ESA Purchase Order No 181635 dated 13/08/98

European Space Agency Contract Report

The work described in this report was done under ESA contract.
Responsibility for the contents resides in the author or organization that prepared it

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III. DEVICE INFORMATION

III.1 DEVICE DESCRIPTION

Quad Voltage Comparator.

III.2 PROCUREMENT OF TEST SAMPLES

4 standard samples have been procured by Hirex.

III.3 PREPARATION OF SAMPLES

4 devices have been serialized with the following numbers #1, #2, #3, #4, and then delidded by ESA.
No sample has been mechanically damaged during this operation.

III.4 SAMPLES CHECK OUT

A functional test sequence has been performed on delidded samples to check that devices have not been degraded by the delidding operation.

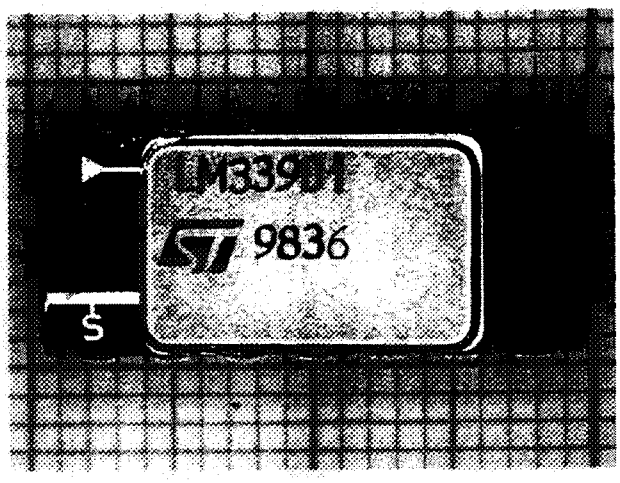
III.5 DEVICE DESCRIPTION

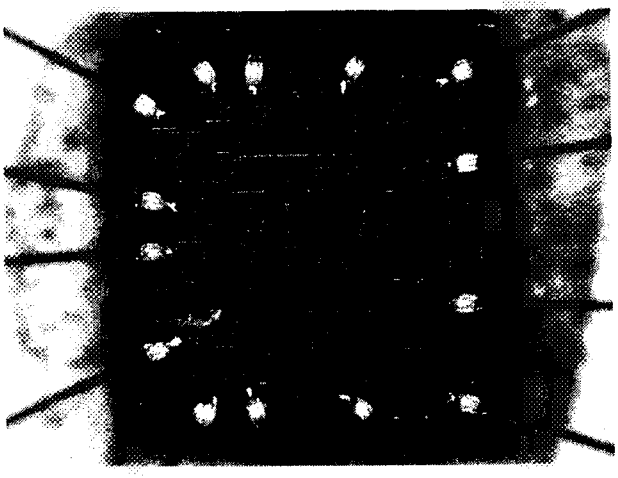
Description of the devices is as follows:

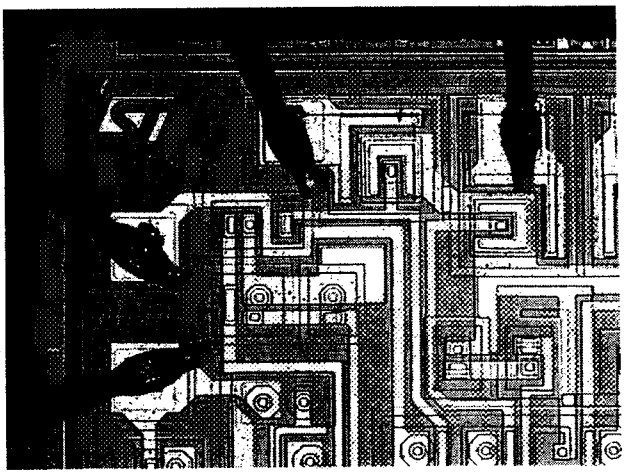
Part type :	LM339D1
Manufacturer :	SGS Thomson
Package :	Side brazed DIL-14
Quality Level :	Standard
Date Code :	9836
Serial Number :	#1, #2, #3, #4
Die Technology :	Bipolar
Top Marking:	LM339D1 ST 9836
Die Size :	1.4 mm x 1.3 mm approximately
Die Marking :	0339 1993 PD98
Tested samples :	4 (#1, #2, #3, #4)

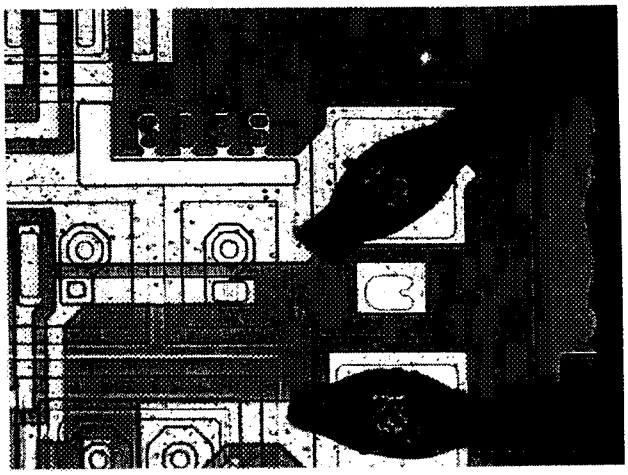
External and Internal Photos are shown in Figure III-1.

Figure III-1 - External and Internal Photos









IV. DEVICE TEST PATTERN DEFINITION

IV.1 PREPARATION OF TEST HARDWARE AND PROGRAM

Overall device emulation, SEU and Latch-up detection, data storage and processing were implemented using an in-house test hardware and an application specific test board.

The generic in-house test equipment is driven by a PC computer through a RS232 line. All power supplies and input signals are delivered and monitored by the in-house equipment which also stores in its memory the output data from the device throughout the specific test board.

The application specific test board allowed to interface the standard test hardware with the device under test, in order to correctly emulate the relevant part, to record all the different type of errors during the irradiation and to set output signal for processing and storage by the standard test equipment.

At the end of each test run, data are transferred to the PC computer through the RS232 link for storage on hard disk or floppies.

IV.2 GENERIC TEST SET-UP

The complete test equipment is constituted of:

- A PC computer (to configure and interface with the test system and store the data),
- An electronic rack with the instrumentation functions provided by a set of electronic modules,
- A mother board under vacuum which allows for the sequential test of up to 4 devices
- A digital oscilloscope to store analog upset waveform

Generic device test set-up is presented in Figure IV-1.

IV.2.1 Mother board description (ref. IL110)

The motherboard acts as a standard interface between each DUT test board and the control unit :
For each DUT board slot , the following signals can be considered:

- 8 inputs signals
  - 4 programmable power supplies
  - 4 programmable clocks
- 8 output signals
  - 4 logic counting signals
  - 2 fast analog signals
  - 2 accurate analog signals

- Each device needs a dedicated plug-in test board compatible with IL110 mother board.
- IL110 board has been designed to comply with Louvain Test facilities .
- The number of slots is limited to four

Operation is multiplexed and only one slot is powered at one time.

Mother board synoptic is shown in Figure IV-2.

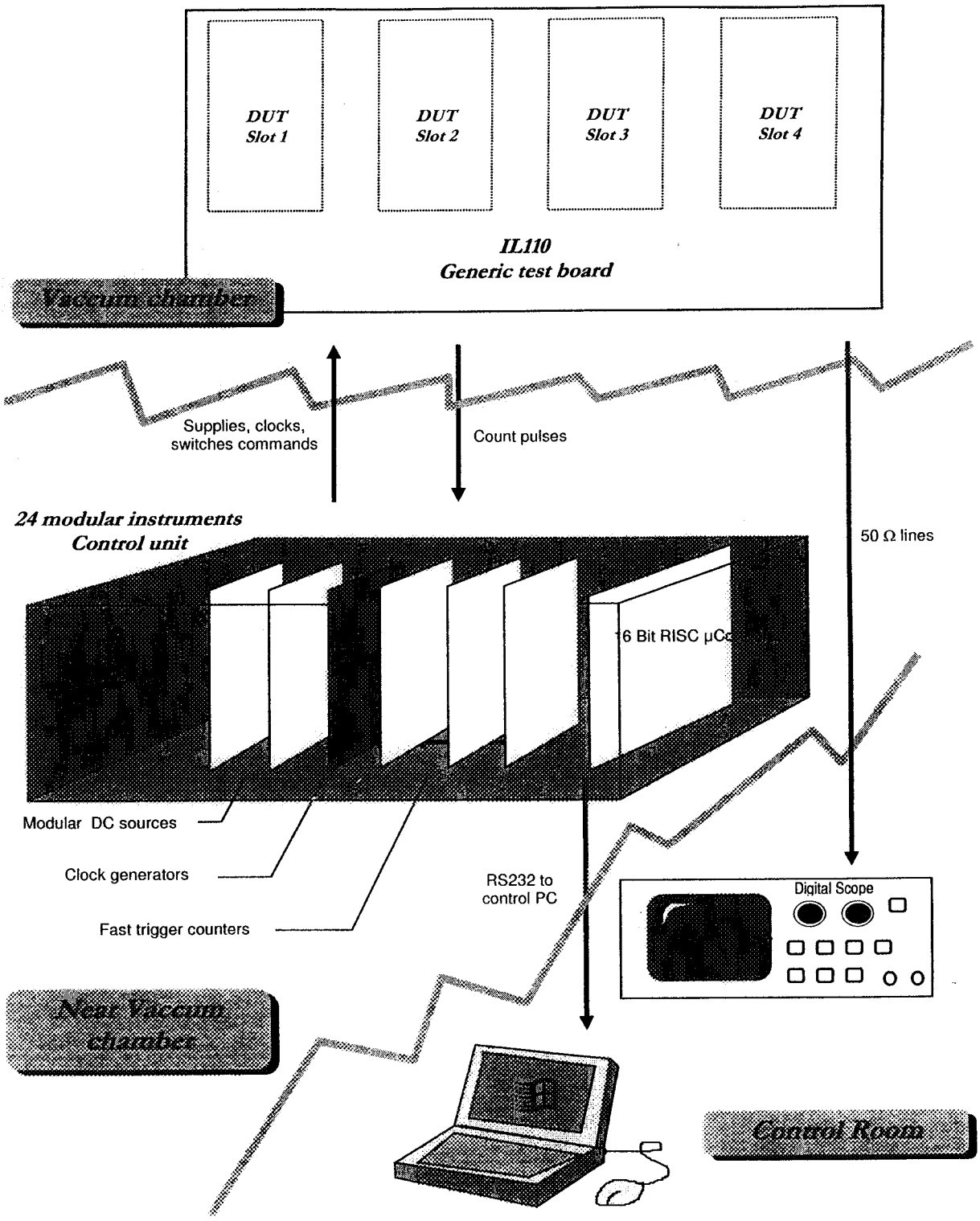


Figure IV-1 - Generic Device Test Set-up

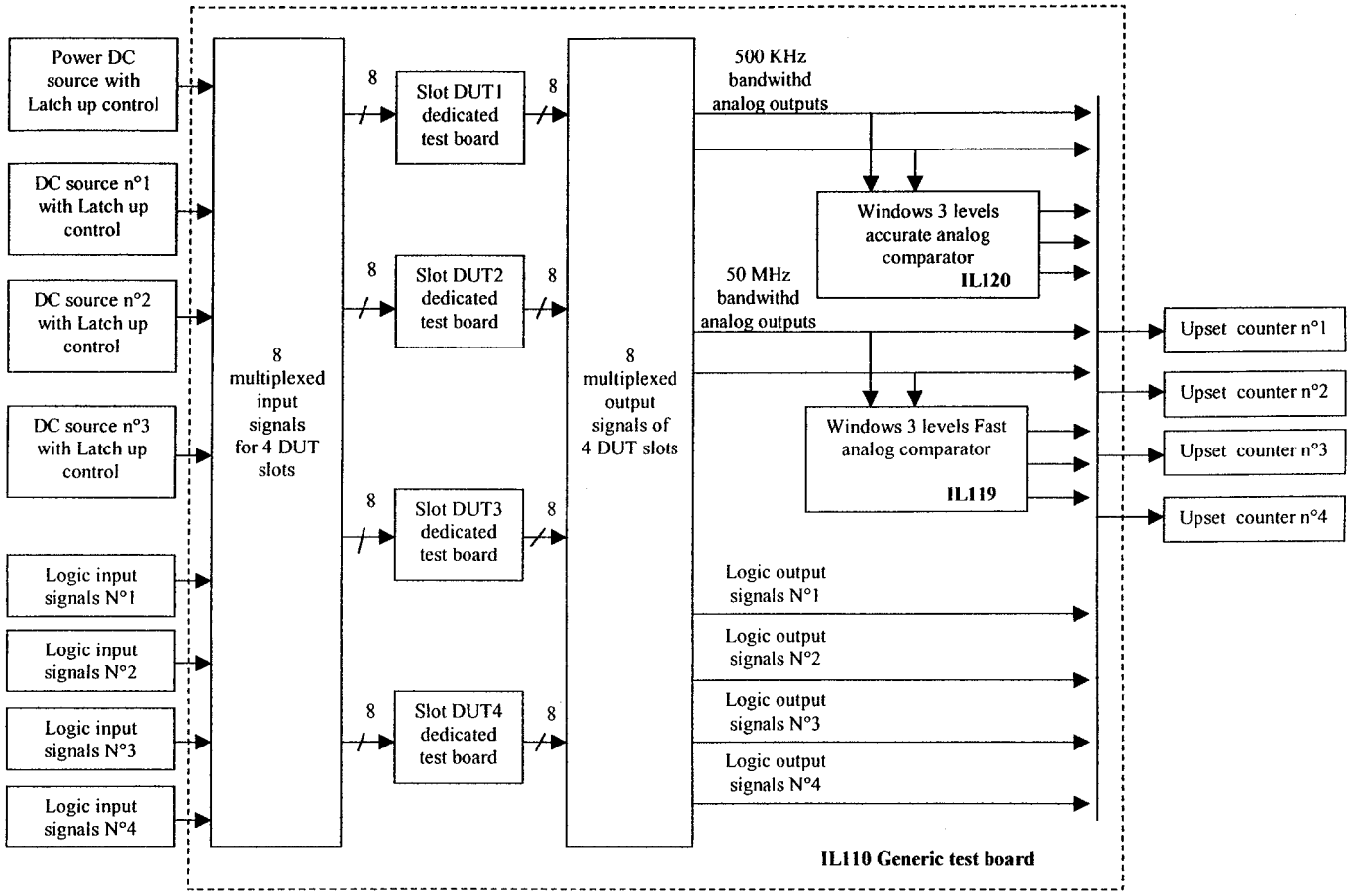


Figure IV-2 - Mother board synoptic

IV.2.2 DUT Test board description

The device under test is mounted on a specific board support which is plugged onto the motherboard.
Mechanical outlines : 141 mm x 50 mm, wrapping or printed circuit board with two 20 pins connectors.
According to test set up and device operating conditions, the test board can accept the mounting of :

- The DUT package with beam positioning constraints (unique for Louvain facilities)
- The golden chip
- The pattern generator
- any interface circuit such as buffer, latches ...
- a standalone micro controller if necessary...

Note : Beam focus diameter is limited to maximum 25 mm, to prevent the exposure of others devices which might be sensitive.

IV.3 TEST CONFIGURATIONS

Two test configurations have been used :

- First one is equivalent to a design implemented on XMM, called "Virgo Design" in the present report, where the comparator is used in a latched command which is triggered when the comparator input level exceeds a given threshold. Command re-initialization requires a power off-power-on cycle of the equipment.

- Second configuration is the comparator function itself where the amplifier output is always saturated, the output signal direction depending on the relative magnitude of the two comparator inputs.

IV.3.1 Virgo Design

Virgo Application :

- This comparator is used to control a shunt over-current with voltage levels from 10 to 30mV.
- The latch section is designed using discrete components (2 transistors and one diode).
- The only way to re-initialize the latch (when level comparison is over passed) is to switch off power supply.

Test principle :

The comparator input levels are generated using two programmable sources.

Each input is connected to a resistor bridge (divider by 10) and de-coupling capacitors that present an impedance equivalent to the one used in the application.

The latch is slightly modified (a resistor is added to the base of T02 (see Figure IV-3) which correspond to Q04 in Virgo drawing), in order to implement a RESET command allowing continuous testing of the component without switching off power supply after each UPSET.

A delay circuit is added for automatic reset of the latch, after a wait state of 1ms in order to detect which SEU is a transient pulse only and which one induces a permanent state.

Types of events detected :

- Transient upset limited to the comparator.
- Comparator or latch upset leading to a latch change.

Functional Check :

A 100µs @ 1Hz signal modifying the reference threshold and allowing activation of counting function.

Design change to improve upset tolerance :

Adding a de-coupling capacitor of 1 nF on the base of T02 allows introduction of a wait state on the locking of the transistor latch : thus transients at the outputs of the comparator would be filtered.

Different test set-up conditions :

Two different set-up conditions have been used and corresponding bias figures are given in the here below table :

Test board		Signal definition	Signal state	Set-up Cond. 1	Set-up Cond. 2
DC source	PVI	DUT supply	10V 1.6mA	5mA limit threshold	
DC source	VI1	Reference voltage input		300mV	300mV
DC source	VI2	Line voltage input		290mV	250mV
Scope chan 1	FO1	Latch output	10V to 0V	5V / Div	
Scope chan 2	FO2	Comparator output	10V to 0V	5V / Div	
Counter 1	FO1	Latch output	10V to 0V	Trig @ 5V ↓	
Counter 2	FO2	Comparator output	10V to 0V	Trig @ 8V ↓	
Counter 3	LO1	Latched SEU	Logic level	Trig @2.5V ↑	

Note : Actual differential input level is computed as follow :
(Reference) – (line) + (50mV external hysteresis effect with R1 resistor).

Table IV-1 - Virgo Design Test Conditions

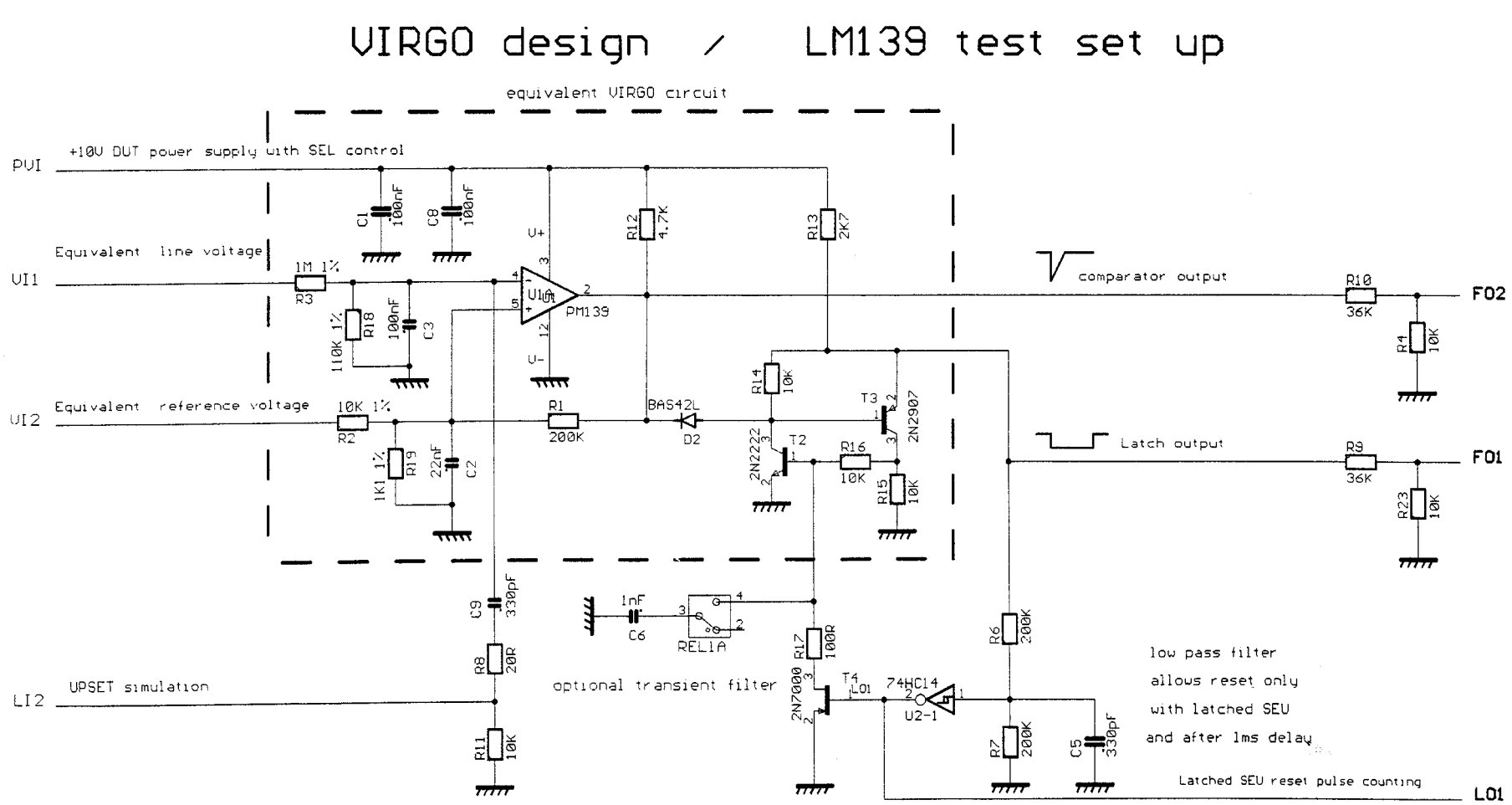


Figure IV-3 – LM339 Virgo Design Synoptic

IV.3.2 Comparator Application

Test principle :

The comparator input levels are generated using two programmable sources.

Types of events detected :

Comparator output is at +10 Volts in absence of event.
Transients are detected and counted into two different bins :

- Large errors, corresponding to the 2 Volts threshold : Comparator output transients with an amplitude higher than 8 volts are counted.
- Small errors, corresponding to the 8 Volts threshold : Comparator output transients with an amplitude higher than 2 volts (thus, include the large errors) are counted.

Functional Check :

A 100µs @ 1Hz signal modifying the reference threshold and allowing activation of counting function.

Different test set-up conditions :

Two different set-up conditions have been used and corresponding bias figures are given in the here below table :

Test board		Signal definition	Signal state	Set-up Cond. 1	Set-up Cond. 2
			Close to GND	Half supply CMV	
DC source	PVI	DUT supply	10V, 1.6mA	5mA limit threshold	
DC source	VI1	+ input		100mV	7.08V
DC source	VI2	- input		50mV	7.02V
Scope chan 1	FO1	Comparator output	10V to 0V	5V / Div	
Counter 1	FO1	small	10V to 0V	Trig @ 8V ↓	
Counter 2	FO2	large	10V to 0V	Trig @ 2V ↓	

Note : Actual differential input level is calculated as follow : (+input) – (-input)

Table IV-2 – LM339 Comparator Test Conditions

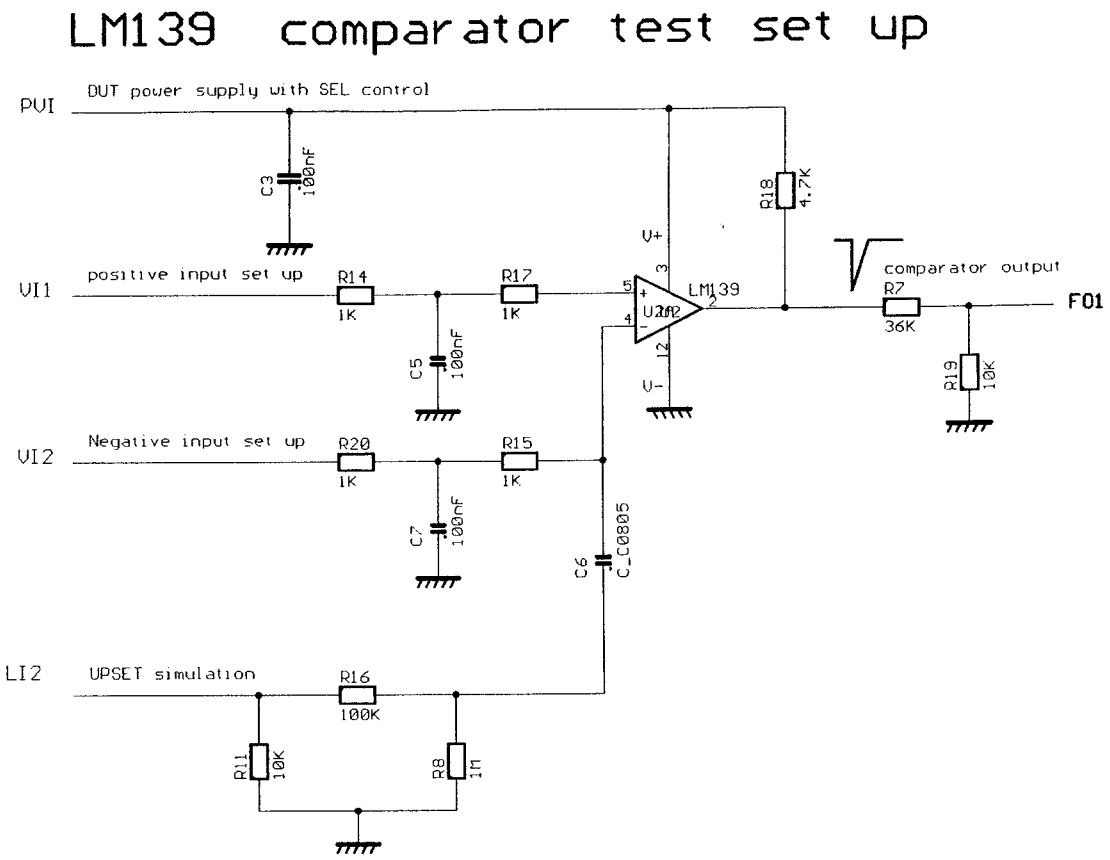


Figure IV-4 – LM339 Comparator Test Synoptic

Table VI-2 – Test results on SGS Thomson LM339 using Virgo configuration
Test T007 Virgo Condition 1

Run ID No	Test ID No	Sample ID No	Ion ID No	Date	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Eff. Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Eff. Fluence P/cm²	Errors		
													Comparator	Latch	Latched SEU
R00247	T007	S025	I003	27/09/98	0	34	67	-	4,48 E+03	8,49 E+02	3,00 E+05	-	164	164	164

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S025	#1	LM339D1	9836	SGS Thomson
S026	#2	LM339D1	9836	SGS Thomson
S027	#3	LM339D1	9836	SGS Thomson
S028	#4	LM339D1	9836	SGS Thomson

Note	Condition 1 :			
		VI1	Reference voltage input	300mV
		VI2	Line voltage input	290mV

Table VI-3 – Test results on SGS Thomson LM339 using Virgo configuration
Test T009 Virgo Condition 1 plus 1nF filtering capacitor

Run ID No	Test ID No	Sample ID No	Ion ID No	Date	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Eff. Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Eff. Fluence P/cm²	Errors		
													Comparator	Latch	Latched SEU
R00099	T009	S026	I004	25/09/98	0	14,1	93	-	5,38 E+03	1,83 E+02	5,00 E+05	-	186	185	0
R00100	T009	S026	I004	25/09/98	45	19,94	119	-	4,20 E+03	3,43 E+02	5,00 E+05	-	154	154	0
R00101	T009	S026	I004	25/09/98	60	28,2	154	-	3,25 E+03	5,69 E+02	5,00 E+05	-	146	143	0
R00102	T009	S025	I004	25/09/98	0	14,1	68	-	7,35 E+03	1,13 E+02	5,00 E+05	-	186	186	0
R00103	T009	S025	I004	25/09/98	45	19,94	108	-	4,63 E+03	2,72 E+02	5,00 E+05	-	166	166	0
R00104	T009	S025	I004	25/09/98	60	28,2	168	-	2,98 E+03	4,98 E+02	5,00 E+05	-	167	166	0
R00105	T009	S025	I005	25/09/98	60	11,7	231	-	2,18 E+03	5,92 E+02	5,03 E+05	-	8	6	0
R00106	T009	S026	I005	25/09/98	60	11,7	355	-	2,82 E+03	7,56 E+02	1,00 E+06	-	10	9	0
R00107	T009	S026	I005	25/09/98	0	5,85	120	-	8,33 E+03	8,49 E+02	1,00 E+06	-	7	6	0
R00108	T009	S025	I005	25/09/98	0	5,85	125	-	8,00 E+03	6,86 E+02	1,00 E+06	-	6	5	0
R00248	T009	S025	I003	27/09/98	0	34	65	-	4,62 E+03	1,01 E+03	3,00 E+05	-	177	176	0
R00249	T009	S025	I003	27/09/98	45	48,08	92	-	3,26 E+03	1,24 E+03	3,00 E+05	-	148	147	0
R00250	T009	S025	I003	27/09/98	60	68	113	-	2,65 E+03	1,57 E+03	3,00 E+05	-	114	114	0
R00251	T009	S026	I003	27/09/98	60	68	133	-	2,26 E+03	1,18 E+03	3,00 E+05	-	140	140	0
R00252	T009	S026	I003	27/09/98	45	48,08	91	-	3,30 E+03	1,41 E+03	3,00 E+05	-	145	143	0
R00253	T009	S026	I003	27/09/98	0	34	64	-	4,69 E+03	1,57 E+03	3,00 E+05	-	147	147	0
R00302	T009	S026	I007	27/09/98	60	3,4	109	-	4,59 E+03	2,32 E+03	5,00 E+05	-	0	0	0
R00303	T009	S025	I007	27/09/98	60	3,4	100	-	5,00 E+03	2,32 E+03	5,00 E+05	-	0	0	0

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S025	#1	LM339D1	9836	SGS Thomson
S026	#2	LM339D1	9836	SGS Thomson
S027	#3	LM339D1	9836	SGS Thomson
S028	#4	LM339D1	9836	SGS Thomson

Note	Condition 1 :			
		VI1	Reference voltage input	300mV
		VI2	Line voltage input	290mV

Table VI-4 - Results on SGS Thomson LM339 using comparator configuration
Test T010 – Comparator Condition 1

Run ID No	Test ID No	Sample ID No	Ion ID No	Date	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Eff. Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Eff. Fluence P/cm²	Errors Small	Errors Large
R00092	T010	S028	I004	25/09/98	0	14,1	103	-	4,85 E+03	1,13 E+02	5,00 E+05	-	414	414
R00093	T010	S028	I004	25/09/98	45	19,94	148	-	3,38 E+03	2,72 E+02	5,00 E+05	-	436	430
R00094	T010	S028	I004	25/09/98	60	28,2	188	-	2,66 E+03	4,98 E+02	5,00 E+05	-	342	332
R00095	T010	S027	I004	25/09/98	0	14,1	102	-	4,90 E+03	1,13 E+02	5,00 E+05	-	385	382
R00096	T010	S027	I004	25/09/98	45	19,94	137	-	3,65 E+03	2,72 E+02	5,00 E+05	-	420	419
R00097	T010	S027	I004	25/09/98	60	28,2	200	-	2,50 E+03	4,98 E+02	5,00 E+05	-	420	403
R00109	T010	S027	I005	25/09/98	60	11,7	169	-	2,96 E+03	5,92 E+02	5,00 E+05	-	294	286
R00110	T010	S027	I005	25/09/98	45	8,27	296	-	2,61 E+03	6,94 E+02	7,72 E+05	-	508	496
R00111	T010	S027	I005	25/09/98	0	5,85	167	-	2,99 E+03	7,40 E+02	5,00 E+05	-	324	311
R00112	T010	S028	I005	25/09/98	0	5,85	124	-	4,03 E+03	5,45 E+02	5,00 E+05	-	301	289
R00113	T010	S028	I005	25/09/98	45	8,27	109	-	4,59 E+03	6,11 E+02	5,00 E+05	-	306	303
R00114	T010	S028	I005	25/09/98	60	11,7	167	-	2,99 E+03	7,04 E+02	5,00 E+05	-	290	276
R00260	T010	S026	I003	27/09/98	0	34	71	-	4,23 E+03	1,73 E+03	3,00 E+05	-	325	265
R00261	T010	S026	I003	27/09/98	45	48,08	102	-	2,94 E+03	1,96 E+03	3,00 E+05	-	358	294
R00262	T010	S026	I003	27/09/98	60	68	143	-	2,10 E+03	2,29 E+03	3,00 E+05	-	320	279
R00263	T010	S025	I003	27/09/98	60	68	145	-	2,07 E+03	1,90 E+03	3,00 E+05	-	322	281
R00264	T010	S025	I003	27/09/98	45	48,08	105	-	2,86 E+03	2,13 E+03	3,00 E+05	-	297	243
R00265	T010	S025	I003	27/09/98	0	34	71	-	4,23 E+03	2,29 E+03	3,00 E+05	-	334	280
R00296	T010	S028	I007	27/09/98	0	1,7	66	-	7,58 E+03	7,18 E+02	5,00 E+05	-	212	209
R00297	T010	S028	I007	27/09/98	45	2,4	93	-	5,38 E+03	7,37 E+02	5,00 E+05	-	241	234
R00298	T010	S028	I007	27/09/98	60	3,4	128	-	3,91 E+03	7,64 E+02	5,00 E+05	-	291	261
R00299	T010	S027	I007	27/09/98	60	3,4	75	-	6,67 E+03	7,68 E+02	5,00 E+05	-	277	253
R00300	T010	S027	I007	27/09/98	45	2,4	80	-	6,25 E+03	7,87 E+02	5,00 E+05	-	211	209
R00301	T010	S027	I007	27/09/98	0	1,7	55	-	9,09 E+03	8,00 E+02	5,00 E+05	-	214	211

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
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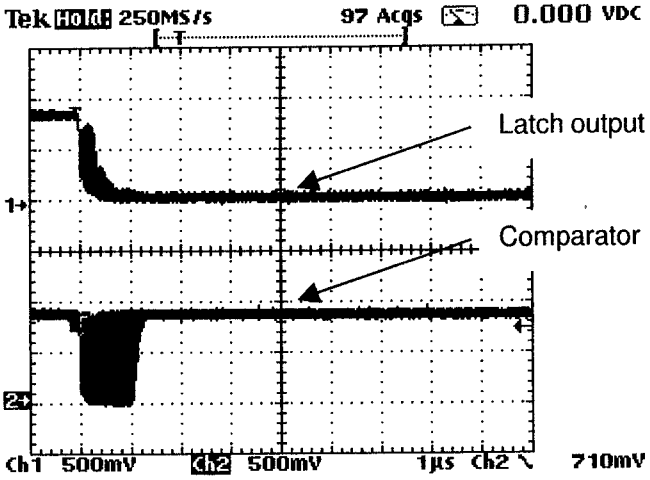
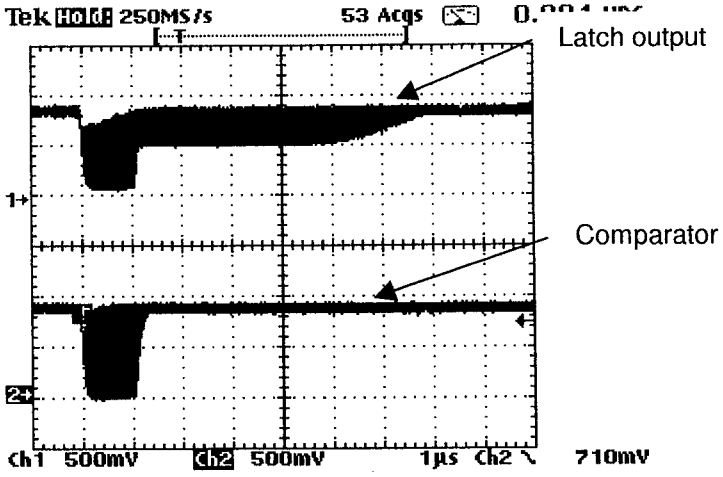
S026	#2	LM339D1	9836	SGS Thomson
S027	#3	LM339D1	9836	SGS Thomson
S028	#4	LM339D1	9836	SGS Thomson

Note	Condition 1 :	VI1	+ input	100mV
		VI2	- input	50mV



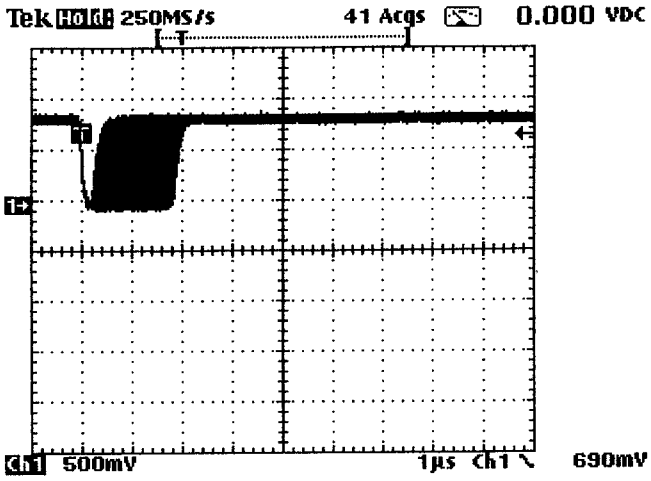
(5V/div 2µs)
In this case, the change of the latch state can be observed

Figure VI-2 – Typical Waveform, Virgo configuration without filter capacitor



(5V/div 2µs)
This scope record shows that the latch output change
does not latch thanks to the filtering capacitor

Figure VI-3 – Typical Waveform, Virgo configuration with 1nF capacitor filter



(5V/div 1µs)
This scope record shows the envelop of SEU pulses of different transient duration

Figure VI-4 – Typical Waveform, Comparator configuration

VII. CONCLUSION

SEU test have been conducted on LM339D1 Quad Voltage Comparator from SGS Thomson, using the heavy ions available at the University of Louvain facility.

SEU susceptibility was obtained through the error cross section versus LET curve for two different test configurations.

The effect of a capacitor filter applied in the Virgo equivalent configuration has been assessed and drastic improvement has been obtained.

With these results, upset predictions on XMM orbit, can be performed for each error type and the risk associated with the present Virgo design can be assessed.