



# SINGLE EVENT EFFECTS RADIATION TEST REPORT

**Part Type : BUZ100SL**

**Package : TO-220AB**

**N-Channel Power MOSFET**

**Siemens**

**Report Reference : ESA\_QCA990907S\_C**

**Issue : 01**

**Date : July 2<sup>nd</sup> 1999**


ESA Contract No 13413/98/NL/MV dated 25/01/99

European Space Agency Contract Report

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<b>Hirex reference :</b>	HRX/99. 4599	Issue : 01	Date :	July 2, 1999
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I. **ABSTRACT**

Under ESA/ESTEC contract n° 13413/98/NL/MV covering "Radiation Evaluation of Power MOSFET Devices from Different European Manufacturers", a large number of commercial Power MOSFET device types were radiation assessed. Results from these assessments, primarily focused on the radiation sensitivity of the MOSFETs to Total Ionizing Dose (TID) and Single Event Effects (SEE), are reported in individual TID and SEE reports. Below summary table list manufacturer and evaluated types, and give references to the various reports issued.

Manufacturer	Type	TID Report	SEE Report
Philips	PHP50N06T	ESA_QCA990901T_C	ESA_QCA990901S_C
Philips	BUK456-200A	ESA_QCA990902T_C	ESA_QCA990902S_C
Motorola	MTP50N06VL	ESA_QCA990903T_C	
Motorola	MTW32N20E	ESA_QCA990904T_C	
Motorola	MTP50N06V	ESA_QCA990905T_C	
Siemens	BUZ100S	ESA_QCA990906T_C	ESA_QCA990906S_C
Siemens	BUZ100SL	ESA_QCA990907T_C	ESA_QCA990907S_C
Siemens	BUZ341	ESA_QCA990908T_C	ESA_QCA990908S_C
SGS-Thomson	SP60	ESA_QCA990909T_C	ESA_QCA990909S_C
SGS-Thomson	SP100V	ESA_QCA9909010T_C	ESA_QCA9909010S_C
SGS-Thomson	SP200V	ESA_QCA9909011T_C	ESA_QCA9909011S_C
Siemens	SPP1N60S5	ESA_QCA9909012T_C	ESA_QCA9909012S_C
Philips	BUK7508-55	ESA_QCA9909013T_C	ESA_QCA9909013S_C
Harris	HUF75639P3	ESA_QCA9909014T_C	ESA_QCA9909014S_C

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## II. INTRODUCTION

This report presents the results of a heavy ion Single Event Effects (SEEs) test program carried out on BUZ100SL N-Channel Power MOSFET from Siemens.

Devices were tested at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

This work was performed for ESA/ESTEC under ESA Contract No 13413/98/NL/MV dated 25/01/99

## III. DOCUMENTS

### III.1 APPLICABLE DOCUMENTS

AD1. Hirex Engineering proposal ref. HRX/98.3475 Issue 1, "Radiation Evaluation of Power MOS Devices from Different European Manufacturers"


AD2. ESA memorandum Appendix 1 to ESTEC/Contract No 13413/NL/MV

### III.2 REFERENCE DOCUMENTS

RD1. Siemens data sheet

RD2. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100

RD3. The Heavy Ion Irradiation Facility at CYCLONE, UCL document, Centre de Recherches du Cyclotron (IEEE NSREC'96, Workshop Record, Indian Wells, California, 1996)

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#### IV. DEVICE INFORMATION

##### IV.1 DEVICE DESCRIPTION

N-Channel Power MOSFET, 55 Volts, 70 A encapsulated in TO-220AB package

##### IV.2 PROCUREMENT OF TEST SAMPLES

Delivered by ESA

##### IV.3 PREPARATION OF SAMPLES

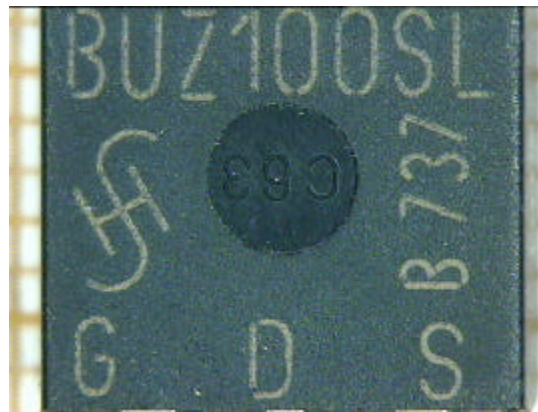
Devices have been opened by chemical etch by Hirex Lab.

##### IV.4 SAMPLES CHECK OUT

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

##### IV.5 DEVICE MARKING


Device marking is provided in Figure 1



**Figure 1 – Device marking**

Technology : SIPMOS  
 Die metallization : Aluminum  
 Die dimensions (approximately, mm<sup>2</sup>) : 4,2 x 3,5

Further details on die description are provided in "Comparative Description and Analysis of Various Power MOSFETs", ESA document ref. ESA\_QCA9909015\_C (Hirex ref. HRX/99.4775) / ESA Contract No 13413/98/NL/MV dated 25/01/99.

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## V. DEVICE TEST DEFINITION

### V.1 PREPARATION OF TEST HARDWARE AND PROGRAM

Overall device emulation, SEE, data storage and processing were implemented using an in-house test hardware and application specific test boards.

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.

### V.2 GENERIC TEST SET-UP

Generic device test set-up is presented in Figure 2.

This set-up is constituted of the following units:

- 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 10 devices.
- A digital oscilloscope to store analog SEE waveform


SEE Test functional diagram is shown in Figure 3.

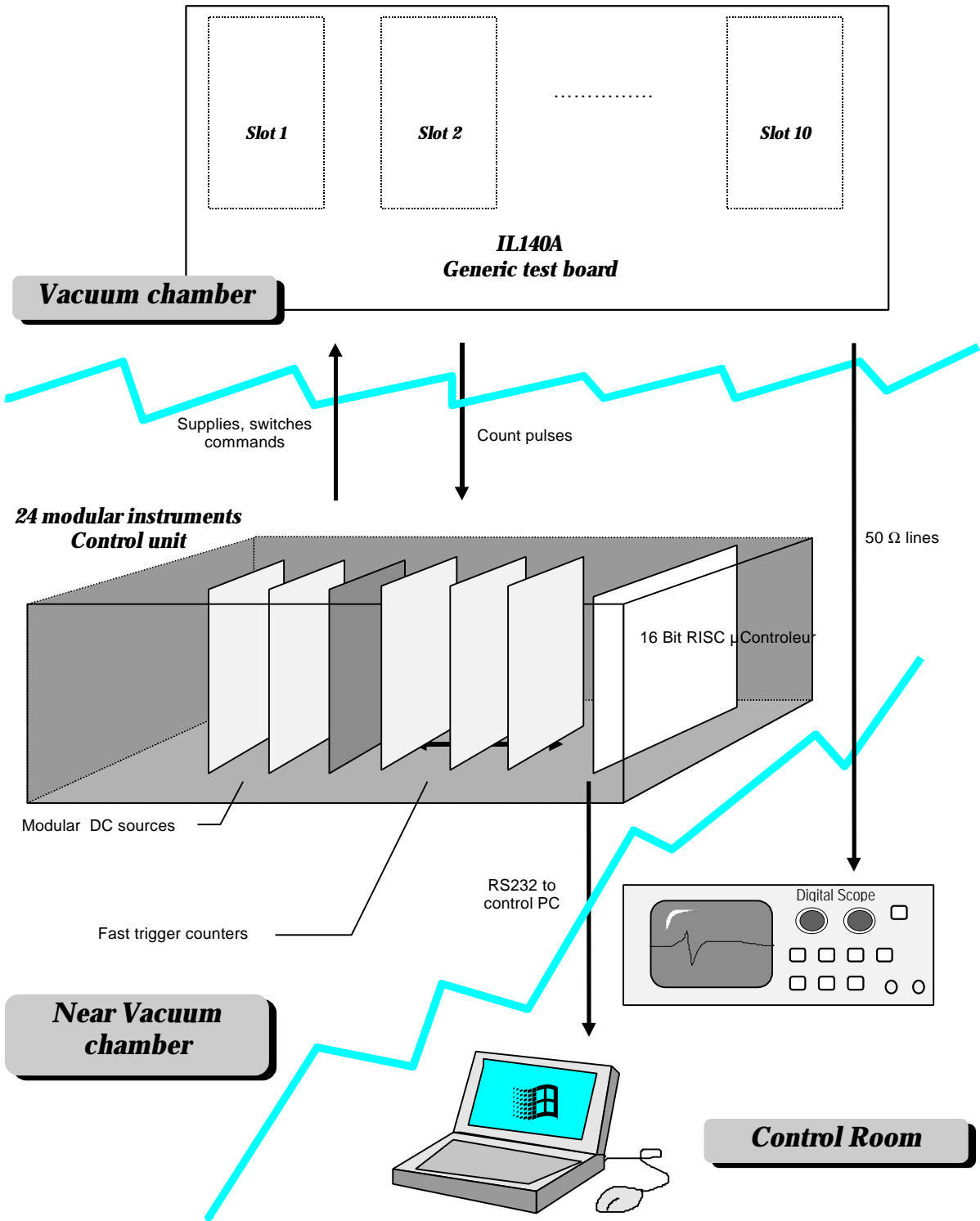
#### V.2.1 Mother board description (Ref. IL140A)

The motherboard acts as a standard interface between each DUT test board and the control unit :

For each slot, the following signals can be considered:

- 4 inputs signals
    - Drain Source programmable power supply
    - Gate Source programmable power supply
    - Simulation signal
    - Heater control signal
  - 1 output signal
    - 1 fast analog output signal
- IL140 board has been designed to comply with both PSI and Louvain test facilities .
  - Each device needs a dedicated plug-in test board compatible with IL140 mother board.
  - The number of slots is limited to 10: Up to 10 TO220 DUT test boards can be plugged or 5 TO3 DUT test boards.
  - Operation is multiplexed and only one slot is powered at one time.

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**Figure 2 - Generic Test Set-up**



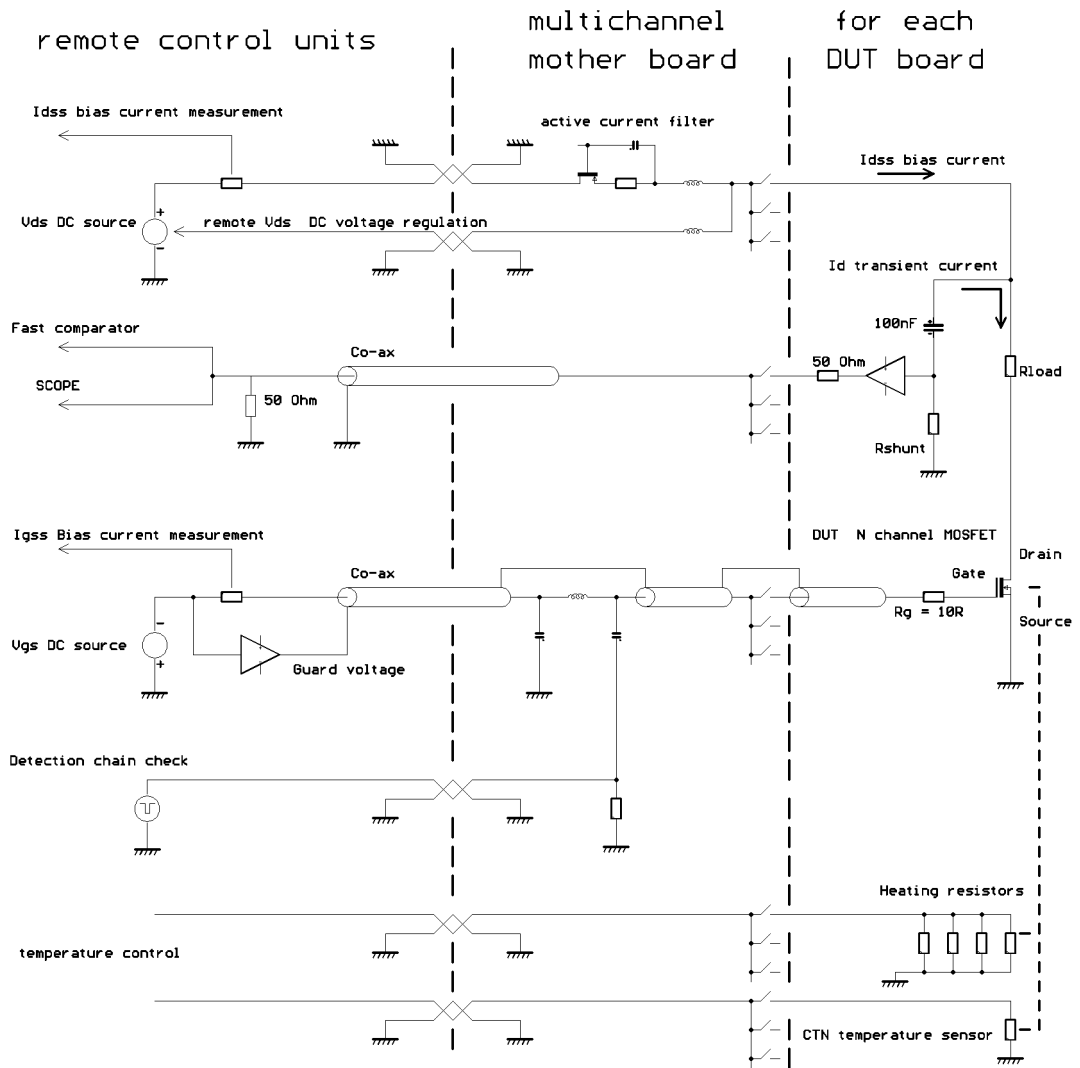


Figure 3 – Functional diagram for SEE Test

V.2.2 DUT Test board description

The device under test is mounted on a specific PCB board which again is connected to the motherboard.

Two different DUT boards have been designed which can be fitted with either a TO2xx plastic package device or with TO3 metal package device.

On each individual DUT board, a limiting current serie resistance and a shunt resistor are mounted for SEB pulse measurement.

To prevent the destructive burn-out of the DUT when the parasitic Bipolar Junction Transistor (BJT) is triggered on by a strike, the DUT Drain is biased with a capacitor and a limiting current resistor mounted on each DUT board. This is to limit the amount of energy available as well as the maximum transient current value.

For testing at elevated temperature, each board is equipped with surface mount heating resistors plus a CTN thermistor for temperature control.

V.3 TEST CONFIGURATION

Test set-up which has been used for the present test report, allows for the detection of both Single Event Burn-out (SEB) and Single Event Gate Rupture (SEGR) effects

V.3.1 Single Event burnout (SEB)

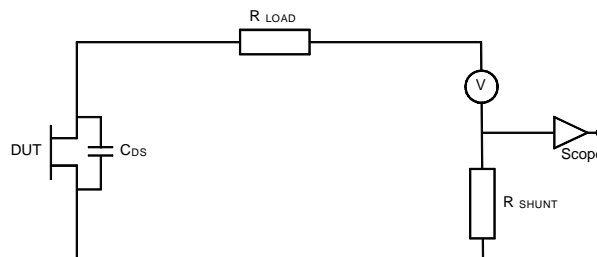
SEB can be observed with the MOSFET in the off mode.

To get non destructive SEBs, selected test principle was to limit as much as possible the energy which could flow into the DUT when the parasitic bipolar transistor enters second breakdown.

To achieve this goal, a resistor Rload (see Figure 3) in serie with the DUT drain limits the current which can flow from the bias circuit (capacitor of 100nF, see Figure 3). In that case the only available energy which can flow into the DUT without any external current limitation is the one stored into the output DUT capacitance  $C_{DS}$ .

The equivalent circuit when an SEB is triggered is shown in Figure 4.

Observation of VDS transients is done at Rshunt which form a resistor divider with Rload.



**Figure 4 – Equivalent circuit for SEB including the parasitic capacitor of the MOSFET.**


Actual resistor values for the test results presented in this report are shown in the Table 1 here below.

Symbol	Value
$R_{load}$	1,6 kohms
$R_{Shunt}$	25 ohms

**Table 1 – Test circuit resistor values**

Events are counted thanks to a programmable threshold comparator of 50MHz bandwidth. Moreover the monitoring of changes in the leakage dc current  $I_{dss}$  will allow to check for eventual permanent degradation.

Temperature effect may be evaluated as each DUT single board is provided with surface mount heating resistors and a thermistor mounted on the back side of the board, which give the ability of testing at elevated temperature.


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V.3.2 Single Event Gate Rupture (SEGR)

SEGR is a destructive effect which can be observed with the MOSFET in the off mode. Monitoring of the IGSS current allows for the detection of a SEGR which corresponds to a permanent degradation of the gate current.

This requires the measurement of  $\mu$ amp current amplitude under high impedance. Test board design is compatible with the accelerator environment by the use of a complete guard ring.

Fluence is recorded during each run by monitoring with a modular counter, the TTL signal delivered by an on-line Beam Detector. Information on the reached fluence at the time of an eventual SEGR occurrence can then be retrieved by analysis of the run data.

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## VI. TEST FACILITIES

### VI.1 HEAVY IONS

Test at the cyclotron accelerator was performed at Université de Louvain (UCL) in Louvain la neuve (Belgium) under HIREX Engineering responsibility.

#### VI.1.1 Beam Source

In collaboration with the European Space Agency (ESA), the needed equipment for single events studies using heavy ions has been built and installed on the HIF beam line in the experimental hall of Louvain-la-Neuve cyclotron.

CYCLONE is a multi particle, variable energy, cyclotron capable of accelerating protons (up to 75 MeV), alpha particles and heavy ions. For the heavy ions, the covered energy range is between 0.6 MeV/AMU and 27.5 MeV/AMU. For these ions, the maximal energy can be determined by the formula :

$$110 Q^2/M$$

where Q is the ion charge state, and M is the mass in Atomic Mass Units.

The heavy ions are produced in a double stage Electron Cyclotron Resonance (ECR) source. Such a source allows to produce highly charged ions and ion "cocktails". These are composed of ions with the same or very close M/Q ratios. The cocktail ions are injected in the cyclotron, accelerated at the same time and extracted separately by a fine tuning of the magnetic field or a slight changing of the RF frequency. This method is very convenient for a quick change of ion (in a few minutes) which is equivalent to a LET variation.

#### VI.1.2 Beam Set-up

##### VI.1.2.1 Ion Beam Selection

The LET range was obtained by changing the ion species and incident energy and changing the angle of incidence between the beam and the chip.

For each run, information on the beam characteristics is provided in Table 2.

##### VI.1.2.2 Flux Range

For each run, the averaged flux value is provided in Table 2.

##### VI.1.2.3 Particle Fluence Levels

Fluence level was comprised between few  $\times 10^4$  and  $5 \times 10^5$  ions/cm<sup>2</sup>

##### VI.1.2.4 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.


##### VI.1.2.5 Accumulated Total Dose

For each run, the computed equivalent cumulated doses received by the DUT sample, is provided here below:

S/N	Dose (rads)
#1G8	2,28 E 2
#1G9	4,65 E 2
#2G8	1,90E 2
#2G9	1,71E 2

##### VI.1.2.6 Test Temperature Range

All the tests performed were conducted at room temperature with the exception of two runs performed at an ambient temperature of 65°C to check the influence of temperature on SEB error cross-section.

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## VII. HEAVY IONS RESULTS

### VII.1 BUZ100SL TEST RESULTS

Krypton and Argon ions have been used with respective LETs of 34 and 14.1 MeV/mg/cm<sup>2</sup>. Results per run are presented in Table 2.

Run A068 and A081 performed with a tilt angle of 30°, confirms that worst case corresponds to normal incidence (to be compared with respectively runs A066 and A078).

It can also be observed with runs A069 and A082 that sensitivity to SEB decreases when the device is tested at elevated temperature (to be compared with respectively runs A066 and A078).

Main outcomes can then be summarized as follows :

With Krypton (34 MeV/mg/cm<sup>2</sup>) and device biased with a fixed Gate Source Voltage (VGS) of -2V :

- Devices are SEB free when VDSS. does not exceed 50% of maximum rating.
- Devices are not sensitive to SEGR (limit of the present test was 70% of VDSS).

With Argon (14.1 MeV/mg/cm<sup>2</sup>) and device biased with a fixed Gate Source Voltage (VGS) of -2V :

- Devices are SEB free when VDSS. does not exceed 60 % of maximum rating.
- Devices are not sensitive to SEGR (limit of the present test was 80% of VDSS).


With Argon, when devices are tested at a VDSS rating (60%) such that no SEB is expected, the maximum gate source voltage which can be applied without occurrence of SEGR event is -15V (limit of the present test).

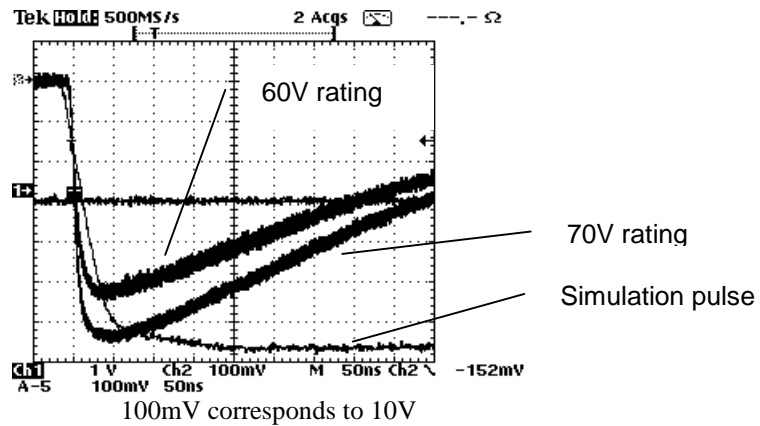
### VII.2 TYPICAL SEB WAVEFORM

Figure 5 show a typical example obtained with a 100V transistor. In this figure, voltage variation across R<sub>shunt</sub> can be observed for a SEB pulse waveform at two rated V<sub>DS</sub> conditions, 60V and 70V.

The superposition of the simulation pulse (observed at R<sub>shunt</sub>) which consist to turn on the DUT allows to compare in each case, which part of the circuit is involved:

- In the SEB case, it can be seen that drain source voltage drops to zero in a very short time, then once the energy stored in the output DUT capacitance is dissipated, the current limitation provided by R<sub>load</sub> allows for leaving the burn-out sustaining condition and DUT output capacitance start to reload with a current limited by R<sub>load</sub>.  
The very high dV/dt (> 10 000V/μs) induce a peak current greater than 2 A, which discharge the internal C<sub>DS</sub> DUT capacitor in a few ns.
- In the case of simulation pulse, once the DUT is switched on, the supply current which flows into the DUT is limited by R<sub>load</sub>.

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**Figure 5 – Example of non destructive SEBs observed on a 100V transistor at 60V and 70V Vds ratings**

**VIII. CONCLUSION**

SEU test have been conducted on BUZ100SL N-channel Power MOSFET from Siemens, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF), at Cyclone, Université Catholique de Louvain, Belgium.

With Krypton (34 MeV/mg/cm<sup>2</sup>) and device biased with a fixed Gate Source Voltage (VGS) of -2V :

- Devices are SEB free when VDSS. does not exceed 50% of maximum rating.
- Devices are not sensitive to SEGR (limit of the present test was 70% of VDSS).

With Argon (14.1 MeV/mg/cm<sup>2</sup>) and device biased with a fixed Gate Source Voltage (VGS) of -2V :

- Devices are SEB free when VDSS. does not exceed 60 % of maximum rating.
- Devices are not sensitive to SEGR (limit of the present test was 80% of VDSS).

With Argon, when devices are tested at a VDSS rating (60%) such that no SEB is expected, the maximum gate source voltage which can be applied without occurrence of SEGR event is -15V (limit of the present test).

**Table 2 – Heavy Ion Test results on BUZ100SL N-Channel Power MOSFET from Siemens :**

Run #	Date	S/N	Ion	LETeff (MeV/mg/cm <sup>2</sup> )	Angle (°)	T(°C) (°C)	VDS (V)	VGS (V)	%VDSS (%)	Fluence (p/cm <sup>2</sup> )	Flux (p/cm <sup>2</sup> /s)	Time (s)	SEB		SEGR		Comparator Threshold mV	Equivalent Pulse height V	
													Nbr (-)	Sigma cm <sup>2</sup>	Nbr (-)	Sigma cm <sup>2</sup>			
VGS=-2V, Ion Krypton, LET =34 MeV/mg/cm <sup>2</sup>																			
A060	09/01/99	1G8	84-Kr	34	0	25	27,5	-2	50%	100920	1246	81	0					-152	-10
A065	09/01/99	2G8	84-Kr	34	0	25	27,5	-2	50%	100041	1334	75	0					-152	-10
A075	09/01/99	2G9	84-Kr	34	0	25	27,5	-2	50%	101313	1559	65	0					-152	-10
A080	09/01/99	1G9	84-Kr	34	0	25	27,5	-2	50%	100903	1345	75	0					-152	-10
A063	09/01/99	1G8	84-Kr	34	0	25	30	-2	55%	100112	1317	76	3773	3,77E-02				-152	-10
A064	09/01/99	2G8	84-Kr	34	0	25	30	-2	55%	100819	1400	72	4028	4,00E-02				-152	-10
A076	09/01/99	2G9	84-Kr	34	0	25	30	-2	55%	100259	1373	73	1885	1,88E-02				-152	-10
A077	09/01/99	1G9	84-Kr	34	0	25	30	-2	55%	50858	1338	38	771	1,52E-02				-152	-10
A061	09/01/99	1G8	84-Kr	34	0	25	33	-2	60%	50767	1238	41	2307	4,54E-02				-152	-10
A066	09/01/99	2G8	84-Kr	34	0	25	33	-2	60%	30059	1307	23	1592	5,30E-02				-152	-10
A073	09/01/99	2G9	84-Kr	34	0	25	33	-2	60%	80666	1391	58	3264	4,05E-02				-152	-10
A078	09/01/99	1G9	84-Kr	34	0	25	33	-2	60%	20805	1300	16	807	3,88E-02				-152	-10
A062	09/01/99	1G8	84-Kr	34	0	25	38,5	-2	70%	30397	1216	25	2027	6,67E-02				-152	-10
A067	09/01/99	2G8	84-Kr	34	0	25	38,5	-2	70%	31195	1300	24	2352	7,54E-02				-152	-10
A074	09/01/99	2G9	84-Kr	34	0	25	38,5	-2	70%	31319	1362	23	2194	7,01E-02				-152	-10
A079	09/01/99	1G9	84-Kr	34	0	25	38,5	-2	70%	20319	1270	16	1415	6,96E-02				-152	-10
VGS=-2V, Ion Krypton, LET =34 MeV/mg/cm <sup>2</sup> , tilt angle = 30°																			
A068	09/01/99	2G8	84-Kr	39,26	30	25	33	-2	60%	30814	1467	21	1268	4,12E-02				-152	-10
A081	09/01/99	1G9	84-Kr	39,26	30	25	33	-2	60%	20342	1130	18	432	2,12E-02				-152	-10
VGS=-2V, Ion Krypton, LET =34 MeV/mg/cm <sup>2</sup> , ambient temperature = 65°C																			
A069	09/01/99	2G8	84-Kr	34	0	65	33	-2	60%	50616	1298	39	2271	4,49E-02				-152	-10
A082	09/01/99	1G9	84-Kr	34	0	65	33	-2	60%	50687	1300	39	1532	3,02E-02				-152	-10
VGS=-2V, Ion Argon, LET =14,1 MeV/mg/cm <sup>2</sup>																			
A219	10/01/99	1G8	40-Ar	14,1	0	25	27,5	-2	50%	101664	3910	26	0					-152	-10
A220	10/01/99	1G8	40-Ar	14,1	0	25	33	-2	60%	103308	3973	26	0					-152	-10
A225	10/01/99	1G9	40-Ar	14,1	0	25	33	-2	60%	101899	4246	24	0					-152	-10
A223	10/01/99	1G8	40-Ar	14,1	0	25	36	-2	65%	101032	2591	39	5	4,95E-05				-152	-10
A221	10/01/99	1G8	40-Ar	14,1	0	25	38,5	-2	70%	100354	3860	26	223	2,22E-03				-152	-10
A226	10/01/99	1G9	40-Ar	14,1	0	25	38,5	-2	70%	102958	4680	22	2	1,94E-05				-152	-10
A228	10/01/99	1G9	40-Ar	14,1	0	25	41	-2	75%	104451	5497	19	28	2,68E-04				-152	-10
A222	10/01/99	1G8	40-Ar	14,1	0	25	44	-2	80%	101768	3392	30	3415	3,36E-02				-152	-10
A227	10/01/99	1G9	40-Ar	14,1	0	25	44	-2	80%	100472	4567	22	2166	2,16E-02				-152	-10
VGS=-10V, Ion Argon, LET =14,1 MeV/mg/cm <sup>2</sup>																			
A224	10/01/99	1G8	40-Ar	14,1	0	25	33	-10	60%	502865	3781	133	0					-152	-10
VGS=-15V, Ion Argon, LET =14,1 MeV/mg/cm <sup>2</sup>																			
A229	10/01/99	1G9	40-Ar	14,1	0	25	33	-15	60%	502852	6795	74	0					-152	-10
A230	10/01/99	1G9	40-Ar	14,1	0	25	33	-15	60%	503396	7296	69	0					-152	-10