Switching DC-DC converters' TID and SEE hardness investigation

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Total dose and SEE experimental data for switching DC-DC converters and its basic parts (MOSFETs, error amplifiers, PWMs, optocouplers) is presented. The most total dose and SEE sensitive parts are revealed.

I. Introduction

One of the important problems of designing space equipment is the creation of an effective and radiation hard power supply system. The base power system element is switching DC-DC converter. The sufficient information on DC-DC converter total dose and SEE behavior is essential for space applications [1-3].

We conducted over 50 different total dose experiments on switching DC-DC converters and found its hardness levels vary drastically from 1 to 360 krad depending on manufacturing process and electrical conditions (fig. 1).

The aim of this work is to explain different hardness of DC-DC converters, base on analysis radiation behavior of their main parts.

Over 60 experiments were done for MOSFETs, error amplifiers (operational amplifiers and comparators), PWMs and optocouplers in order to find the most dose and SEE sensitive parts of the DC-DC and to suggest the hardness improvements. Electrical mode inherent to switching DC-DC converter was taken into account in every experiment.

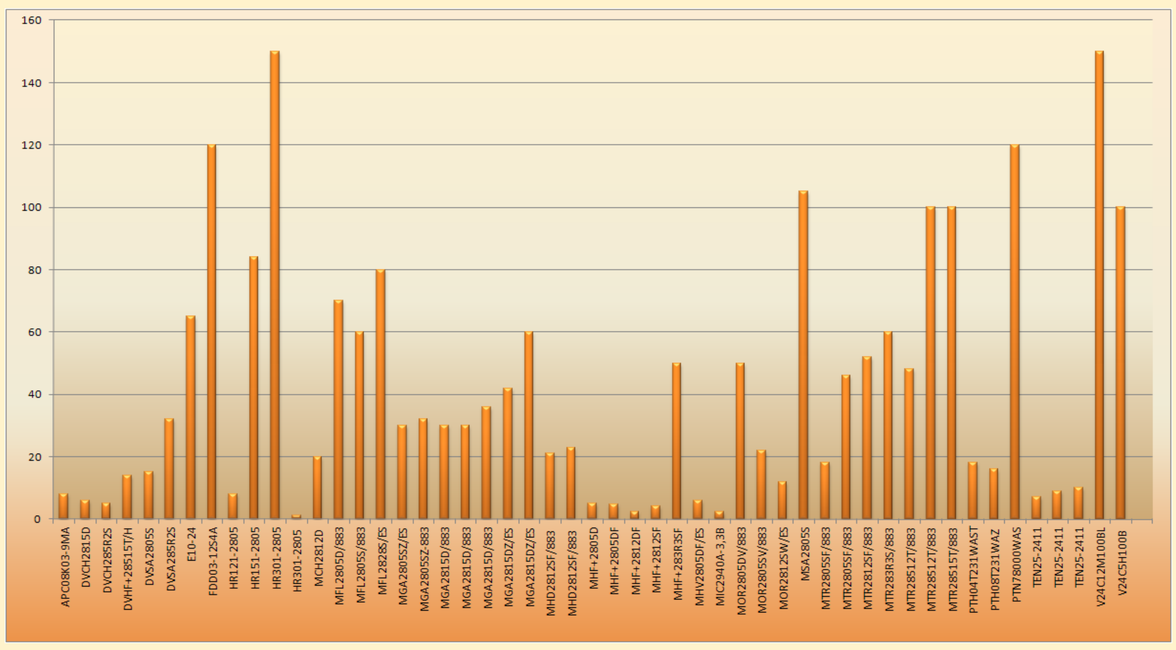
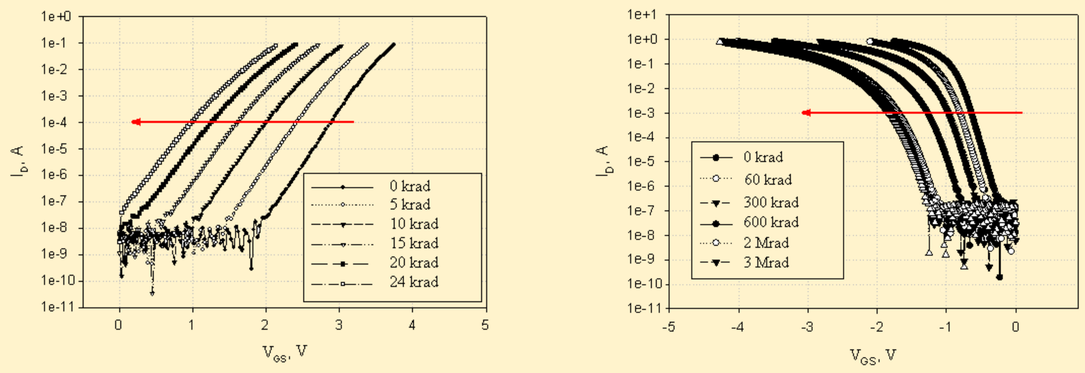


Fig. 1. Experimentally obtained total dose hardness levels of DC-DC converters

II. Total Ionizing Dose

Power MOSFETs are used in DC-DC converters as switching elements. It is well known that threshold voltage decreases for n-channel and increases for p-channel MOSFETs during total ionizing dose irradiation. The total dose experiments for up-to-date powerful MOSFETs with respect to the electrical mode in DC-DC converters exhibit similar degradation (fig. 2). Usage of p-channel MOSFETS with additional gate-source voltage level pull-up unit (in order to equalize the threshold voltage degradation) can improve total dose hardness of the DC-DC converter.



n-channel IRFI640GPBF p-channel IRLML6401

Fig. 2. Powerful MOSFETs total dose degradation

The error amplifiers in the DC-DC converters are usually built on operational amplifiers or voltage comparators. More than 20 total dose experiments on operational amplifiers and voltage comparators with respect to the electrical mode in DC-DC converters demonstrated no degradation up to 80 krad which could affect the proper converter operation.

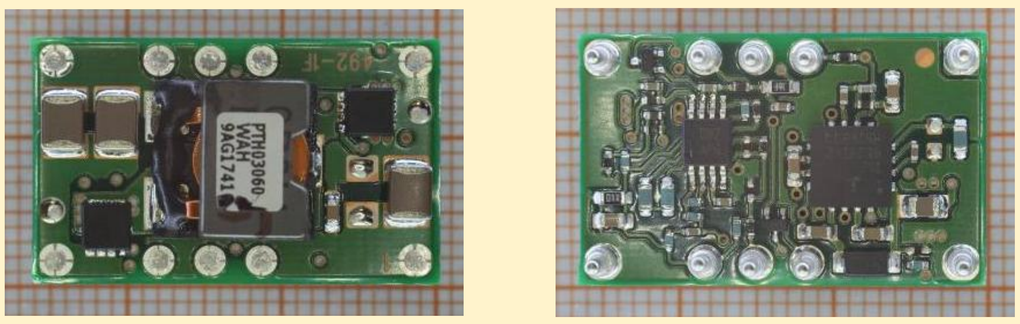
Over 20 experiments have found optocouplers (Avago Technologies, Agilent Technologies, Fairchild, etc.) to be potentially total dose and SEE sensitive. In some cases employment of the transformers instead of optocouplers can improve DC-DC converter total dose and SEE hardness.

Bipolar **PWMs** are experimentally proved to be less total dose sensitive regarding CMOS and BiCMOS devices. Therefore bipolar PWM employment can improve DC-DC converter total dose hardness.

III. Single Event Effects

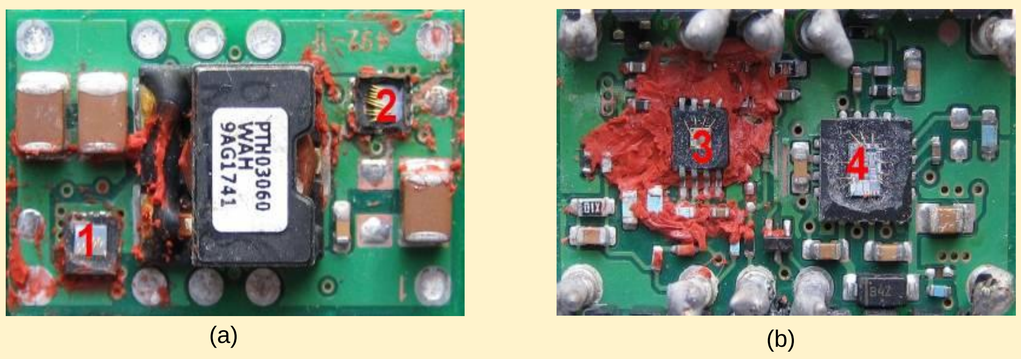
The experimental studies of these effects are related with some objective difficulties, i.e. the need for decapsulation of microcircuits, limited measurement availability, heating in vacuum camera during irradiating etc. Decapsulated and then irradiating different microcircuits in DC-DC converters we can find critical parts to heavy ions impacts.

PTH03060WAH is hybrid switching DC-DC converter (Fig. 3). It consists of power MOSFETs (1,2 on Fig. 4), operational amplifier (3 on Fig.4) and PWM-controller (4 on Fig.4).



(a) (b)

Fig.3. Foto of PTH03060WAH: top view (a) and bottom (b)



(a) (b)

Fig.4. Decapsulated PTH03060WAH: 1,2 – power MOSFETs, 3 – operational amplifier, 4 – PWM controller

Ion irradiation experiments revealed that powerful MOSFETs and PWM controllers are the most SEE sensitive parts of the DC-DC converters. In order to distinguish the response of each part, separate irradiation experiments were conducted (fig. 5, 6).

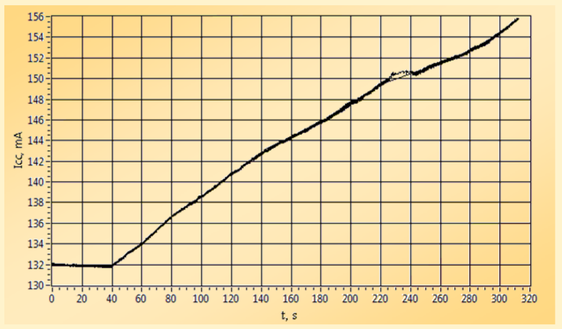


Fig.5. PTH03060WAH supply current vs. time during Xe-ion irradiation (only MOSFET is irradiated)

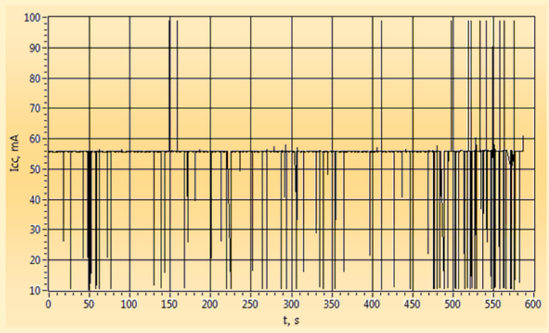


Fig.6. PTH03060WAH supply current vs. time during Xe-ion irradiation (only PWM is irradiated)

IV. Conclusion

Power MOSFETs and PWM controllers are experimentally proved to be the most total dose and SEE sensitive parts of the DC-DC converters. Usage of the p-channel MOSFETS with additional gate-source voltage level pull-up unit, transformers and bipolar PWM controllers can improve total dose hardness of the DC-DC converters.

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