Radiation Hardened Circuits in Multiple Harsh Environments

Chakradhar Adupa¹, T Chandhra Prakash², P. Ramchandar Rao³, J. Tarun Kumar⁴, Ch. Rajendra Prasad⁵

¹Department of Electronics and Communication Engineering, SR University Warangal, Telangana, India-506371
²Department of Electronics and Communication Engineering, Sumathi Reddy Institute of Technology for Women, Telangana, India-506371
³Center for Embedded & IoT, Department of ECE, S R Engineering College, Warangal, Telangana, India-506371
⁴,⁵Department of ECE, S R Engineering College, Warangal, Telangana, India-506371

¹adupa.chakradhar@gmail.com, ²rajendraprasad.ch@srup.edu.in,
³chandupanulaparthi@gmail.com, ⁴tarunjulu@gmail.com,
⁵sandeep_kumar_v@srecwarangal.ac.in

Abstract: Semiconductor electronic devices and Circuits most of the times there is a possibility that they will be exposed to the harsh environments where they may exposed to ionization radiation environments and due to that the circuits may get malfunctioned and the total modules of the system may get collapsed so there is need of RADHARD circuits. Usually these RADHARD circuits are used in nuclear reactors And Space Application circuit Modules as well as in the device internal modules where the circuits should run without any functional Interruption due to the ionization Radiation Effects. Actually RADHARD is a Procedure of Designing a electronic circuit Such that, the circuit Will Function in ionization radiation affected areas Without Fail. Even when any sort of Ionization Effects are Present there. we preferably design these kind of Circuits Because there is a huge need of these circuits to work accurately and efficiently for the modules which we design especially in Nuclear Power Plants And Space Equipments Space Crafts, Military Aircrafts, Satellites, Nuclear Power Plants, And Nuclear Power Weapons, etc.. Because in these applications the electronic circuits are most of the times affected by Ionization Radiation.

Keywords: Radiation hardened (RADHARD), SEE, TID RHBD, Harsh environment extreme environments, CMOS

1. Introduction

The Ionization Radiation can be like from a particle radiation and high energy electromagnetic radiation where it the electromagnetic wave will carries a enough energy so that it can remove or ionize a electron from the orbit of its atom and due to this the minority charge carriers will be affected and the transistor behavior will change from its original functionality so that the circuits will get damage and in turn the modules give poor performance and the application circuit may get vanished.[1] The electronic circuits whatever we design must be susceptible to radiation damage so we should design a circuit which will resist the ionization radiation to the electronic circuits those circuits we call them as radiation hardened circuits.[2] these kind of circuits especially preferred in space application modules and particle accelerators also in high altitude flights and also during nuclear warfare weapons, nuclear accidents in all these kinds of applications there is a Possibility of different kinds of sources the electronic circuits can be affected from radiation under space environments by radiation belts, cosmic rays, Solar Particle events, Nuclear Reactors, particle accelerators, and in earth environments by atmospheric neutrons and in military environment conditions when a huge amount of energy is released by a fission process in nuclear weapons and at the process of Chip Packaging Materials due to the small tiny particles of radiating elements left behind there is a possibility that they may produces alpha particles while the chips are packing[3]. However, it can be difficult to apply...
RHBD approach to advanced synthesizable commercial processors Since the designs target state-of-the-art manufacturing processes for commercial semiconductors and push the technology limits for gate count, die size, power density, and lifetime / reliability [14]. In the presence of ionizing radiation, modern semiconductor processes use extremely thin, high-quality oxides that decrease the amount of charge trapping that can occur, making them inherently difficult against the Overall Ionizing Dose (TID). CCDs and CMOS Active Pixel Sensors are very sensitive analogue instruments, and it is always possible to detect Signals as poor as a couple of dozen electrons. This makes them sensitive to the effects of radiation in the natural space climate. A detector would be bombarded in this setting by electrons and protons existing in the trapped radiation belts of the planet. Spacecraft and shielding materials absorb part of these particles but generate a gamma ray dose due to Bremsstrahlung radiation. Bremsstrahlung radiation is the radiation produced by a charged particle (most often an electron) because of the movement of another charged particle (most often a proton or an atomic nucleus) by an electric field[17]. For a broad range of applications, solid-state optical sensors are commonly used in the space world. These applications include robotic and navigation cameras, astronomy and earth observation imagers, star trackers, and satellite constellation tracking sensors (e.g. for laser communications), lander and rover imagers[17].

2. Types of Radiation Mechanisms
For electronics, the space atmosphere is not at all pleasant—nor is it for human beings, here it directly influence devices by changing their properties, beyond the protection that our environment gives us with regard to space radiation[13]. This can result in major changes in the Integrated Circuit. Performances. In reality, it can even cause their complete collapse or produce severe failures. In order to ensure stable and long-term actions, space-embedded electronics such as spacecraft for long-term exploratory missions and satellite payloads must also take radiation effects into account[13]. There are two different fundamental mechanisms are available for radiation ionization they are lattice displacement Mechanism and effect of ionization because of these two mechanisms the electronic circuits are damaged[4].

**Lattice displacement mechanism:**

![Figure 1. Lattice displacement mechanism][15]

In this mechanism displacement of atoms from its positions takes place because of the nuclease particles, alpha particles as well as big ions and vast intensity gamma photons will modify the position of the Particles in the network structure of the atom due to this recombination rate increases.
and which in turn depletes the minority carriers and it will disturb the original junction properties and these type of problems are particularly significant in bipolar transistors[5].

Ionization effect:

![Ionizing emission effect](image)

Figure 2. Ionizing emission effect[19]

These effects are seen due to the charged particles these effects are usually lasts for a very short period of time and creates a malfunction suddenly leads to destroy the device uncertainly they activates the other vandalization Mechanisms. these kind of operations are seen when there is a energy deposited in a semiconductor or in a insulating layer generally in sio2 layer where free charge carriers are get drifted or diffused to different locations and trapped in the layers which leads to unbalanced concentration of charges and parasitic fields. Ionization effect the devices mainly by the surface conduction. and this primarily effect caused due to the x rays and gamma rays and charged particles[6]. These damaging mechanisms usually results in accelerate the count of rejoining centers, and extensive defects and it in turn reduces the life time of outvoted charge particles thus it effects the transistor operation. [7]Resultant effects The end user groups are grouped into several groups such as i)Total ionizing dose effects, ii) Transient dose effects, iii)Systems-generated EMP effects, iv)Single-event effects The need for hardening against these effects has been removed by these developments in process capability. For stable operation in a space radiation environment, SEE hardening is needed.

Single-Event Effects

![Radiation solitary occurring outcome](image)

Figure 3. Radiation solitary occurring outcome [18]

These primarily affects only the digital devices when a soaring energy particle Progress across the semiconductor material then it pull outs a Bonded path supporting it and this bonding effect is similar to the transient effect. and also the solitary occurring outcome have much importance in electronic circuits of satellites ,military, aerospace and civilian applications .Some of the other types of solitary occurring outcome are a) solitary occurring outcome upset, b) solitary occurring outcome latch up, c) solitary occurring outcome snapback, d) single event induced burnout, e) single event gate rupture.
3. Problems due to Ionization Radiation

The Figure shows how the standard structure of an NMOSFET looks like and the path for the radiation induced leakage current how it flows inside its structure. However, it can be difficult to apply a RHBD method to foster synthesizable mercenary processors since the designs earmark ultra modern mercenary semiconductor fabricating processes and strike the ceiling of technology for number of gates, dimensions of chip, power density, and authenticity. Environment which have a very high level of ionization radiation creates a special challenges where a single charged particle will collide with the loose electrons in the atom and causes a electronic noise and signal spikes are observed. If it's a digital circuits then inaccurate results are seen. these are the most particular serious problems while designing the necessary circuits for satellites, spacecrafts, defence aircrafts, atomic power stations nuclear property weapons. to avoid all these kind of problems held due to radiation there is a need of manufacturing of integrated circuits and sensors intended for all these kinds of different harsh environment applications the designer needs to employ multiple ways of providing proper resistant methods for designing circuits to free from radiation. Radiation hardening is a process of designing the circuits to resist the damage towards the radiation ionization. The problems due to the radiation ionization are radiation hardened circuits can be tested by two ways one is physical process and another way is logical way.

4. Challenges in Radiation Hardening Circuits

It is well-known that reducing memory circuit sensitivity to effects of induces leakage currents due to radiation, such as solitary occurring outcome upsets (SEU) and multiple-bit upsets (MBU), is of critical importance for space applications. There are challenges are seen when the environments contains a abundant atomic radiation then Depiction of an silicon chip is a very challenging task. it is very much particular when we go for designing a artificial satellites ,military aircrafts, nuclear weapons and spacecrafts and nuclear power stations the Van Allen radiation belts seen due to the stereotypical Pedigree of exposure of electronics to ionizing radiation for satellites and also from cosmic radiation is seen in space crafts and high altitude aircrafts and potentially in all military and civilian electronics.
5. Techniques of Radiation Hardening
According to the state-of-the-art, key techniques of mitigation design[13].
1) On the device level, spatial redundancy-based techniques.
2) Architectural-level Error Detection And Correction (EDAC) techniques.
3) Radiation-Hardening-By-Design (RHBD) at the circuit stage of the memory cells (SRAM cells, latches, flip-flops) The techniques for radiation hardening are involves like two categories:
   3.1 Corporal Solutions
   3.2 Logical Solutions.

Corporal Solutions: These kind of techniques use various types such as sheathe substrates, Utilizing bipolar integrated circuits, adopting radiation tolerant static random access memories etc to realize the hardening purpose, and also we should take care of proper shielding the package against the radio activity from the environment. it is a type of protection what we provide for the integrated circuits to reduce the exposure of the bare devices to the radiation.[5]

Logical radiation Hardening Techniques: In this type of technique we adopt different types of logical things like using error correcting memories, utilizing redundant elements, adopting a watch dog timer etc., and reliability evaluation can also be introduced[5]

6. Applications
Radhard and dispersion magnanimous components are frequently in space and military utilization like aircrafts, space crafts, high altitude communication circuits and switching as well as point of load applications and power supplies systems of satellites in space and origin of FPGA power as well as bow out power switching and high coherence squat voltage subsystem power supplies and nuclear power stations etc.

7. Conclusion
In a nut shell this study paper is discussed about the radiation and ionization effects and the prime radiation impairment sources also the two radical vitalization processes and quinary type of extremity user effects as well as six types of SEE effects and what is the use of radhard circuits at multiple work environments like nuclear power stations and defence aircrafts as well as spacecrafts is discussed and also shown the diagrammatic representation of radiation induced leakage current path in a NMOSFET operation, and the possible radiation mechanisms are shown and disused briefly and how the circuits are exposed to radiation etc..with this the reader can able to know about the need of radiation hardened circuits.

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