

Critical RF switch design parameters for space

Greg Horvath, Product Applications Engineer, Peregrine Semiconductor Corporation

Harsh environments associated with space applications pose particularly demanding radiation requirements on Radio Frequency (RF) components. The effects of radiation can lead to additional device parameter degradation, performance interruptions or destructive failure modes. The primary requirement for space-qualified components is the ability to withstand the radiation that is present throughout space while maintaining long-term, reliable operation. Radiation-hardened devices are capable of operating in this environment with a long lifetime when submitted to solar electromagnetic radiation, heavy ions or charged particles.

Single Event Effect (SEE) and Total Ionizing Dose (TID) Radiation

The complex space environment consists primarily of two types of radiation. Single Event Effects (SEEs) are instantaneous failure mechanisms that are caused by naturally-occurring space-based radiation. There are two main types of SEEs. Single Event Upsets (SEUs) are non-destructive or soft errors that can be corrected. These may appear as transient pulses in logic or support circuitry, or as state changes in memory cells or registers. Single Event Latchups (SELs), on the other hand, are often catastrophic, resulting in permanent damage and requiring, at a minimum, a reset or a power cycle to recover. SELs can occur when a high-energy particle strikes a semiconductor device, causing a short circuit from power to ground within the device.

Total Ionizing Dose (TID) is a cumulative effect related to long-term exposure of electrons and protons due to solar activity. Gradual degradation to component parameters such as supply and leakage currents, threshold voltages, and propagation times are characteristic of TID failures. Spacecraft and satellite mission duration and orbit altitude requirements determine the level of ionizing radiation levels that components must survive. Typical levels are between 10 and 100 krad (Si).

Lower doses of ionized exposure (< 0.1 rad/sec) have been found to significantly degrade some bipolar devices. Exposure of this nature is referred to as Enhanced Low Dose Rate Sensitivity (ELDRS).

Solid-state switch technology

RF switches play an important role in spacecraft communication systems and RF payloads, such as signal routers, antenna arrays, and transmitter/receiver circuits. There are many RF switch technologies available to the market, and each has its advantages and disadvantages. Solid-state RF switches are attractive to the space market because they are typically more reliable and exhibit longer lifetime than electromechanical switches. However, most off-the-shelf components are not intended for space applications and may require additional radiation mitigation

Critical RF switch design parameters for space

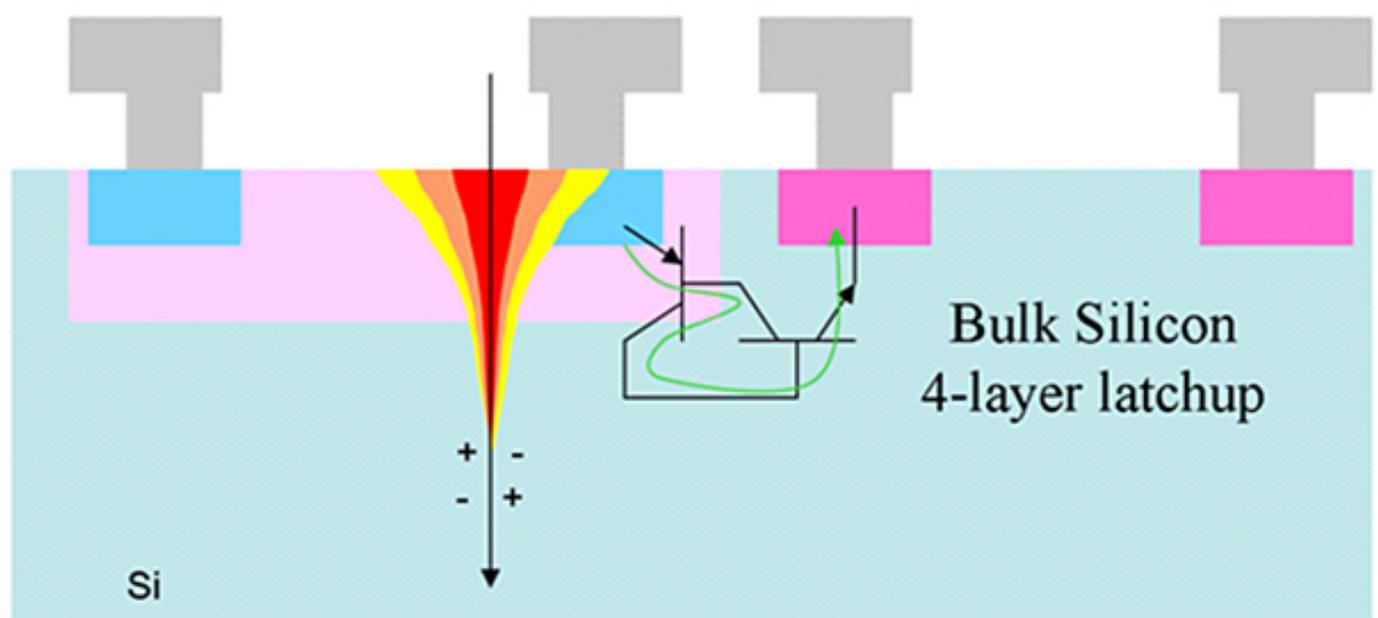
Published on Electronic Component News (<http://www.ecnmag.com>)

techniques, and qualification efforts, resulting in high development costs. The harsh environments associated with space radiation limit designers' choices.

PIN diode switches—one of the oldest technologies—provide good high-frequency operation, with low insertion loss and better power-handling capabilities in comparison to most solid-state switches. However, PIN diode switches do not operate near DC as their electrical performance degrades at lower frequencies due to the thickness of their intrinsic region. They also require additional components and more current to operate in comparison to other solid-state switches. PIN diodes demonstrate adequate radiation tolerance and are often used in nuclear and electromagnetic radiation detection devices.

GaAs MESFET and the more recent Pseudomorphic High Electron Mobility Transistor (PHEMT) switches offer compelling performance for most low to moderate power, high-frequency and broadband applications. GaAs switches are more vulnerable to damage from ESD than Silicon technology and the implementation of logic control circuitry is more difficult. Due to their planar structure, GaAs MESFET and PHEMT switches do not suffer from SEL. However, SEU susceptibility is a concern for high-speed GaAs integrated circuits. The implementation of techniques designed to mitigate the effects of radiation upsets becomes more difficult as clock rates and operating speeds increase, with smaller technology.

Bulk CMOS switches are the most inexpensive to manufacture, but they exhibit high insertion loss and low isolation due to the physical properties and conductivity of the silicon substrate. Additionally, the parasitic effects of Bulk CMOS restrict the switches' operating frequency and linearity. Designs that are implemented with Bulk CMOS are susceptible to SEL, as illustrated in Figure 1. When a high-energy particle strikes the parasitic thyristor inherent in the substrate, latch up can occur, causing a short circuit from power to ground within the device.



CMOS Silicon-on-Insulator (SOI) technology is better suited for RF switches than Bulk CMOS due to the low parasitic nature of its insulating substrate. New advances in

Critical RF switch design parameters for space

Published on Electronic Component News (<http://www.ecnmag.com>)

this technology have demonstrated competitive electrical performance to the solid-state RF switch market while offering unique radiation properties without the need for costly mitigation techniques.

Micro-Electro-Mechanical Systems (MEMS) switches provide noteworthy improvements to RF performance, while offering low power consumption and small size. SEL is not possible in MEMS switches, since there is no path for the current to flow. However, the control electronics are susceptible to SEE and component reliability remains questionable for space applications. Further research is needed to understand the long-term reliability and the effects of radiation on RF MEMS switches.

Gallium Nitride (GaN) is the latest technology, offering high levels of power handling, low insertion loss and low current. Aside from requiring high voltages levels to operate, the successful growth of device-quality epitaxial GaN on silicon wafers is still in its infancy. For the space environment, devices made from GaN promise to deliver reliable operation, and initial test results indicate that this technology is also capable of withstanding most high levels of radiation.

In summary, design parameters related to component process technology and radiation survivability are expected to continue to be a primary concern of the space industry. Radiation hardened electronic components are vital in spacecraft and satellite payloads, where failures are not acceptable. RF switches play an important role in these electronic systems and continue to improve with advancing technology.

Source URL (retrieved on 07/22/2014 - 12:39pm):

<http://www.ecnmag.com/articles/2013/06/critical-rf-switch-design-parameters-space>