HITACHI
Inspire the Next

FPGA Soft Errors

1. What is the “soft error” phenomenon?

An enormous number of cosmic rays rain down around us. When cosmic rays enter the atmosphere, they collide with various atomic nuclei, producing particles, such as neutrons and muons. A large number of these particles reach the earth (ground level). Figure 1 shows the atomic decay of cosmic rays. Most of the particles pass through all objects, including human bodies. However, some of them collide with objects. Neutrons, muons, and other particles can accidentally hit semiconductors, causing data stored as zeros (0) and ones (1) to be inverted (data corruption). This phenomenon is called a *soft error*.

2. The soft error phenomenon is nasty!

There are two types of device errors: *hard errors* and *soft errors*. Figure 2 shows the difference between a hard error and a soft error, using a failure in computer memory as an example.

A memory hard error refers to the case in which the memory itself is corrupted. In the case of a hard error, the memory error can always be reproduced when the computer is restarted because the memory has a physical problem.

A memory soft error is a temporary inversion of memory data caused by neutron beams, as described previously. In the case of a soft error, the memory error does not re-occur after the computer restarts, because the data has returned to normal. This is a nasty situation because no matter how much you check the memory, the abnormality cannot be reproduced, and the cause of the problem remains unknown.

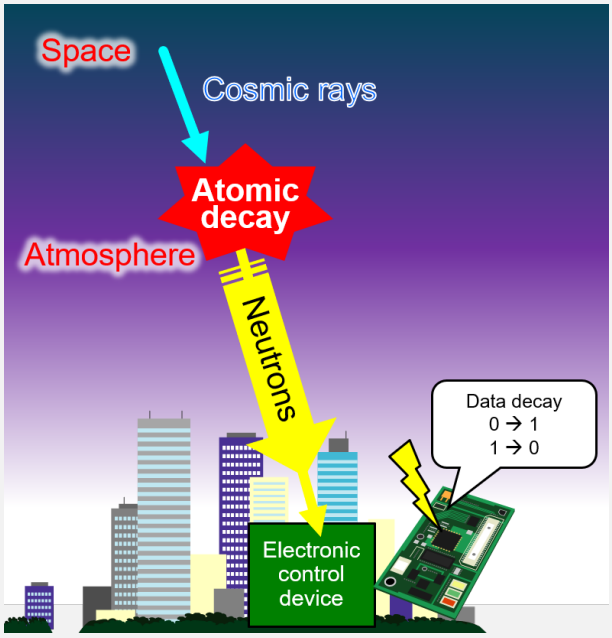

Figure 1. Atomic decay caused by cosmic rays

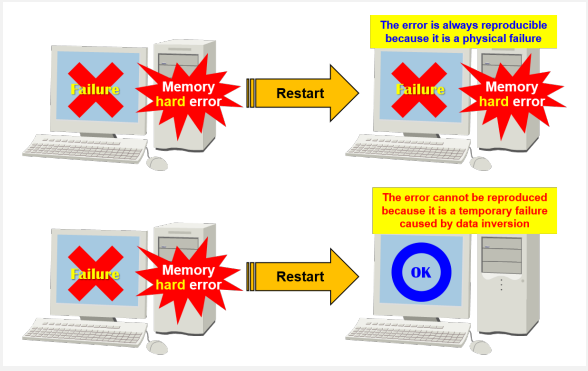

Figure 2. Difference between a memory hard error and a memory soft error

3. Assume that soft errors will occur

Malfunctions caused by soft errors have been reported since the 1970s, and the mechanism was elucidated at the end of the 1970s. The risk was discovered more than half a century ago, and research, which is mainly focused on the aerospace area, has continued ever since.

As semiconductors become finer and lower in voltage, the risk of soft errors occurring at ground level can no longer be ignored.

To measure soft errors at ground level, researchers lined up boards containing semiconductor memories (about 1,000 in total) in a specific area of a building. A total of 11 soft errors were detected during the 30 days of observation.

The results show that a soft error occurred once every three days on average, so you need to assume that soft errors are likely to occur.

4. Standards apply to soft errors

On November 13, 2018, ITU-T (ITU Telecommunication Standardization Sector, a specialized organization of the United Nations) established international standards for the design, testing, evaluation methods, and quality related to measures against malfunctions (soft errors, primarily caused by cosmic rays) in terrestrial telecommunication equipment.

Notably, the standards defined measures against soft errors caused by an FPGA (field programmable gate array) . Based on the standards, measures against soft errors must be implemented in products in which an FPGA is installed.

5. What is an FPGA soft error?

Before we describe FPGA soft errors, note that Figure 3 below shows the structure of an FPGA. The circuit configuration information (logic and wiring) of an FPGA is stored in the configuration RAM (commonly abbreviated to CRAM).

The CRAM reads the FPGA configuration information from the external flash ROM when power is turned on.

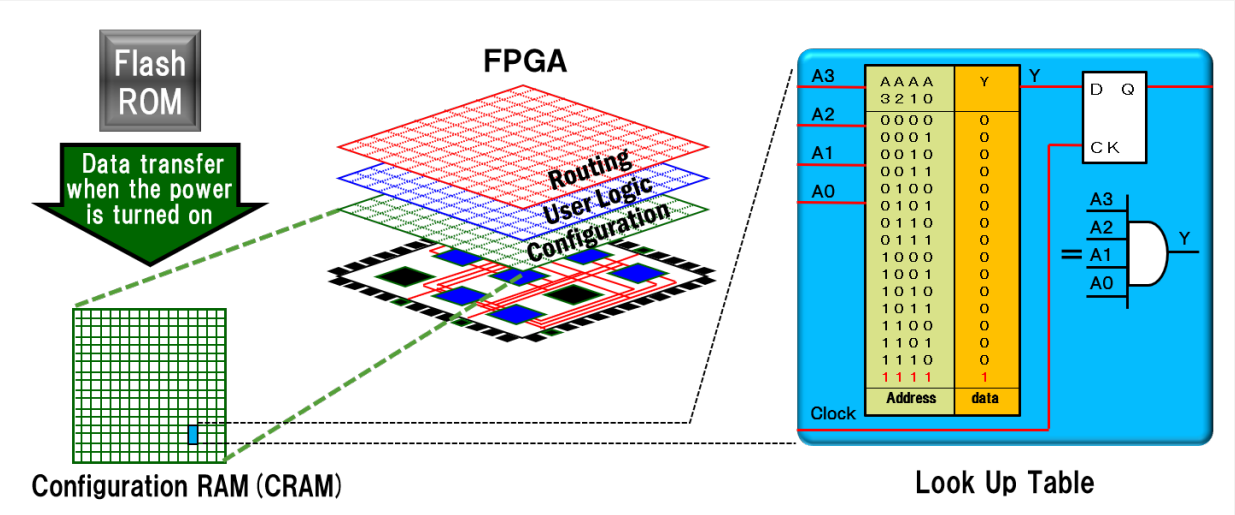

Figure 3 Structure of an FPGA when the power is turned on

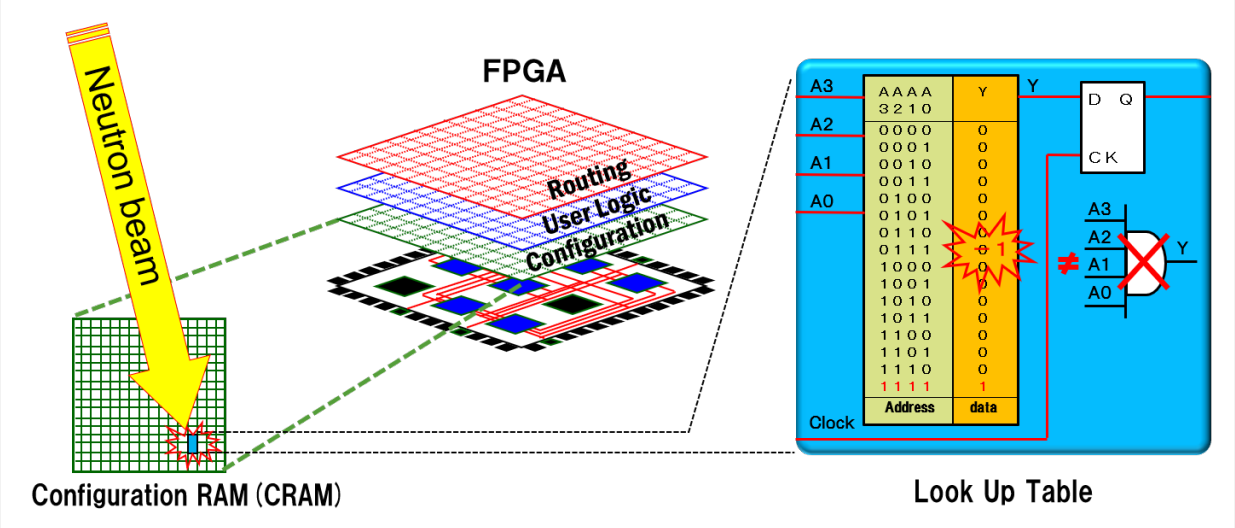

Figure 4. The status when an FPGA soft error occurs

The actual user logic consists of a lookup table (commonly abbreviated to LUT). The LUT is stored in the CRAM in a configuration that is similar to RAM in which input signals are stored as address lines. The LUT shown in figure 3 consists of 4-input AND gates from the data stored in the SRAM.
Figure 4 shows the status when an FPGA soft error occurs. A neutron beam strikes the CRAM in the FPGA causing inversion of a part of stored data. This is called an FPGA soft error.

6. Problems caused by FPGA soft errors

An FPGA soft error might cause problems such as the following:

(1) A soft error can change the logic, which can cause the device to malfunction.

(2) CRAM data of an FPGA is read only when the power is turned on, so the circuit configuration information of the CRAM remains inverted and the logical malfunction continues as if a physical failure occurred.

(3) When the FPGA is rebooted (the power is turned on again) to recover the failed device, the FPGA loads the circuit configuration information from the flash ROM to the CRAM. The inverted data caused by the soft error is overwritten, so the failure symptoms cannot be reproduced.

To resolve these problems, measures against FPGA soft errors must be implemented based on the definitions of system requirements.

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