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An Autonomous Nonvolatile Counter for Radiation Environments

Radiant Technologies, Inc. has developed an autonomous nonvolatile memory latch capable of operating independently of a microprocessor or controller. The autonomous non-volatile latch is described in the document “An Autonomous Nonvolatile Memory” from Radiant. The latch enables new circuit architectures for stand-alone sensors and smart devices that operate in an intermittently powered environment. One example is a binary counter where the flip-flops in the counter use autonomous non-volatile latches as their outputs. The autonomous counter circuit and its energy requirements are described in the document “An Autonomous Nonvolatile Digital Counter”. The counter will always power up with its last count. The circuit uses so little power it can be designed *to power up, advance one count, and power down* using the energy of a sensor it monitors, eliminating the need for a separate power supply. This counter offers new and unique functionality in a radiation environment. Since a ferroelectric capacitor is the memory storage element of the latch, the latch will be intrinsically hardened if the latch circuit is built with radiation-hardened circuit technology. One unique function is described below.

Ferroelectric capacitors retain their memory state encoded in distortion of their material lattice. As such, the state is difficult to destroy by a hit from a single energetic particle. The larger the capacitor area, the higher the energy the particle must have to noticeably affect the stored memory state. Thin PZT film capacitors fabricated by Radiant require approximately 600µJ per square centimeter to switch from one state to the other. A capacitor 10µ on a side thus requires 600pJ. The PZT capacitor, when used in the autonomous non-volatile latch circuit, is ambivalent about switching speed and can operate from hertz to megahertz. The switching energy will remain constant independent of switching time so the power required to set a state will be controlled by the speed of the circuit. By adjusting the capacitor area and switching speed, the circuit can be designed to operate in a high radiation environment from a power supply, a battery, or from the power generated by the sensor it is recording. Powered by the sensor, the autonomous counter can operate during high radiation flux recording information even though the system electronics may be shut down.

In one implementation, a high energy particle detector acts as a “solar cell” and stores the energy impinging upon it. Once enough energy is stored to advance the count of an autonomous counter, the detector uses the stored energy to generate a single pulse into the counter. The counter powers up using energy from the clock pulse, advances one count, and powers down at the end of the pulse, all without a separate power supply or a controller to give commands. The detector will generate pulses at a rate proportional to the rate of energy deposition so the change in the count represents the total energy received during a high flux. An external controller can later power up the autonomous counter, read the count, and reset the counter to zero.

The autonomous measurement system described above will generate a count equal to the total energy deposited on the detector independent of the rate of energy deposition. A high particle flux in a short period or a low particle flux over a longer period will produce the same count if the total energies of the two different situations are the same. More detail may be gathered by adding more counters. Some of the extra counters may be hooked to detectors that are sensitive only to certain particle energies. Others may have internal timers that set the maximum rate at which they may be activated to count. Multiple autonomous counters thus may gather spectroscopic information for the system in which they reside.

The autonomous spectrograph could make decisions about system safety while the system is powered down during a high radiation flux. For instance, if impinging radiation becomes strong enough to damage a subsystem, a counter monitoring the radiation would determine that damage occurred when its count exceeded a certain value. It could then set individual autonomous memory latches used as memory in the control unit for that subsystem so the subsystem would not power up when the radiation flux dissipates or would power up using a different procedure to check and isolate the damage.

The function described above is an example of how zero-energy autonomous memory integrated with intelligence may make decisions for the protection of a much larger system. Such a memory that operates without a microprocessor or controller eliminates complexity and enables new architectures unlike any that have been conceived before. Please contact Radiant Technologies, Inc.