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粒子センサ用高速検出回路の小型集積化に関する研究

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Study on Development and Integration of the High-Speed Current Detection Circuits in Particle Sensors

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Since space plasmas show a collision less feature, wave-particle interaction dominate electromagnetic environment. Observation of both particles and waves are essential to understand energy and momentum transfer mechanisms. For observations of spatially non-uniform space plasmas, it is critical to perform the formation flight consisting of multiple satellites. Recent trends of spacecraft fleet missions in the terrestrial magnetosphere such as Cluster II [Escoubet et al., 2001], THEMIS [Angelopoulos, 2008] and MMS missions [Burch et al., 2015] consist of at most five satellites. More satellites are necessary to observe spatial structures and temporal variations of the space plasmas in more detail. However, it is difficult to realize simultaneous multi-point observations of tens to hundreds satellites due to huge resource demands including weight, size and power consumption. The use of small satellites such as CubeSat is effective in realizing large-scale multi-point observations.

Minimization of weight, size and power consumption is essentially important for building an instrument onboard satellite. The present study focuses on the miniaturization of particle instruments. A time-of-flight (TOF) technique is commonly used for mass discrimination of incoming particles. Typical TOF measures speed of incoming particles using a timing difference between their passages at two points inside a sensor. Required resolution of the elapsed time measurement is 1 ns or more since particle path length of a TOF sensor is a few to tens of centimeters, and incoming particles have energies in keV range. Thus a high-speed particle detector that operates at 1 ns or faster is necessary to perform TOF measurements. A conventional particle detector consists of 15 substrates that are the size of 60 mm x 57 mm each, and consumes a volume of more than 1400 cm^3. Here we are developing an ASIC (Application Specific Integration Circuit) based fast particle detector for satellite-borne plasma particle sensors. By using ASIC technology, required size for the circuit can be drastically reduced. The new detector is a size of less than 5 mm x 5 mm (implemented on a chip) that can handle more than 1 million signals per second. Laboratory experiment shows that the developed ASIC can detect output signals of MCP (Micro Channel Plate) within timing fluctuation of 1 ns, which can be applied for typical TOF-based ion energy-mass spectrometers. We will report the performances of the developed ASIC and results of laboratory experiment using a TOF-based ion mass analyzer.