

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

*菊川 素如¹、小嶋 浩嗣¹、斎藤 義文²、浅村 和史²

*Motoyuki Kikukawa¹, Hirotsugu Kojima¹, Yoshifumi Saito², Kazushi Asamura²

1. 京都大学生存圏研究所、2. 宇宙科学研究所

1. Research Institute for Sustainable Humanosphere, Kyoto University, 2. Institute of Space and Astronautical Science

In outer space near the earth, many high-energy electrons are captured in the radiation band. Since these electrons cause charging of satellites and interfere with their operations, it is important to predict a fluctuation of electron flux in the radiation band. When a geomagnetic storm occurs, electron flux in the radiation band decreases greatly, but after a while, the flux recovers to an original level. We assume that there are some kinds of accelerating mechanisms that produce relativistic energy electrons in space. One of the accelerating mechanisms is “wave-particle interaction.” In this theory, ions and electrons in the intermediate energy band (5-200 keV) are thought to excite plasma waves that produce relativistic energy electrons. However, particle observation techniques in this energy band are not yet sufficiently developed, and there are few examples of observations on wave-particle interactions. The Medium-Energy Particle Experiments (MEPs) are developed to observe particles in the intermediate energy band, and have electrodes in the shape of a spherical shell with an electric field applied to measure the velocity vector of particles coming inside.

To observe the wave-particle interaction, we need the phase difference information between the plasma wave vector and the particle velocity vector. In other words, the information on the time when the particle is arrived in the MEP is important. In order to obtain the time information, the satellite is equipped with a circuit that amplifies and detects the weak current pulses generated at the moment of particle arrival in the MEP. This is called the particle detection circuits, and these conventional circuits are composed of discrete electronic components. These discrete components lead to an increase in volume and weight. This is why they place a heavy burden on the satellite. We integrate the particle detection circuits using ASIC (Application Specific Integrated Circuit) technology. The developed chip is highly small and light-weight. Since the developed chip is expected to be mounted on micro-satellites, simultaneous multipoint observation of wave-particle interactions can be realized at low cost.

Our developed chip consists of two stages. The first stage is the current-voltage conversion circuit. It picks up each current pulse and converts into voltage signals with enough amplitude to drive the second stage. The second stage contains a comparator and a peak-hold circuit. They ensure picking up real signals by setting a threshold level.

In this study, we develop the circuit which can output detection signals within 30ns after the arrival of particles and can be reset within 12ns on inputting the reset command. The size of one channel of the developed circuit is 210 μm $\times$ 570 μm . Since the conventional circuit was several centimeters in size, we have reduced the area of this circuit by more than one tenth in this study.

In this session, we show the details of the chip designed for the particle detection circuits including experimental results.

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