

Multi-Channel Charge Amplifier-Discriminator-Counter IC for the Space Sciences

Victoria B. Cajipe, *Member, IEEE*, James H. Clemmons, Martin Clajus, William R. Crain, Satoshi Hayakawa and Tümay O. Tümer, *Member, IEEE*

Abstract— We have developed a multi-channel, mixed-signal integrated circuit (IC) as part of a resource-conserving approach to the design of instruments for missions flown under the Geospace Missions Network (GMN) of NASA's Living With a Star (LWS) program. Specifically, the IC was designed to read out microchannel plates (MCPs) which allow detection of single hot plasma particle by emitting a pulse of charge when struck by the plasma particle. The IC, named AIDA (Amplifier Discriminator ASIC) includes several Charge-Amplifier Discriminators in one package without sacrificing performance, thus simplifying the MCP electronics and saving on space, power and cost. Reduction of power and mass requirements by several tens of percent relative to existing MCP instrument electronics was the primary goal. A secondary goal was to integrate the pulse counting function into the IC, thereby eliminating the need for additional counters and conserving resources further. We present the features and capabilities of the AIDA IC and evaluation system, and initial characterization data for the chip.

I. INTRODUCTION

HOT plasma, defined as charged particles in the energy range 10 eV – 30 keV, is an extremely important element of the geospace environment. This plasma responds strongly to solar variability and manifests itself in many ways. It forms the parent population for the ring current, a primary indicator of geomagnetic activity and variability. As an important component of the conduit connecting the magnetosphere with the ionosphere, hot plasma includes precipitating charged particles. These particles strongly influence the ionosphere, thereby affecting technology on Earth through currents induced in power grids and communication interruptions. In many regions of geospace, hot plasma is a key player in surface charging of spacecraft, one of the most important causes for anomalies on spacecraft.

The properties of hot plasma have been measured throughout the solar system over the past decades using techniques that have evolved dramatically. Instruments with many features and capabilities are crucial for several NASA missions, but resource-conserving techniques have become increasingly important in many cases. The GMN is no exception to this trend and has encouraged development

projects that aim to reduce the resource requirements of key components used in many state-of-the-art plasma analyzers.

Most hot plasma instruments flown in space utilize an “analyzer,” which separates particles based on their energies and/or travel directions, and a detector, which records particle arrivals. Analyzers are based on electric and/or magnetic fields. A common technique, an electrostatic analyzer (ESA), utilizes a pair of curved conductors separated by a gap across which a potential is maintained. Only particles within a certain energy passband pass through the gap to be detected by the detector. An energy spectrum is measured by changing the potential across the gap as a function of time and measuring the resulting sequence of particle arrivals.

In conjunction with the analyzer, detectors based on channel electron multipliers, such as microchannel plates (MCPs), are commonly used. MCPs allow the detection of a single hot plasma particle by emitting a pulse of charge when struck by the plasma particle, so the sensitivity is very good. The charge pulses typically contain about 10^6 or more electrons, so they are large enough to be registered by conventional electronics. Several techniques are currently employed for imaging using MCPs. One commonly used for hot plasma measurements collects the charge pulses with a sequence of discrete metal anodes. Each anode is instrumented by its own electronics which are relatively straightforward since the method does not require that the amount of charge be quantified. Rather, the amount of charge need only be compared to a preset threshold to determine whether a “count” was received. High count rates are possible with this technique since standard electronics are capable of 10 MHz count rates and greater. A typical ESA will use 32 such anodes to provide 11-degree angular resolution. 32 charge-amplifier/discriminator circuits are thus required. Simplifying the implementation of the charge-amplifier discriminators would contribute significantly to resource saving when flying on the GMN.

Within this context, we developed a multi-channel, mixed-signal IC called AIDA to read out MCP imaging detectors used for hot plasma measurements.

II. DESCRIPTION OF AIDA

The AIDA chip has 16 channels plus two test channels. Each channel accepts a negative-current pulse from the MCP-detector and employs circuits to amplify and shape the signal and deliver a digital pulse to the output. The channel also includes counting circuits and registers to present the

Manuscript received November 17, 2006. This work was supported by NASA Grant No. NAG5-12811.

V. B. Cajipe, M. Clajus, S. Hayakawa and T. O. Tümer are with NOVA R&D, Inc., 1525 Third Street, Suite C, Riverside, CA 92507 (telephone: 951-781-7332, e-mail: victoria@novarad.com).

J. H. Clemmons and W.R.Crain are with The Aerospace Corporation, 2350 E. El Segundo Bl., El Segundo, CA 90245.

its layout and a photograph of the chip wirebonded inside a commercial 144-pin CQFP package.

An evaluation system was designed to enable characterization of the chip. Fig. 3 displays a photograph of the system hardware designed in a mother-board/daughter-card architecture. The daughter board holds the IC to be tested (assembled in a CQFP package) and circuits that need to be close to the chip to minimize noise. The mother board contains the power supplies, control and support electronics and the fiber-optic data link to a custom PCI card housed in the system PC. Its heart is an FPGA that takes commands from the PC and executes those commands by adjusting values of digital-to-analog (DAC) converters that control bias voltages and currents as well as comparator thresholds, directly interfacing with the AIDA IC, or by sending responses back to the computer. The standard daughter card of Fig. 3 mounts directly to the mother board when using the chip for bench testing with test pulse inputs. Another version of the daughter board is being developed for use with MCP detectors inside a vacuum chamber.

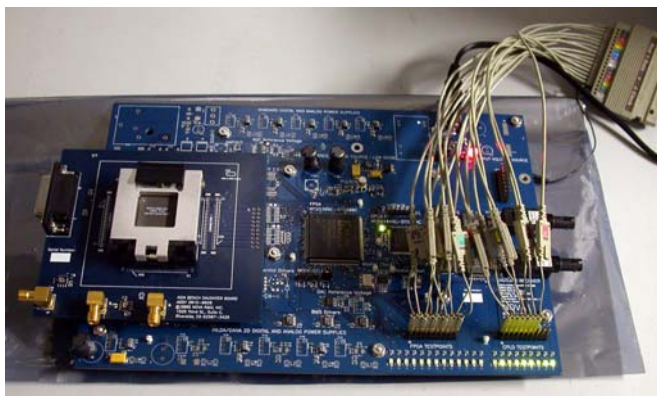
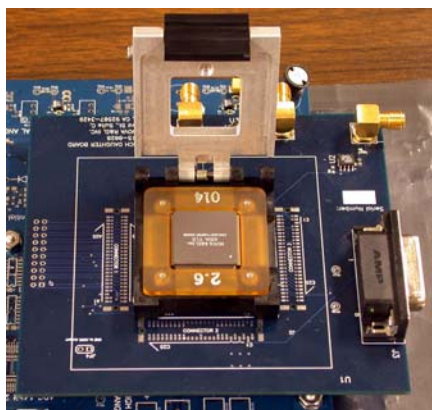


Fig. 3. Photographs of the: AIDA chip sealed in the CQFP packaged positioned in the socket mounted on the standard daughter board (top); and, AIDA evaluation system, powered up (bottom).

IV. INITIAL CHARACTERIZATION RESULTS

We first investigated the preamplifier performance. Shown in Fig. 4 is the preamplifier output for 1.3Me injected in high gain mode. A 30ns peaking time is observed which compares well with simulation results.

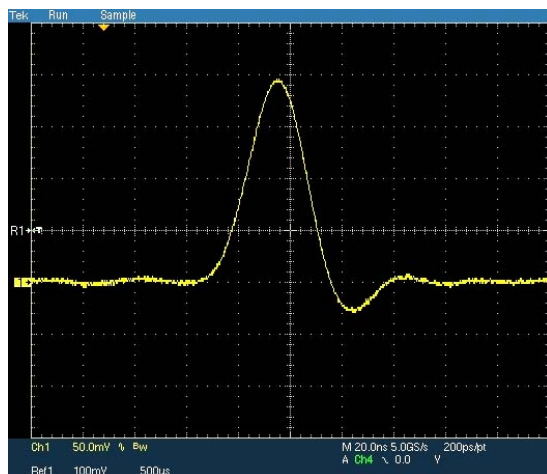


Fig. 4. Oscilloscope trace for typical preamplifier output when 1.3 million electrons are injected into test channel #16 (high gain mode).

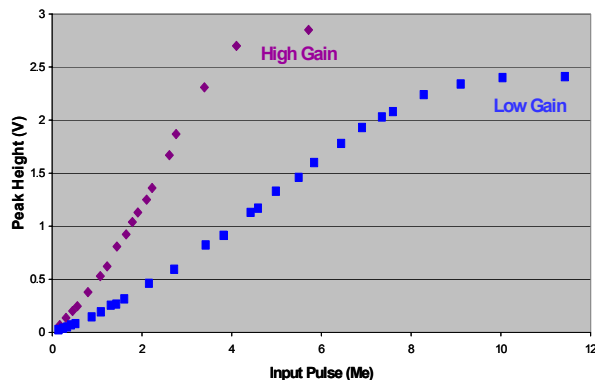


Fig. 5. Preamplifier pulse output height versus input pulse size, obtained using test channel #16 in high and low gain mode.

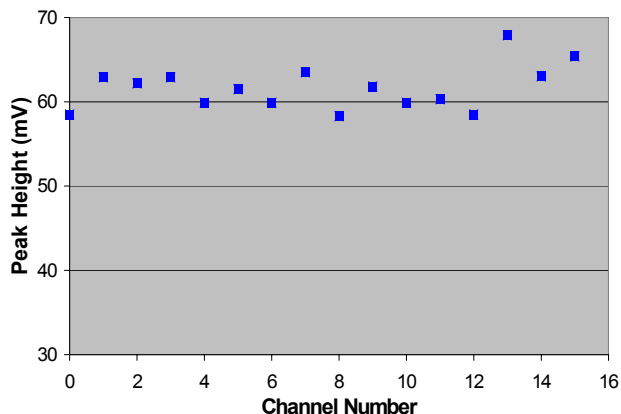


Fig. 6. Preamplifier output on the 16 channels observed with 125ke injected charge (high gain).

The preamplifier pulse output height was measured as a function of the input pulse size. The results are plotted in Fig. 5. Good linearity is observed up to greater >3.1 Me in high gain mode and about 9Me in low gain: this covers the size range for signals of interest in the hot plasma application. Observing the preamplifier output on the 16 channels, we see that it is fairly uniform from channel to channel as displayed in Fig. 6 which gives the sample result for the case of 125ke injected charge.

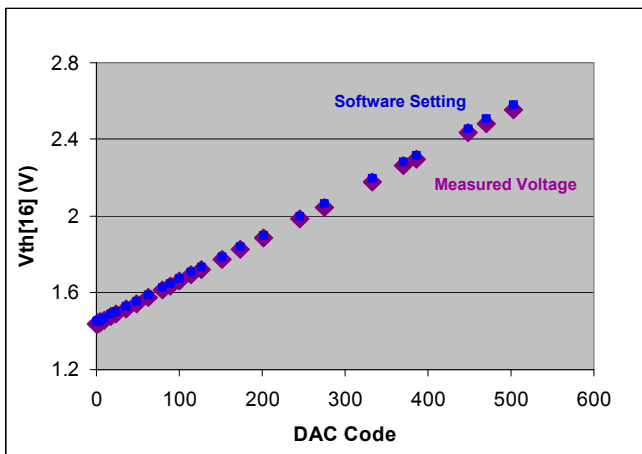


Fig. 7. DAC output monitored by increasing DAC code on test channel #16.

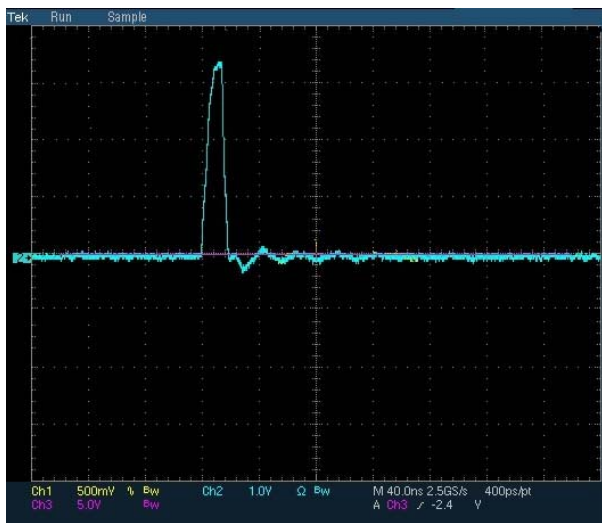


Fig. 8. One shot pulse generator output showing a 3.3V swing.

The direct DAC output was monitored in the test channel and good linearity is observed as shown in Fig. 7. The test system software allows for selection of the DAC voltage. The figure also compares the actual voltage readings and the readings on the dialog box, showing very good agreement. The one-shot pulse generator was examined and the one-shot pulse generator output from one of the channels is displayed in Fig. 8. A 3.3V swing is clearly observed; this can be fed into an off-chip counter.

Studies of entire counter sequences were also undertaken. The chip incorporates serial and parallel methods for reading the contents of the counters and readout sequences for both cases were demonstrated to work properly. The parallel readout mode was provided in AIDA for the case of a microprocessor interface. It has advantages over serial readout in that it shortens the readout time and allows for the collection of counter data from user-selected channels.

Other characterization results may be summarized as follows: the noise is estimated to be of the order of 10ke; the DAC resolution is about 5ke per DAC code; the quiescent power is approximately 2.8mW per channel; and recovery

time from a 30MeV signal was found to be of the order of 1μsec.

We also started doing counting experiments using signals from a PMT illuminated with a green LED in lieu of the MCP detectors of the target application, which require a vacuum chamber. It is hoped that a broader applicability can be demonstrated for the AIDA chip by continuing these measurements using PMTs.

V. SUMMARY

In summary, the fabricated AIDA is functional and ready for evaluation under MCP application conditions. More detailed chip characterization will be carried out and the work will be extended to multi-channel measurements using MAPMT devices. Studies of AIDA with MCP imaging detectors in a high vacuum environment will be conducted at the Aerospace Corporation. Also planned are temperature and radiation tolerance testing of the chip and the development of new prototype readout electronics based on AIDA for application in future GMN missions.

ACKNOWLEDGMENT

We thank our collaborators and consultants Gary Kline, Gerard Visser, Dave Ward and Oded Yossifor for their contributions to the development of the AIDA chip and evaluation system.