

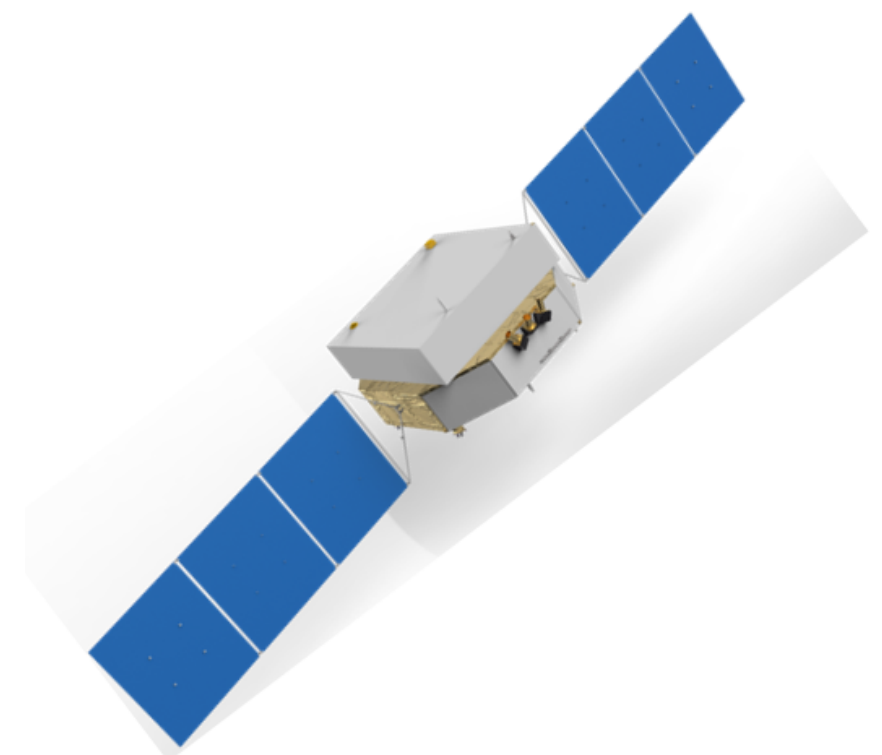
Design of the Readout Electronics for the CsI(Tl) Calorimeter of VLAST-P Payload



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Introduction

- The VLAST-P (Very Large Area gamma-ray Space Telescope-Pathfinder) is a miniaturized space detector designed to reliably detect high-energy gamma-rays from the Sun (in the MeV to GeV energy range), as well as high-energy protons from solar flares.
- The VLAST-P payload consists of three sub-detectors: an anti-coincidence detector, a tracker, and an electromagnetic calorimeter.
- The CsI(Tl) electromagnetic calorimeter is used to measure the energy deposited by incident particles and to identify particles.
- Signals from the APDs are amplified and shaped by CSA (Charge Sensitive Amplifier), then split into high and low electronics gain to achieve a large dynamic range (0.4 MeV to 6.5 GeV). The analog signals are digitized by ADC (Analog-to-Digital Converter), and the FEE sends the scientific data to the electronics control unit.
- The VLAST-P payload is scheduled for launch at the end of 2026.



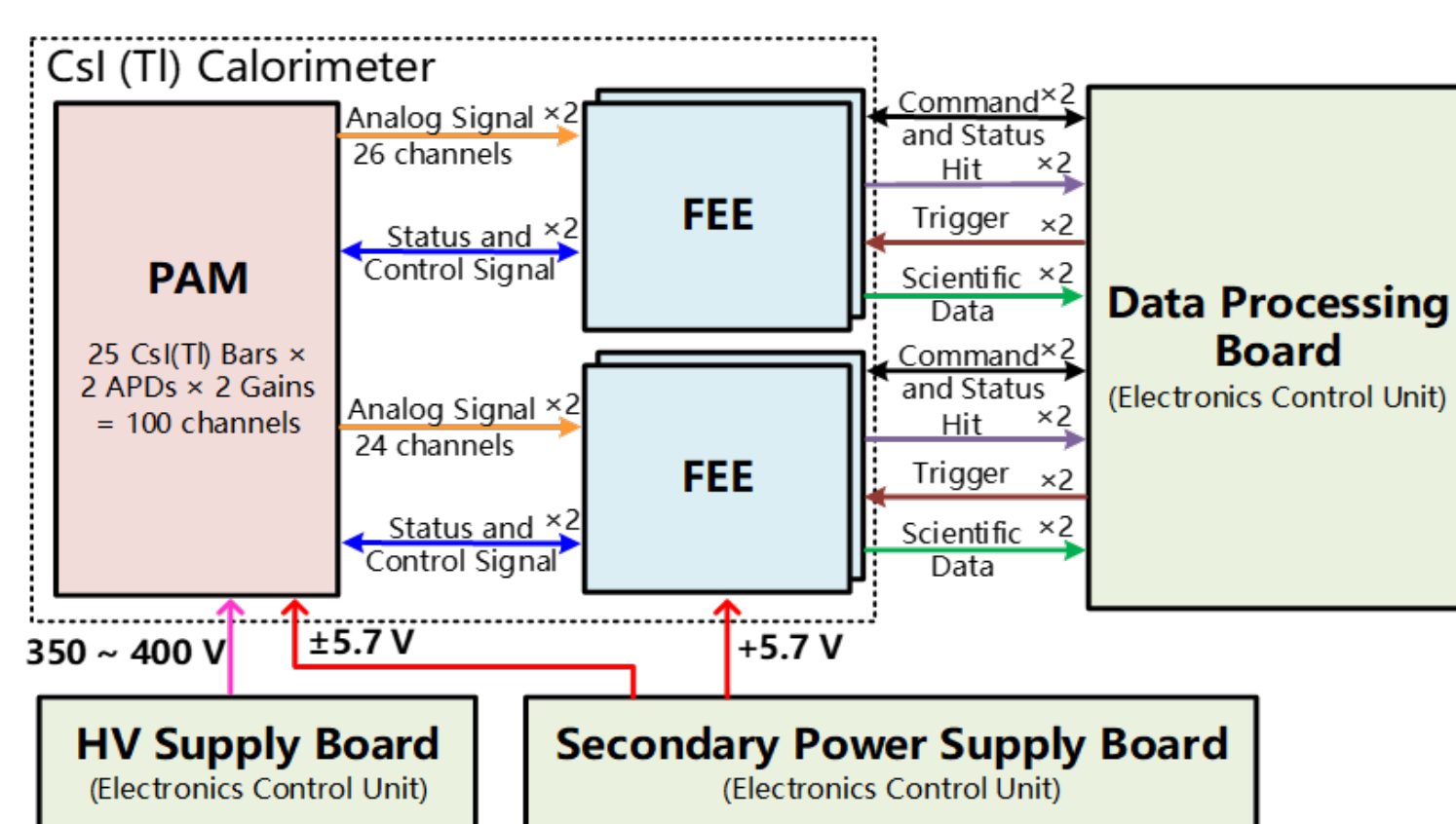
Electronics Design

Overall Design

The calorimeter is composed of 25 CsI(Tl) crystal bars with a longitudinal depth of about 10 radiation lengths. Two Avalanche photodiodes (APD) are used for each crystal to collect scintillation light (one serving as a hot backup).

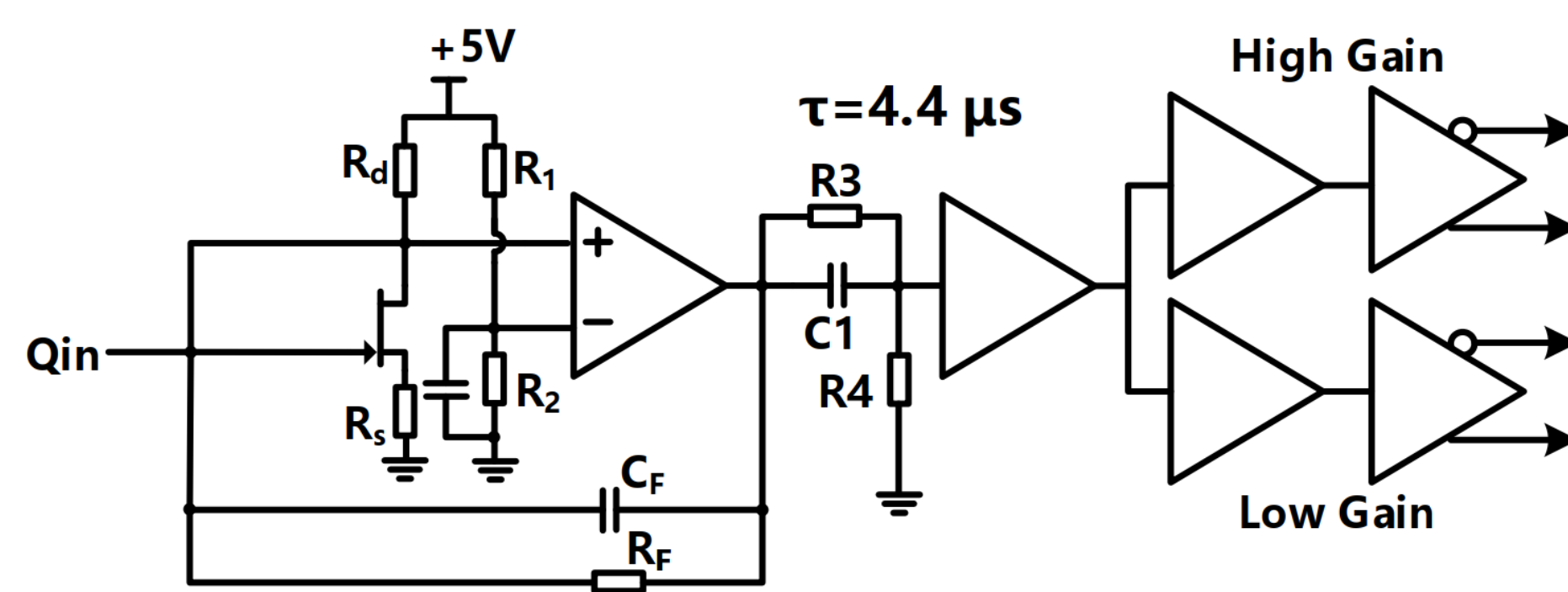
The whole system includes following parts:

- PAM (Pre-Amplifier Module): Pre-amplification and shaping of APD signals.
- FEE (Front End Electronics): Analog signals are digitized and scientific data are uploaded to the electronic control unit.



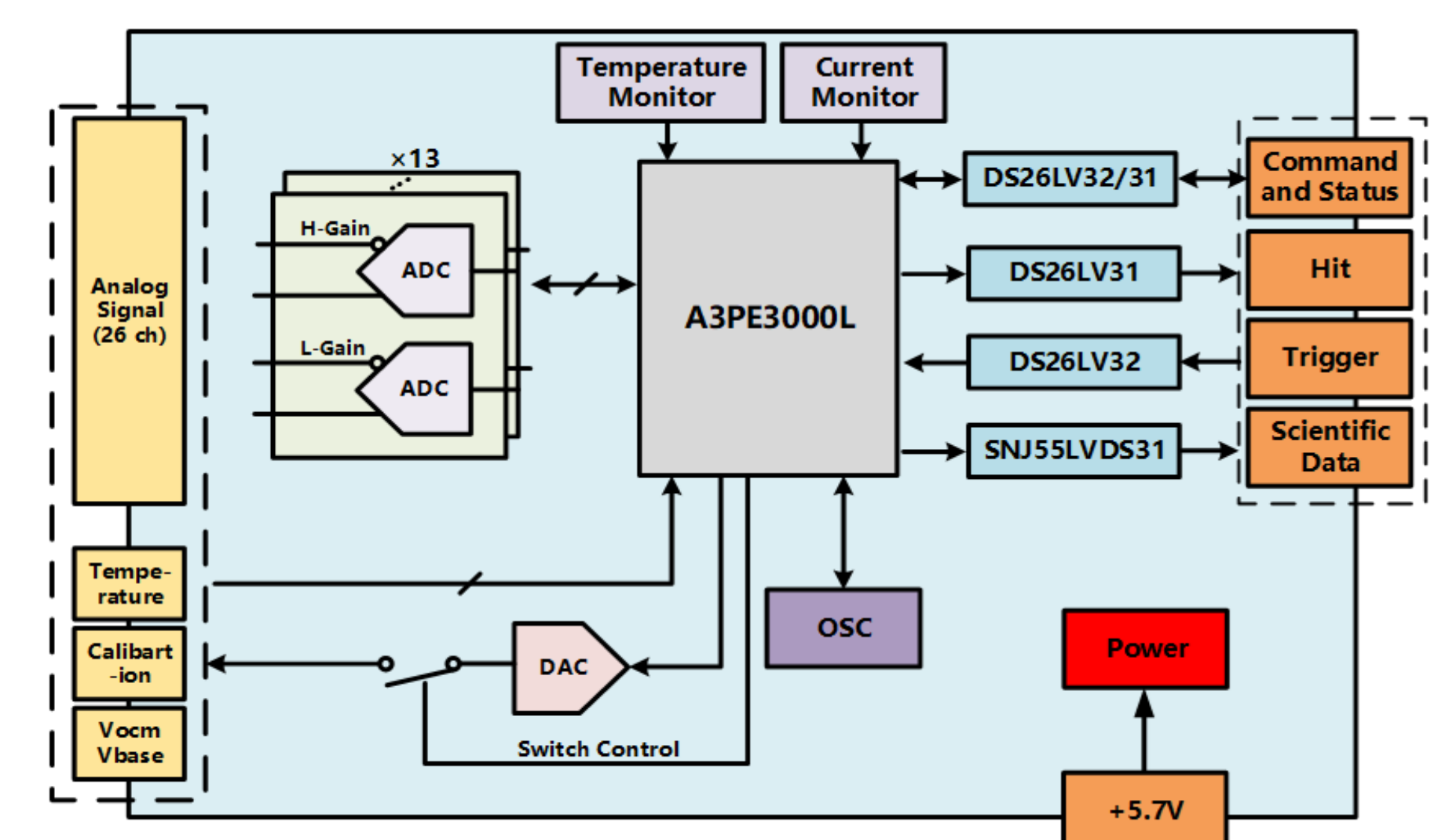
Pre-Amplifier Module

For each APD, a low-noise, CSA with minimal sensitivity to input capacitance is used to integrate the input charge and generate a voltage output. To allow the calorimeter to cover a wide dynamic range, the preamplified signal is split into high- and low-gain channels with a gain ratio of approximately 10 times. The FDA (Fully Differential Amplifier) then converts the single-ended signals into differential signals, which is used as the differential driving input of the ADC and improve the anti-interference capability of the analog signal.



Front-End Electronics

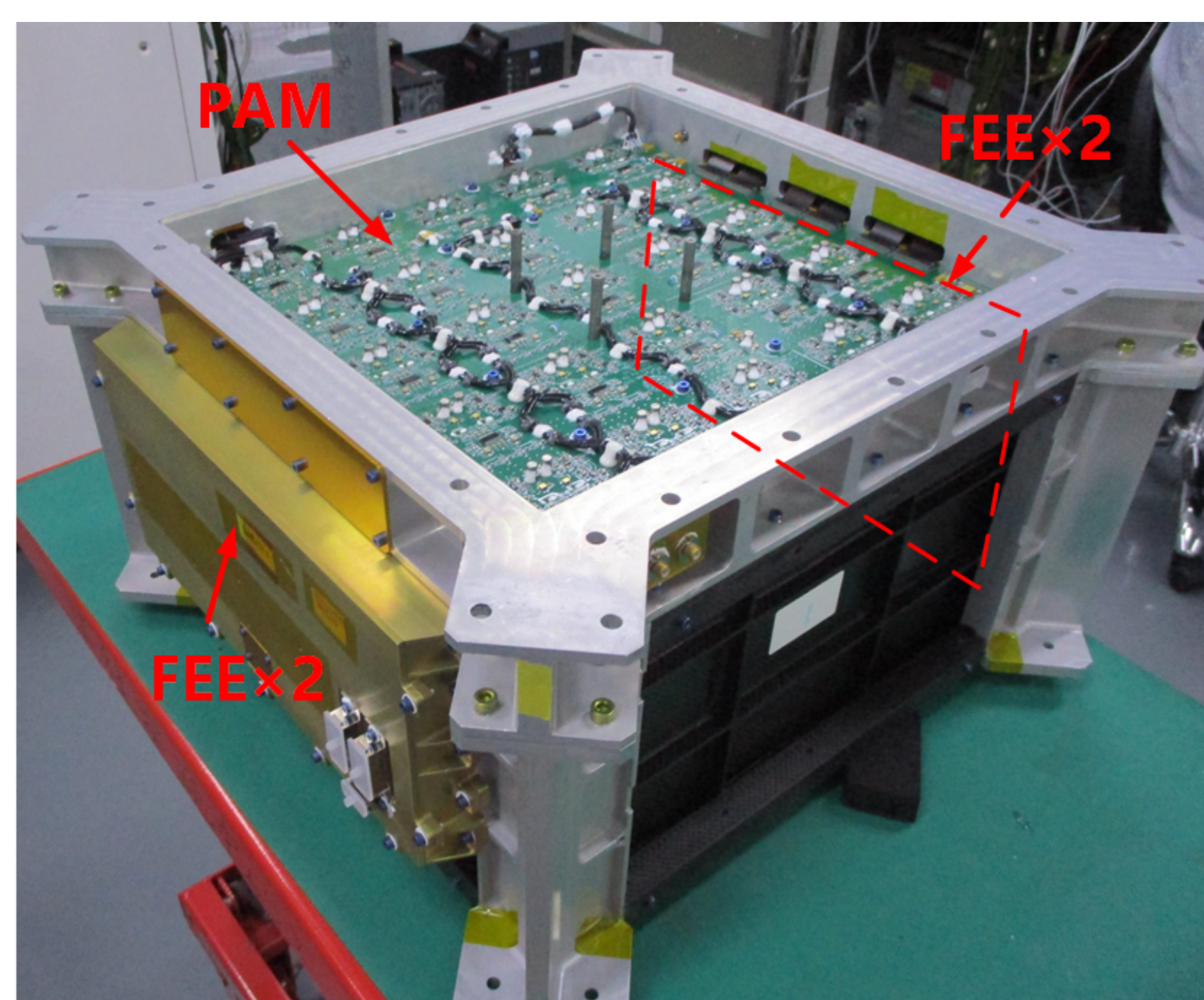
The FEE uses a flash-based FPGA (A3PE3000L-1FGG896M) for multiple functions: ADC data acquisition/storage (26 ADCs, 10 MSPS, 16-bit), digital waveform processing, peripheral control, status monitoring, configuration, and data interface management. It includes a DAC/switch calibration circuit for in-orbit monitoring. Supply currents are monitored for overcurrent detection and SEL mitigation via LDO power switches. ADC registers are read back continuously to recover from SEU.



Performance Test

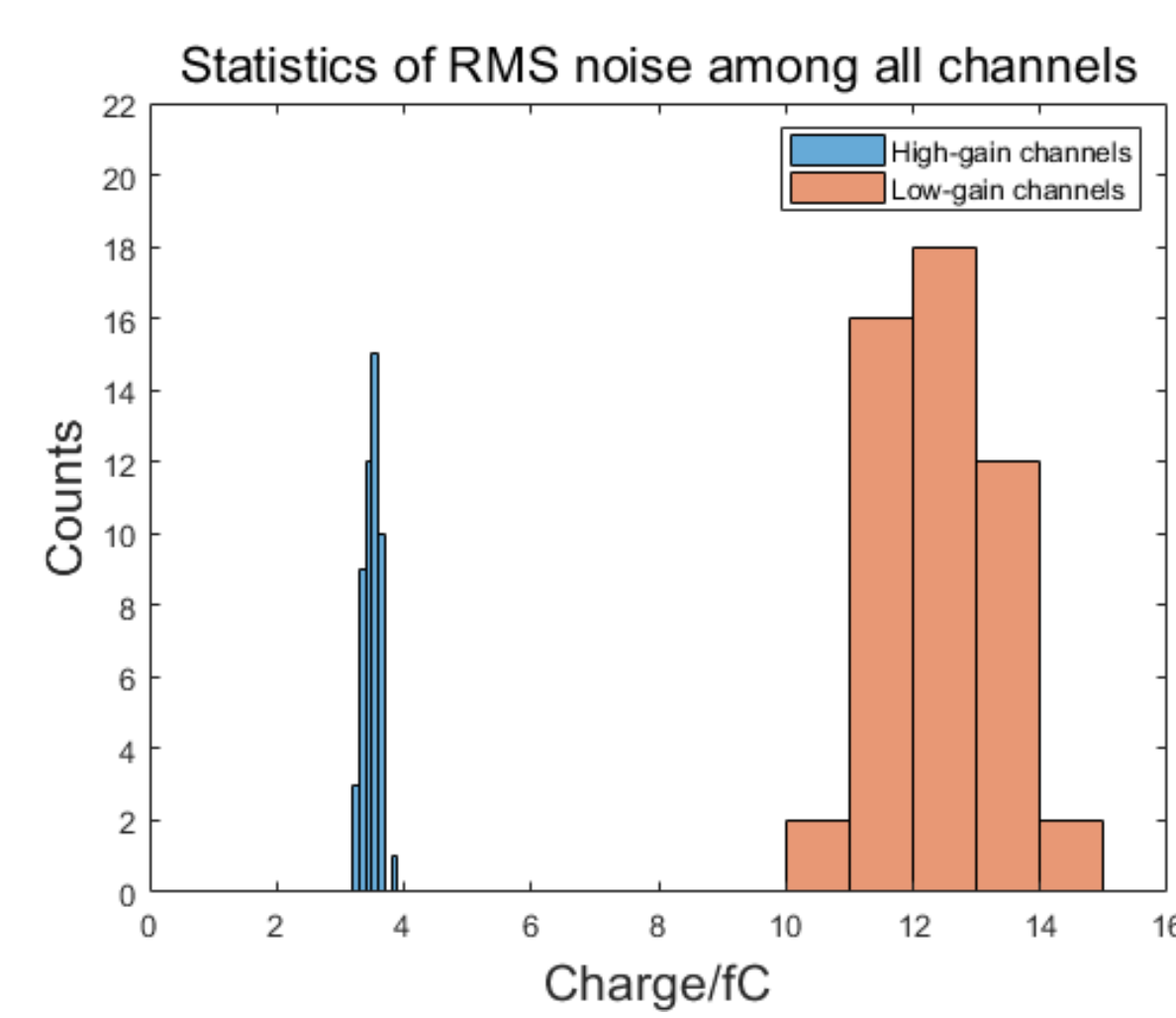
Experimental Setup

A 100 Hz periodic trigger signal is used to acquire the baseline waveform to obtain the electronics noise level of baseline. To obtain the gain and linearity of the readout electronics channel, the calibration circuit within the FEE generates step pulses of varying amplitudes, which are injected into the electronics channels as current pulses via series capacitors. The calibration of detector is performed by the energy deposited in the detector by cosmic ray muon, which is about 36 MeV for a horizontally placed CsI(Tl) crystal.

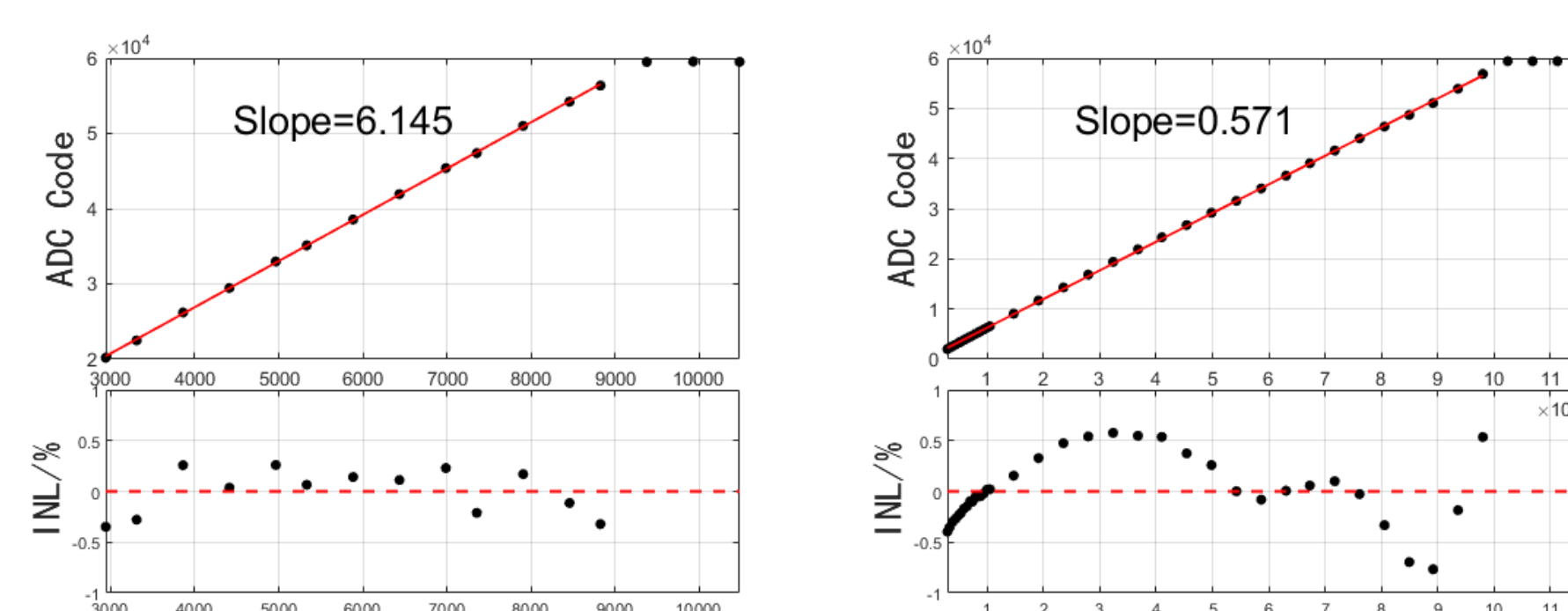


Test Result

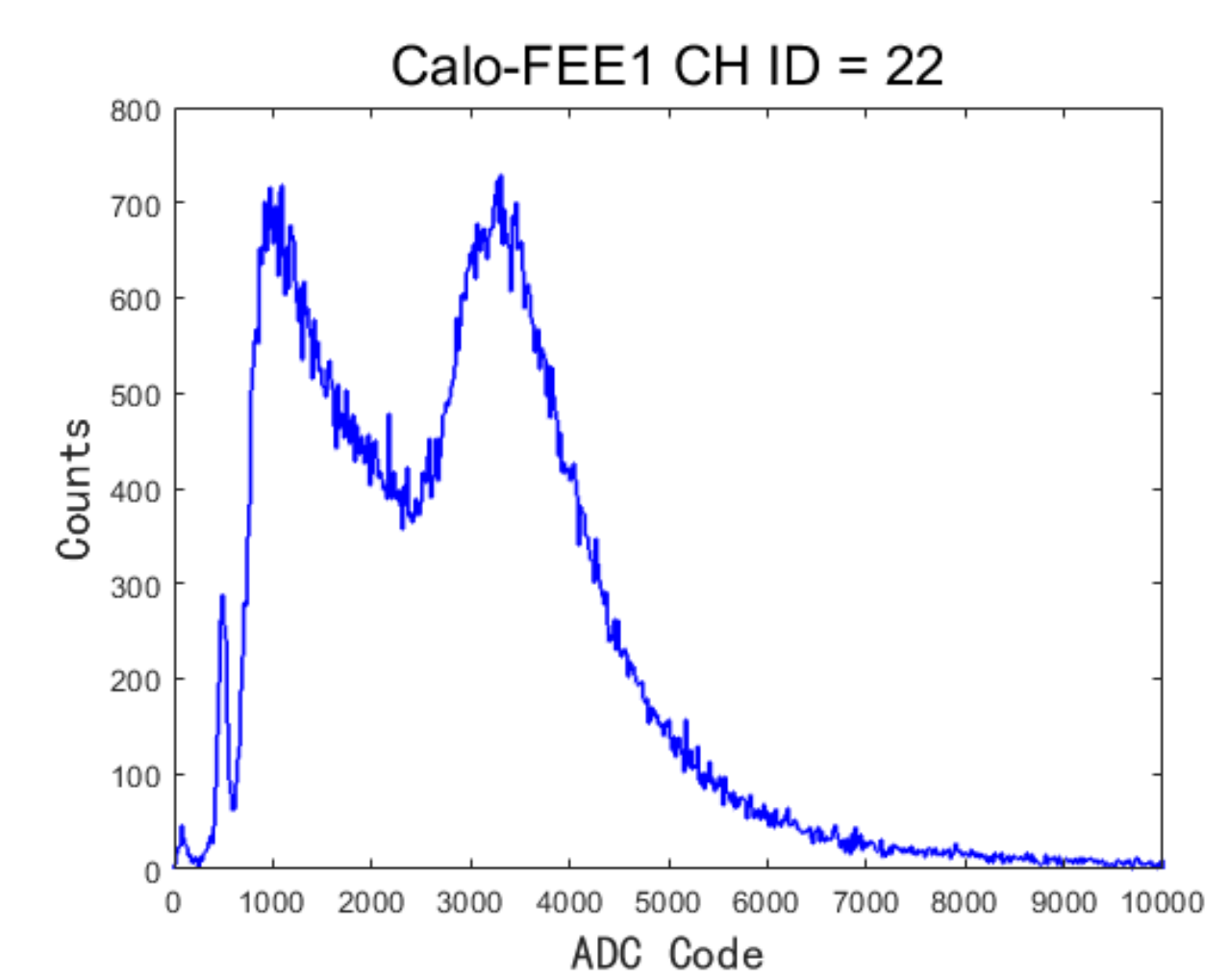
The ENC (Equivalent Noise Charge) of the high-gain channel is about 3.5 fC, and the ENC of the low-gain channel is about 13 fC.



The linear range for the high-gain channel is approximately 0 ~ 900 fC, whereas the integral non-linearity is less than 0.5%. And the linear range of the low-gain channel is approximately 0 ~ 100 pC, whereas the integral non-linearity is less than 0.8 %.



The input charge corresponding to the MIP signal was estimated to be about 600 fC. The ENE (Equivalent Noise Energy) of the high-gain channel is about 0.4 MeV, while the measurement upper limit of the low-gain channel reaches 6.5 GeV, meeting the physical requirements of the detector.



Summary

A large dynamic range and low power readout system has been successfully designed and produced, for the CsI(Tl) calorimeter of VLAST-P payload. The key indexes of energy linearity, noise level, and dynamic range were preliminarily studied. Test results showed that the electronics design meets the physical requirements.

Conclusion

- Low noise: ~ 3.5 fC (0.4 MeV)
- Long-term reliability in harsh space environments
- A large dynamic range: electronics dynamic range: from 3.5 fC to 100 pC, prototype calorimeter: from 0.4 MeV to 6.5 GeV

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