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Document Title **Calorimeter Front-End Electronics ASIC Specification**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Glast Calorimeter Front-End Electronics (GCFE) ASIC Specification

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes

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1 PURPOSE

This document describes the conceptual design for the GLAST Large Area Telescope (LAT) Calorimeter Front-end Electronics (GCFE) ASIC.

2 SCOPE

This document gives an overrview over the conecptual architecture of the GLAST LAT Calorimeter Front-end Electronics (GCFE) ASIC.

3 DEFINITIONS

3.1 Acronyms

AGN	Active Galactic Nuclei
CAL	LAT calorimeter subsystem
FOV	Field of View
FWHM	Full Width Half Maximum
GLAST	Gamma-ray Large Area Space Telescope
IRD	Interface Requirements Document
LAT	Large Area Telescope
SI/SC IRD	Science Instrument – Spacecraft Interface Requirements Document
SRD	Science Requirements Document
TBR	To Be Resolved
TEM	Tower Electronics Module
TRG	L1 Trigger

3.2 Definitions

γ	Gamma Ray
μsec, μs	Microsecond, 10^{-6} second
A_{eff}	Effective Area
Analysis	A quantitative evaluation of a complete system and /or subsystems by review/analysis of collected data.
Arcmin	An arcmin is a measure of arc length. One arcmin is 1/60 degree.
Background Rejection	The ability of the instrument to distinguish gamma rays from charged particles.
Backsplash	Secondary particles and photons originating from very high-energy gamma-ray

	showers in the calorimeter giving unwanted ACD signals.
Beam Test	Test conducted with high energy particle beams
cm	centimeter
Cosmic Ray	Ionized atomic particles originating from space and ranging from a single proton up to an iron nucleus and beyond.
Dead Time	Time during which the instrument does not sense or record gamma ray events during normal operations.
Demonstration	To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.
eV	Electron Volt
Field of View	Integral of effective area over solid angle divided by peak effective area.
GeV	Giga Electron Volts. 10^9 eV
Inspection	To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
MeV	Million Electron Volts, 10^6 eV
μsec, μs	Microsecond, 10^{-6} second
ph	photons
s, sec	seconds
Simulation	To examine through model analysis or modeling techniques to verify conformance to specified requirements
sr	steradian, A steradian is the solid (3D) angle formed when an area on the surface of a sphere is equal to the square of the radius of the sphere. There are 4 Pi steradians in a sphere.
Testing	A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements.
Validation	Process used to assure the requirement set is complete and consistent, and that each requirement is achievable.
Verification	Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products.

4 APPLICABLE DOCUMENTS

Documents that are relevant to the development of the GCFE specifications include the following:

4.1 Requirement Documents

GLAST00010, “GLAST Science Requirements Document”, P.Michelson and N.Gehrels, eds., July 9, 1999.

LAT-SP-00010, “GLAST LAT Performance Specification”, August 2000

LAT-SS-00018, “LAT CAL Subsystem Specification”, January 2001

4.2 Conceptual Design Documents

[1] GLAST Calorimeter Analog Front-End ASIC Design Consideration, Neil Johnson, NRL

[2] LAT Electronics System – Conceptual Design

[3] LAT Calorimeter Electronics System

[4] LAT GCFE Conceptual Design

[5] LAT TKR-CAL Tower Electronics Module – Conceptual Design

[6] LAT Control Protocol within LAT – Conceptual Design

[7] LAT Data Protocol within LAT – Conceptual Design

[8] LAT Housekeeping within LAT – Conceptual Design

[9] LAT L1 Trigger System – Conceptual Design

5 REQUIREMENTS

5.1 Introduction

The *GLAST* electronics system is described in [2]. The calorimeter sub-system electronics is documented in [3]. The front-end analog processing for the calorimeter subsystem shall be performed by the Glast Calorimeter Front-End Electronics (GCFE) ASIC. The basic functions of the GCFE include charge-sensitive amplification, shaping, multi-range post-amplification, trigger function, track&hold function, and auto-range selection. The key challenges for the ASIC are the large dynamic range and low power dissipation as specified in [4].

The ASIC amplifies signals from 2 diodes per crystal end, a large area diode processing the low energy range, and a small area diode processing the high-energy range. The signals from the two diodes are converted into voltages by charge-sensitive preamplifiers. The gain of the preamplifiers can be adjusted digitally. The output signal of the preamplifiers are split into two paths each: a 0.5-µsec (fast) and a 3.5-µs (= slow peaking time) shaping amplifier with a gain of 1.

The 0.5-µsec shapers are called Fast Low-Energy (FLE) and Fast High-Energy (FHE) shapers. Those shaper outputs are compared to analog (trigger) thresholds by discriminators. The discriminator outputs leave the ASIC for use in the CAL trigger generation logic.

The 3.5-µsec shapers, called Slow Low-Energy (SLE) and Slow High-Energy (SHE) shapers, are used for energy deposition measurements. The output of the high-energy shaper is split into two post-gain stages, a times one (HEX1) and a times eight (HEX8). The output of the low-energy shaper is split into a times one (LEX1) and a times eight (LEX8) post-gain stage. The four post-gain amplifier outputs are followed by Track and Hold (T&H) circuits. Timing signals external to the ASIC enable the sampling of the shaper output around the time of the peak via a HOLD signal.

The outputs of the T&H circuits are connected to a set of discriminators and to an analog muliplexer block. Three discriminators on the LEX8, LEX1, and HEX8 circuits are used as upper level discriminators for autoranging. The autoranging logic selects the T&H output with the best energy resolution but that is not saturated. A fourth discriminator on the LEX8 output is used for data readout sparsification or “zero suppression”. If the energy deposition in the crystal is above this accept threshold, the CAL acquisition electronics will include the energy measurement in the data stream.

The autoranged or optionally commanded T&H output leaves the ASIC via an analog multiplexer and a buffer amplifier. This output is digitized by an external successive approximation analog to digital converter (ADC) under the control of the CAL acquisition electronics.

The configuration of the GCFE is controlled via a command interface which permits programming of subfunction enables, digital to analog converter (DAC) programming of discriminator levels, and implementation of diagnostic modes. A separate interface supports precision voltage reference and controls for charge injection test pulses to the front end preamps for gain and linearity calibrations. Configuration information can be read out from the ASIC on read requests.

5.2 GCFE Energy Range

The GCFE shall process energy depositions in the energy range from 0.4 MeV to 100 GeV.

5.3 Low Energy Range

A large area (~150 mm^2) PIN photodiode provides the input signal for the low energy range charge amplifier. The low energy charge amplifier shall process energy depositions in the 2 MeV to 1.6 GeV range. The characteristics of the inputs to the low energy range are summarized in Table 1.

Table 1. Characteristics of GLAST dual PIN photodiode.

Diode	Area (mm^2)	Cap (pF)	Leakage (25 °C)	Signal e/MeV
Low Energy	150	< 90	< 8 nA	5000
High Energy	25	< 25	< 2 nA	800

Table 2. Relative time constants in CsI(Tl)

Exponential Time Constant	Total Charge %
25 ns	2%
700 ns	60%
3.5 µs	40%

5.3.1 Low Energy Charge Sensitivity

The low energy range amplifier shall receive a charge of ~ 5000 e^-/MeV (TBR) with time constants defined by CsI(Tl) scintillation constants. These are identified in Table 2.

5.3.2 Low Energy Input Capacitance

The low energy charge amplifier shall meet performance specs when attached to PIN photodiode with capacitance ≤ 90 pF (TBR).

5.3.3 Low Energy Input Dark Current

The low energy charge amplifier shall meet performance specs when attached to PIN photodiode with dark or leakage current ≤ 8 nA (TBR) at a temperature of 20 °C.

5.3.4 Low Energy Overload Recovery

The low energy front end shall recover from a ×1000 overload within 100 µsec (TBR). Recovery is defined as signal amplitude below the accept or zero-suppression threshold.

5.3.5 Low Energy Gain Adjust

The gain of the low energy channels shall be adjustable by at least a factor of 2 in approximately 10 – 25% steps.

Rationale: The gain adjust is needed to compensate for light yield losses caused by manufacturing variability, and radiation damage in orbit. The gain affects the ADC quantization error.

5.4 High Energy Range

A smaller area (~25 mm^2) PIN photodiode provides the input signal for the high energy range charge amplifier. The low energy charge amplifier shall process energy depositions in the 100 MeV to 100 GeV range. The characteristics of the inputs to the high energy range are summarized in Table 1.

5.4.1 High Energy Charge Sensitivity

The low energy range amplifier shall receive a charge of ~ 800 e^-/MeV (TBR) with time constants defined by CsI(Tl) scintillation constants. These are identified in Table 2.

5.4.2 High Energy Input Capacitance

The high energy charge amplifier shall meet performance specs when attached to PIN photodiode with capacitance ≤ 25 pF (TBR).

5.4.3 High Energy Input Dark Current

The high energy charge amplifier shall meet performance specs when attached to PIN photodiode with dark or leakage current ≤ 2 nA (TBR) at a temperature of 20 °C.

5.4.4 High Energy Gain Adjust

The gain of the high energy channels shall be adjustable by at least a factor of 2 in approximately 10 – 25% steps. An additional gain setting shall be used for ground liveness testing. See section 5.12.4.

Rationale: The gain adjust is needed to compensate for light yield losses caused by manufacturing variability, and radiation damage in orbit. The gain affects the ADC quantization error.

5.5 Shaping Amplifiers

The outputs of the charge sensitive preamps shall be shaped with two differing time constants – fast shaping for trigger discriminators and a slower shaping for energy measurements. The slow shaped signals of each charge amplifier are are each divided into two energy domains.

5.5.1 Low Energy Fast Shaper (FLE) Peaking

The low energy fast shaped signals shall peak at 0.5 ± 0.2 μsec.

5.5.2 Low Energy Fast Shaper Energy Range

The low energy fast shaping amplifier shall support the lowest ~25% of low energy range, i.e. nominally 400 MeV maximum energy.

5.5.3 High Energy Fast Shaper (FHE) Peaking

The high energy fast shaped signals shall peak at 0.5 ± 0.2 μsec.

5.5.4 High Energy Fast Shaper Energy Range

The high energy fast shaping amplifier shall support the entire low energy range, i.e. nominally 100 GeV maximum energy.

5.5.5 Low Energy Slow Shapers (SHE) Peaking

The low energy fast shaped signals shall peak at 3.5 ± 0.5 μsec. All ASICs shall have the same peaking time ± 0.2 μsec.

Rationale: Peaking time is a compromise between processing speed and ballistic deficit. Uniform peaking time required for accurate amplitude measurement by track and hold circuit.

5.5.6 Low Energy X1 (LEX1) Amplifier

The LEX1 amplifier of the SLE shall process the entire low energy charge amplifier range, ie. nominally 1.6 GeV maximum energy.

5.5.7 Low Energy X8 (LEX8) Amplifier

The LEX8 amplifier of the SLE shall process the lowest eighth of the low energy charge amplifier range, ie. nominally 200 MeV maximum energy.

5.5.8 High Energy X1 (HEX1) Amplifier

The HEX1 amplifier of the SHE shall process the entire high energy charge amplifier range, ie. nominally 100 GeV maximum energy.

5.5.9 High Energy X8 (HEX8) Amplifier

The HEX8 amplifier of the SHE shall process the lowest eighth of the high energy charge amplifier range, ie. nominally 12.5 GeV maximum energy.

5.6 Track & Hold

Each of the four slow shaped amplifiers (LEX8, LEX1, HEX8, HEX1) shall have track and hold (T&H) circuits designed to hold the peak amplitude of the shaped outputs for amplitude measurements using external ADCs. The timing of the hold signal to capture the peak is controlled externally.

5.6.1 T&H Tracking

When the hold signal is not active, the T&H circuit shall track the amplitude of the shaped input signal. Thus, adjustment of the hold signal timing relative to the energy deposition shall permit mapping of the pulse shape of the shaper output.

5.6.2 T&H Hold

The T&H circuit shall respond to an externally generated hold signal by capturing the amplitude of the shaped signal at the time of the hold. Hold aperture time shall be less than 50 nsec.

5.6.3 T&H Droop

The T&H circuit shall be capable of holding a constant signal amplitude for > 100 μsec with less than).1% droop for a signal amplitude dynamic range of 500 (TBR).

5.7 Analog Multiplexer

An analog multiplexer shall present one of the four T&H signals to an output buffer for external amplitude measurements with an ADC. The analog multiplexer shall be controlled by energy range selection logic as described in 5.9.

5.8 Output Buffer

An output buffer shall accept the output of the analog multiplexer and drive the load of an external ADC.

5.8.1 Output buffer range adjust

The external buffer shall adjust the voltage range of the analog multiplexer to match the input voltage range of the external ADC.

5.9 Energy Range Selection

Energy range selection logic shall control which of the four T&H energy ranges is selected in the analog multiplexer and presented to the output for digitization by the ADC.

5.9.1 Range Selection Discriminators

Range selection discriminators shall test the output of the four T&H ranges to determine which of the ranges have been saturated by the energy deposition in the crystal. Saturation is defined as an amplitude at which the input signal enters a non-linear region.

5.9.2 Range Selection Readout

The results of the range selection logic, i.e. the multiplexer setting, shall be transmitted to external logic for inclusion in the event readout with the associated ADC value.

5.9.3 Auto Range Selection

In auto range selection mode, the range selection discriminators shall be tested to select the T&H output with the lowest energy range (highest gain) that is not saturated and sets the analog multiplexer to this T&H output.

5.9.4 Commanded Range Selection

In commanded range selection, the selection logic shall use a pre-loaded (via command input) range and set the multiplexer to that T&H output.

5.9.5 Sequential Range Selection

In either the auto range or commanded range selection mode, it shall be possible to sample all four T&H outputs in sequence. The sequence starts at the autoranged or commanded range and increments (modulo 4) through the four ranges. The increasing order shall be LEX8, LEX1, HEX8, HEX1.

5.10 Zero Suppression or Measurement Accept Readout

5.10.1 Accept Discriminator

The amplitude of the LEX8 output shall be compared with a programmable threshold – the accept lower level discriminator – to identify CsI crystals with measureable energy depositions. This crystal accept signal shall be transmitted to external logic for determination of crystals to be included in the event readout message.

5.10.2 Accept Discriminator Adjustment

The accept discriminator level shall be adjustable by command to the ASIC with adjustment resolution of ~ 0.25 MeV over the lowest approximately 10% of the LEX8 energy range.

5.11 Trigger Discriminator and Logic

The outputs of the two 0.5 µsec shaping amplifiers (FHE and FLE) are connected to discriminators. The two outputs of the trigger discriminator logic are provided to external logic which forms the calorimeter trigger request inputs to the GLAST trigger system.

5.11.1 Trigger Jitter

The variation in time of the leading edge of the trigger output from the time of energy deposition shall be less than ± 0.2 µsec.

5.11.2 Trigger Enables

Each of the two trigger signals shall be individually enabled or disabled by command input to the ASIC.

5.11.3 Low Energy Trigger Discriminator Adjustment

The low energy trigger (FLE) discriminator level shall be adjustable by command input to DACs inside the ASIC. Two adjustment ranges shall be provided: lowest energies (< ~60 MeV) with ~ 1 MeV resolution and moderate energies (< ~ 400 MeV) with ~ 5 MeV resolution.

Rationale: The two energy domains for the discriminator setting permit self-triggering for ground testing with cosmic muons (the lowest energy domain) and expected nominal flight settings (moderate energy domain).

5.11.4 High Energy Trigger Discriminator Adjustment

The high energy trigger discriminator level shall be individually adjustable by command input to DACs inside the ASIC. The range of adjustment shall include the lowest ~25% of the high energy charge amplifier range (< ~ 25 GeV) and have ~ 200 MeV resolution.

5.12 Calibration System

The GCFE ASIC shall accept a precision calibration voltage from an external DAC as a reference voltage for a calibration charge injection system.

5.12.1 Calibration Range

The test charge injection system shall be capable of testing the entire dynamic range of the GCFE ASIC.

5.12.2 Charge Shaping

The charge injection system shall provide input signals to the charge amplifier with time characteristics similar to the CsI light collection.

5.12.3 Charge Injection

External signals shall cause the injection of charge into the charge amplifiers. Commandable configuration logic shall cause the injection to occur into either or both of the low energy and high energy charge amplifiers.

5.12.4 Test Gain on High Energy Charge Amplifier

The high energy charge amplifier shall provide a test gain to be used in ground liveness tests with cosmic muons. The test gain shall increase the nominal gain by a factor of approximately 10. The test gain configuration is pre-selected by command input to the ASIC.

5.13 Configuration Control

The GCFE ASIC operating configuration shall be selected by commands received via serial command system that is compatible with GLAST standard command protocols.

5.13.1 Command Address

Each GCFE ASIC shall respond to its own command address which shall be programmed via input address pins.

5.13.2 Command Functions

The GCFE shall decode and recognize predefined command functions and internally route associated command function data to the appropriate configuration register.

5.13.3 Configuration Readback

The GCFE shall be capable of reporting its operating configuration to the external data system when requested via configuration readback command requests.

5.14 Signal Acquisition Control

The GCFE ASIC shall capture and readout event amplitudes under the control of external acquisition control timing signal. The external timing shall control the capture of the peak pulse amplitude in the T&Hs, the range selection and readout of the range and crystal accept bits, the selection and readout of sequential ranges, and the final reset of the ASIC to idle, tracking configuration. The timing of this sequence is controlled with the external signal; the control logic and decision making is internal to the ASIC.

5.15 Performance Requirements

The following requirements apply to the signal acquisition by the charge amplifiers, through the shaping amplifiers, track and holds, analog multiplexer and buffer amplifier.

5.15.1 Low Energy Equivalent Noise

The equivalent noise (RMS) on the low energy slow shaped signal paths (LEX8, LEX1) shall be less than 2000 e^-.

The equivalent noise (RMS) on the low energy fast shaped signal path (FLE) shall be less than 3000 e^-.

5.15.2 High Energy Equivalent Noise

The equivalent noise (RMS) on the high energy slow shaped signal paths (HEX8, HEX1) shall be less than 2000 e^-.

The equivalent noise (RMS) on the high energy fast shaped signal path (FHE) shall be less than 10000 e^-.

5.15.3 Integral Linearity

The output of the buffer amplifier for each of the four amplifier ranges shall be monotonically increasing with charge input over the top 99.9% of the energy range. The integral non-linearity shall be less than ±0.5% of full scale. This is the deviation of the best fit straight line from the measured amplitudes over the top 99% of the energy range.

5.15.4 Single Range Processing Deadtime

The signal acquisition and processing time for a single energy range shall be less than 100 μsec. The goal is 20 μsec.

5.16 Environmental Requirements

5.16.1 Operating Temperature Range

The performance specifications shall be achieved over the operational temperature range of –10 to 35 degrees C.

5.16.2 Storage Temperature Range

The GCFE ASIC shall be capable meeting its performance specifications after indefinite storage in the temperature range of –20 to 40 degrees C.

5.16.3 Qualification Temperature Range

The performance of the ASIC shall be tested over the qualification temperature range of –30 to 50 degrees C. It shall survive testing over this range and meet performance specifications when returned to the operational temperature range.

5.16.4 Radiation Single Event Latchup

The GCFE ASIC shall be insensitive to latchup for LETs < 8 MeV/(mg/cm^2)

5.16.5 Radiation Total Dose

The GCFE ASIC shall meet its performance specifications after a total radiation dose of 10 krad.

5.17 Mechanical Configuration

The GCFE ASIC shall support one CsI crystal end.

5.17.1 Mounting

The GCFE ASIC shall be mounted in a quad flatpack carrier with square footprint of size < 15 mm (TBR).

5.17.2 Height

The GCFE carrier height shall be less than or equal to 3 mm.

5.18 Power

The GCFE ASIC power consumption shall be less than 6 mW per CsI crystal end.