# LAT PROJECT DOCUMENT CHANGE NOTICE (DCN)

**DCN No.** LAT-XR-05546-01

**SHEET** 1 **OF** 1

| | | |
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| **ORIGINATOR:** Leonid Sapozhnikov | **PHONE:** 650-926-2002 | **DATE:** 1/7/05 |
| **CHANGE TITLE:** DCN for TEM Specifications and Requirements Documents | | **ORG.:** |

| DOCUMENT NUMBER | TITLE | NEW REV. |
|---|---|---|
| LAT-SS-05522 | TEM Specification – Level V Specification | 01 |
| LAT-SS-05533 | TEM/TPS Specification- Level V Specification | 01 |
| LAT-TD-05534 | TEM Requirements Verification Matrix | 01 |
| LAT-TD-05536 | TEM/TPS Requirements Verification Matrix | 01 |
| | | |

**CHANGE DESCRIPTION (FROM/TO):**

**Initial release**

**REASON FOR CHANGE:**

**ACTION TAKEN:** ☒ **Change(s) included in new release** ☐ **DCN attached to document(s), changes to be included in next revision**
☐ **Other (specify):**

| **DISPOSITION OF HARDWARE (IDENTIFY SERIAL NUMBERS):** | **DCN DISTRIBUTION:** |
|---|---|
| ☒ **No hardware affected (record change only)** | |
| ☐ **List S/Ns which comply already:** | |
| ☐ **List S/Ns to be reworked or scrapped:** | |
| ☐ **List S/Ns to be built with this change:** | |
| ☐ **List S/Ns to be retested per this change:** | |
| ☐ | |

**SAFETY, COST, SCHEDULE, REQUIREMENTS IMPACT?** ☐ **YES** ☒ **NO**
**If yes, CCB approval is required. Enter change request number:**

| APPROVALS | DATE | OTHER APPROVALS (specify): | DATE |
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| **ORIGINATOR:** L. Sapozhnikov (signature on file) | 1/7/05 | | |
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| | Author(s)<br>Leonid Sapozhnikov<br>Philip Hart<br>Jana Thayer | Supersedes |
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Document Title

# Tower Electronics Module (TEM) Specification - Level V Specification

## CHANGE HISTORY LOG

| Revision | Effective Date | Description of Changes |
|---|---|---|
| 1 | 01/05/2005 | Original release |
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# Table of Contents -TOC

# 1. SCOPE

This document defines the level 5 subsystem requirements for the Tower Electronics Module (TEM).

# 2. DEFINITIONS AND ACRONYMS

The following terms, abbreviations, and acronyms are used in this document:

## 2.1 Definitions

| | |
|---|---|
| A, An | Analog |
| A | Analysis |
| D, Dg | Digital |
| DR | Data Rate |
| Eff | Efficiency |
| F | Functional |
| μs | microsecond |
| ns | nanosecond |
| P | Performance |
| P/F | Pass/Fail |
| V | Volt |
| W | Watt |

## 2.2 Acronyms

| | |
|---|---|
| AFEE | Analog Front End Electronics |
| AIDS | Assembly and Inspection Data Sheet |
| BOB | Break Out Box |
| BOC | Break Out Cable |
| CAL | Calorimeter |
| CC | Cable Controller |
| CSAM | Computer Scanning Acoustic Microscopy (computer sweeps the EUT with a tone to detect any voids in the ASIC) |
| EBM | Event Builder Module |
| EGSE | Electrical Ground Support Equipment |
| EICIT | Electrical Interface Continuity and Isolation Test (cold checks) |
| ETech | Electrical Technician |
| EUT | Equipment Under Test |
| FE | Front End |
| FIFO | First-in, First-Out |

| | |
|---|---|
| FPGA | Field-Programmable Gate Array |
| GASU | Global trigger, ACD, System Unit |
| GCCC | GLAST Calorimeter Cable Controller |
| GEM | Global-Trigger Electronics Module |
| GLAST | Gamma Ray Large Area Space Telescope |
| GTCC | GLAST Tracker Cable Controller |
| GTFE | GLAST Tracker Front End |
| GTRC | GLAST Tracker Readout Controller |
| HAST | Highly Accelerated Stress Test |
| ICD | Interface Control Document |
| LAT | Large Area Telescope |
| LATp | Large Area Telescope protocol |
| MCM | Multi Chip Module |
| MGSE | Mechanical Ground Support Equipment |
| STM | Safe To Mate |
| SVT | Stray Voltage Test (hot checks) |
| T&DF | Trigger and Data Flow |
| TACK | Trigger Acknowledge |
| TAM | Trigger Accept Message |
| TEM | Tower Electronics Module |
| TKR | Tracker |
| TPS | Tower Power Supply |
| TRG | Trigger |

## 3. APPLICABLE DOCUMENTS

| Reference | Document Number | Description |
|---|---|---|
| [1] | LAT-SS-00284 | LAT Trigger Subsystems Specification – Level IV |
| [2] | LAT-SS-00285 | LAT Dataflow Subsystems Specification – Level IV |
| [3] | LAT-TD-00605 | TEM Programming ICD Specification |
| [4] | LAT-TD-00606 | LAT Inter-Module Communications, Manual |
| [5] | LAT-SS-00183 | Power Supply Modules Specification – Level IV |
| [6] | LAT-SS-00288 | TEM Specification and ICD |
| [7] | GSFC 433-SPEC-0001 | GLAST Mission System Specification |
| [8] | LAT-SS-00238 | Calorimeter-LAT ICD |
| [9] | LAT-SS-00176 | Tracker Electrical Interface Specification |

# 4. REQUIREMENTS

This section lists the requirements that shall be utilized during design, development, manufacture, assembly, testing and storage of the TEM units.

## 4.1 Redlining and Blacklining Documents

The users of this document shall follow the requirements found in the Redline/Blackline Engineering Documents, LAT-MD-03474.

# 5. DATAFLOW REQUIREMENTS

## 5.1 General

### 5.1.1 LATp

[4], [2] (8.8.5)

The TEM shall communicate on the LATp command/response and event data fabrics.

### 5.1.2 LATp Address

[2] (8.8.5)

The TEM shall accept a unique LATp node number on the command/response fabric.

### 5.1.3 Even/Odd Address

#### 5.1.3.1 Even/Odd Address and Cabling

[6] (6)

In order to support the position-dependent FE cabling scheme, the TEM shall process input data based on the even/oddness of its address.

#### 5.1.3.2 Address independence

[6] (6)

Other than the requirement specified in 5.1.3.1, the TEM's operation shall not depend on the even/oddness of its address.

### 5.1.4 Address Survives Resets

[7] (3.3.4.1.3)

The address setting shall survive either hardware or software resets.

### 5.1.5 Path Redundancy

[7] (3.3.1.5.1, 3.3.1.5.2.2)

The TEM shall support a primary and a redundant path for all communications with the GASU, including event data, trigger accepts/requests, commands, resets, clock, pause signal, and busy signal.

#### 5.1.5.1 Path Indicator

[7] (3.3.1.5.1, 3.3.1.5.2.2, 3.3.3.4.1)

The TEM shall indicate which of the two operating paths it is currently using.

### 5.1.6 Communication to FEs

[2] (8.8.2, 8.8.3)

The TEM shall support communication to the FEs according to their respective ICDs.

### 5.1.7 Event Data Response

[2] (6.1)

For every TAM sent by the GEM, the TEM shall respond with event data.

### 5.1.8 Data Storage Guarantee

[2] (6.1)

The Cable Controllers shall provide a flow mechanism to guarantee there is sufficient storage for one complete event at all times with the exception of the TKR hit data.

#### 5.1.8.1 Handling TKR Hit Data

The TEM shall detect and discard data which overflows the TKR FIFO storage and write the number of received hits into the error data.

#### 5.1.8.2 Handling Low Data Storage

[Derived]

The CCs shall detect a lack of available FIFO storage.

#### 5.1.8.3 Transitory FIFO Signals

[Derived]

For debugging purposes, the TEM shall indicate the transitory state of the event data FIFOs for each cable. These states are defined as *full*, *almost full*, and *empty*.

#### 5.1.8.4 Latched FIFO Signals

[Derived]

For debugging purposes, the TEM shall indicate the latched state of the FIFOs for each cable, defined as write when full, filled to a programmable offset, and read when empty.

### 5.1.9 Output Data Assembly

[3] (4)

The TEM shall assemble CAL and TKR FE input data into a well defined output format.

### 5.1.10 LATp statistics

[2] (8.14), [3], [4], [7] (3.3.3.4.1)

The TEM shall provide counters which are accessible on the LATp command fabric and which are returned to a well-known state on the receipt of either hardware or software resets or a commanded write.

#### 5.1.10.1 Event Statistics

[3] (2.2.0.3), [4]

The TEM shall count the number of events sent.

#### 5.1.10.2 Response Statistics

[2] (8.14), [4]

The TEM shall provide a LATp response statistics register.

#### 5.1.10.3 Command Statistics

[2] (8.14), [4]

The TEM shall provide a LATp command statistics register.

### 5.1.11 Handling Failed Commands

[7] (3.3.3.4.1, 3.3.4.1)

The TEM shall recognize and indicate commands with the wrong parity at each level of communication protocol.

### 5.1.12 Serial Parity Generation

[7] (3.3.3.4.1)

On all serial outputs, the TEM shall be able to generate data of either even or odd parity.

### 5.1.13 Timing Out Cable Controllers

[7] (3.3.1.5.1, 3.3.1.5.2.2)

The TEM shall be able to specify a programmable time to wait for event data from any Cable Controller before declaring a timeout error. This time shall be measured from the receipt of the corresponding TAM.

### 5.1.14 CC Timeout Range

[7] (3.3.1.5.1, 3.3.1.5.2.2)

The CC timeout shall range from 50 ns to not less than 204 μs.

### 5.1.15 Disabling CCs

[7] (3.3.1.5.1, 3.3.1.5.2.2)

The TEM shall be able to disable individual cable controllers.

### 5.1.16 Diagnostic Mode

[1] (14.3.1), [2] (6.6.3, 6.6.4)

When configured in diagnostic mode the TEM shall provide diagnostic data, which consists of CAL log, accept bits and all trigger primitives which potentially triggered the event.

### 5.1.17 Trigger Message in Event Data

[1] (14.3.4), [2] (6.6.1), [3] (4.1)

The TEM shall include in its event data the information contained in its corresponding TAM.

### 5.1.18 FPGA Version Number

[7] (3.3.3.4.1)

The TEM shall provide an FPGA firmware version number which is unaffected by resets.

### 5.1.19 Event Error Reporting

[7] (3.3.3.4.1, 3.3.4.1)

The TEM shall report any errors encountered in constructing an event.

### 5.1.20 Databus Protection

[7] (3.3.3.4.1, 3.3.4.1)

The TEM shall provide a mechanism for preventing any one CC from holding its internal data bus due to failure.

#### 5.1.20.1 CC Power-Up

[Derived]

All cable controllers shall power-up in the disabled state.

### 5.1.21 CC Trigger Primitive Alignment

[1] (7.2)

The TEM shall provide a programmable mechanism to adjust trigger primitive timing from one CC to another.

### 5.1.22 CC Trigger Primitive Alignment Range

[1] (7.2)

The programmable alignment time referred to in 5.1.21 shall range between 50 and 800 ns.

### 5.1.23 Trigger Jitter

[1] (11.4)

The TEM shall introduce no additional trigger jitter.

### 5.1.24 Trigger Round-Trip Alignment

[7] (3.3.3.4.1)

The TEM shall provide a programmable mechanism to delay the transmission of trigger primitives to the GEM.

### 5.1.25 Trigger Round-Trip Delay Range

[7] (3.3.3.4.1)

The range of the programmable delay shall vary from 50 to 800 ns.

## 5.2 Calorimeter Specific

### 5.2.1 CAL Cable Interface

[2] (6.4.1)

The TEM shall provide one cable interface for each of the four sides of the tower.

### 5.2.2 CAL Input Data Format

[2] (6.4.1, 6.4.2)

The TEM shall accept CAL event data in a format as defined by [8].

### 5.2.3 Log-End Assembly

[2] (6.4.3), [3] (4)

The TEM shall combine log-end data and assemble data into the format specified in the TEM ICD.

### 5.2.4 Zero-Suppression

[2] (6.4.5.1)

If zero-suppression is requested, the TEM shall zero-suppress CAL data depending on the state of the log-accept bit.

#### 5.2.4.1 Trigger Zero-Suppression Mode

[2] (6.4.5.2)

If zero-suppression is requested, the TEM shall keep the data of both sides of a log when at least one of the log-end log-accept bits is set.

#### 5.2.4.2 Log-End Accept Masking

286 (6.4.5.3)

The TEM shall provide masking of individual log-end accepts in the zero-suppression logic.

### 5.2.5 One-Or-Four-Range Readout

[2] (6.4.4)

The TEM shall support either single or four-range readout, depending on the contents of the TAM.

### 5.2.6 Calibration Storage

[2] (6.4.6), [7] (3.1.3.2.2), [Derived]

The TEM shall provide storage for 128 full log data entries to ensure storage for complete four-range readout (96 entries).

### 5.2.7 Deadtime Contribution

[2] (6.2)

The TEM event readout shall respect the system deadtime requirement.

### 5.2.8 Data Parity Error Reporting

[7] (3.3.4.1, 3.3.3.4.1)

The TEM shall evaluate and indicate parity errors in its input CAL FE event data.

### 5.2.9 Data Coincidence

[7] (3.3.3.4.1, 3.3.4.1)

The TEM shall indicate if the event data from all GCRCs for a given cable do not arrive in coincidence.

### 5.2.10 First-range Arrival Timeout

[7] (3.3.1.5.1, 3.3.1.5.2.2)

The TEM shall measure the time between the TACK transmission and the arrival of the subsequent event data. If this value is greater than a programmable interval, the TEM shall timeout the event.

### 5.2.11 Subsequent-Range Arrival Timeout

[7] (3.3.1.5.1, 3.3.1.5.2.2)

In the case of multiple ranges, the TEM shall measure the time between adjacent range arrivals. If this value is greater than a programmable interval, the TEM shall timeout the event.

## 5.3 Tracker Specific

### 5.3.1 TKR Cable Interface

[2] (6.5.2)

The TEM shall provide two cable interfaces for each of the four sides of the tower.

### 5.3.2 TKR Input Data Format

[2] (6.5.3)

The TEM shall accept TKR event data in a format as defined by [9].

### 5.3.3 Buffer Model Support

[2] (6.5.6)

The TEM shall support either the 1-buffer or the 4-buffer flow control model for the tracker front-end electronics.

### 5.3.4 Calibration Storage

[7] (3.1.3.2.2), [2] (6.5.3, 6.5.5)

For calibration purposes, the TEM shall provide storage for the maximum event contribution. The maximum event contribution corresponds to two layers per event with 64 entries per GTRC, requiring 128 entries.

### 5.3.5 Cable Trimming

[7] (3.3.1.5.1, 3.3.1.5.2.2, 3.3.3.4.1)

The TEM shall support a variable number of GTRCs per cable.

### 5.3.6 TKR Event Data Masking

[7] (3.3.1.5.1, 3.3.1.5.2.2)

The TEM shall provide masking of the TKR event data.

### 5.3.7 Data Parity Error Reporting

[7] (3.3.4.1, 3.3.3.4.1)

The TEM shall evaluate and indicate parity errors in its input CAL FE event data.

### 5.3.8 FE Error Support

[7] (3.3.4.1, 3.3.3.4.1)

The TEM shall indicate and pass on reported GTRC summary and GTFE tag errors.

### 5.3.9 Tag Consistency Reporting

[7] (3.3.4.1, 3.3.3.4.1)

The TEM shall detect and indicate the occurrence of inconsistent GTRC tags.

### 5.3.10 Input Data Coincidence Reporting

[7] (3.3.4.1, 3.3.3.4.1)

The TEM shall indicate if the event data from all GTRCs for a given cable do not arrive in coincidence.

# 6. TRIGGER

## 6.1 General

### 6.1.1 Trigger Configuration

[1] (14.1, 14.2), [4]

The TEM trigger system shall be configurable by the Dataflow system using the command/response fabric.

### 6.1.2 Trigger Accept Message

[1] (11.1.4), (13.1)

For each event, the TEM shall accept, decode, and respond to a single message from the GEM.

### 6.1.3 TAM processing rate

[1] (12.1)

The TEM shall process the TAM within 1.8 microseconds.

### 6.1.4 Handling Low Data Storage, CAL

[1] (12.2)

The TEM shall assert a throttle to the trigger if it is unable to accept calorimeter event data due to a lack of storage.

### 6.1.5 Handling Low Data Storage, TKR

[1] (12.2)

The TEM shall assert a throttle to the trigger if it is unable to accept tracker event data due to a lack of storage or when all FE buffering is exhausted.

### 6.1.6 TKR Trigger Signal Generation

[1] (13.1), [2] (8.9.4)

The TEM shall generate a unique CALSTROBE and/or TACK command to the TKRs front-end electronics upon receipt of a TAM

### 6.1.7 CALSTROBE Rate for TKR

[2] (8.9.3.1)

The TEM shall be capable of transmitting CALSTROBEs to the TKR Front-End electronics at a rate of at least 10 kHz.

### 6.1.8 CAL Trigger Signal Generation

[1] (13.1), [2] (8.9.4)

The TEM shall generate a unique CALSTROBE and/or TACK command to the CALs front-end electronics upon receipt of a TAM

### 6.1.9 CALSTROBE Rate For CAL

[2] (8.9.2.1)

The TEM shall be capable of transmitting CALSTROBEs to the CAL Front-End electronics at a rate of at least 10 kHz.

### 6.1.10 CAL Zero Suppression Control

[1] (11.1.2)

The TEM shall be configurable for zero-suppression through the TAM.

### 6.1.11 Timing of Trigger Signals to TKR

[1] (11.3)

The TEM shall control the respective timings between the arrival of a TAM from the GEM and the subsequent commands it generates to the Tracker Front-End electronics.

### 6.1.12 Timing of Trigger Signal to CAL

[1] (11.3)

The TEM shall control the respective timings between the arrival of a TAM from the GEM and the subsequent commands it generates to the CAL Front-End electronics.

### 6.1.13 CALSTROBE Timing

[1] (13.2)

The TEM shall be capable of programmed adjustment between 0 and 12.75 μs with respect to the TACK command.

### 6.1.14 CALSTROBE Timing

[1] (13.2)

The requirement described in 6.1.13 is individually adjustable for the CAL and the TKR.

### 6.1.15 Masking of Input Trigger Request Lines

[1] (7.3)

The TEM shall provide individual masking of each input trigger request line from both the CAL and TKR.

### 6.1.16 Separate CAL and TKR Deadtime Masking

[1] (12.4)

The TEM shall provide separate masking for CAL and TKR deadtime counting inputs.

### 6.1.17 Stretch Time Setting

[1] (7.1)

The TEM shall provide one programmable stretch time between 200 and 950 ns to allow setting the width of each trigger primitive.

## 6.2 Calorimeter Specific

### 6.2.1 CAL LO Inputs

[1] (6.2)

The TEM shall receive the 16 CAL LO active signals.

### 6.2.2 CAL LO Trigger Primitive

[1] (8.2.1)

The TEM shall generate one trigger primitive defined as the OR of the CAL LO inputs.

### 6.2.3 CAL HI Inputs

[1] (6.2)

The TEM shall receive the 16 CAL HI active signals.

### 6.2.4 CAL HI Trigger Primitive

[1] (8.2.2)

The TEM shall generate one trigger primitive defined as the OR of the CAL HI inputs.

### 6.2.5 Trigger Primitive Input Masking

[7] (3.3.1.5.1, 3.3.1.5.2.2, 3.3.3.4.1)

The TEM shall provide masking for each active input to each CAL trigger.

### 6.2.6 Trigger Latency

[1] (11.2)

The TEM shall use at most 16 clock cycles from receipt of the TAM until the start bit of the TACK command.

## 6.3 Tracker Specific

### 6.3.1 TKR Trigger Inputs

[1] (6.1)

The TEM shall accept the 72 Layer-OR inputs.

### 6.3.2 3-in-a-Row Trigger Primitive

[1] (8.3.1)

The TEM shall provide one trigger primitive defined as the condition that there is a TKR Layer-OR active in each of three consecutive tower x and y layers (total of 6 layers).

### 6.3.3 3-in-a-Row Input Masking

[1] (7.3)

The TEM shall provide masking for each of 16 TKR trigger 3-in-a-row combinations.

### 6.3.4 3-in-a-Row Input Forced Assert

[1] (7.3)

The TEM shall provide a configurable forced active state for each input to each TKR trigger primitive.

### 6.3.5 Trigger Latency

[1] (11.2)

The TEM shall use no more than 10 clock cycles from receipt of the TAM until the start bit of the TACK command.

# 7. FRONT-END POWER MANAGEMENT

## 7.1 Power Configuration

[2] (8.8.6), [4]

The TEM power system will be configurable by the Dataflow system using the command/response fabric.

## 7.2 Power Distribution

[2] (9.5)

The TEM shall distribute power from the TPS to the TKR and CAL FEs.

## 7.3 FE power Supply Control, CAL

[2] (9.4)

The TEM shall provide on/off control of the CAL power supply.

## 7.4 FE power Supply Control, TKR

[2] (9.4)

The TEM shall provide on/off control of the TKR power supply.

## 7.5 Power-On Condition

[2] (9.1)

The TEM shall power on with the FE power supply controls set to off.

## 7.6 Power Setting Survives Reset

[7] (3.3.4.1.3)

The power supply setting shall survive a hardware or software reset.

## 7.7 High Voltage Setup

[2] (9.1)

The TEM shall provide a setup value to control the CAL and TKR high voltage power on the TPS.

# 8. HOUSEKEEPING

## 8.1 Trigger statistics and dead-time counting

### 8.1.1 Deadtime Counting

[1] (12.5)

The TEM shall measure the amount of deadtime separately for the CAL and TKR. The counter counts at the system clock frequency and has a 24-bit range.

### 8.1.2 TKR Trigger Primitive Counting

[2] (7.3)

The TEM shall provide four 16-bit counters which count active ongoing transitions of four sets of four 3-in-a-row combinations.

### 8.1.3 Masking for TKR Trigger Primitive Counting

[2] (7.3)

The counters shall be individually maskable for each 3-in-a-row combination.

### 8.1.4 CAL Trigger Primitive Counting

[2] (7.2)

The TEM shall provide two identical 16-bit counters which count active-going transitions of the log-end-ORed trigger primitives.

### 8.1.5 Masking for CAL Trigger Primitive Counting

[2] (7.2)

The counters shall be individually maskable at the log-end level for each input.

## 8.2 ENVIRONMENTAL MONITORING

### 8.2.1 Cable Temperature Measurement

[2] (10.1.2, 10.1.3)

The TEM shall digitize and monitor two temperatures per cable. There are 4 CAL cables and 8 TKR cables.

### 8.2.2 FE Voltage Measurement

[2] (10.3)

The TEM shall measure all TKR and CAL voltages.

### 8.2.3 High Voltage Supply Current Measurement

[2] (10.5)

The TEM shall measure both the TKR and CAL high voltage power supply currents.

### 8.2.4 Tower Current Measurement

[2] (10.5)

The TEM shall measure total tower current.

### 8.2.5 Internal Voltage Measurement

[2] (10.3)

The TEM shall provide a measurement of its own 3.3 V level.

### 8.2.6 Signal Acquisition Indicator

[2] (10) (derived)

For all measurements above, the TEM shall indicate when the requested value has been acquired successfully.

### 8.2.7 Temperature Sensors

[2] (10.1.4.2)

The TEM shall provide primary and redundant temperature sensors to be read out by higher-level systems.

### 8.2.8 Redundant Voltage Sensors

[2] (10.3)

The TEM shall provide primary and redundant access for a measurement of its 3.3 V level to be read out by higher-level systems.