Reading out the Tower Electronics Module (and a smidgen of Trigger, too)

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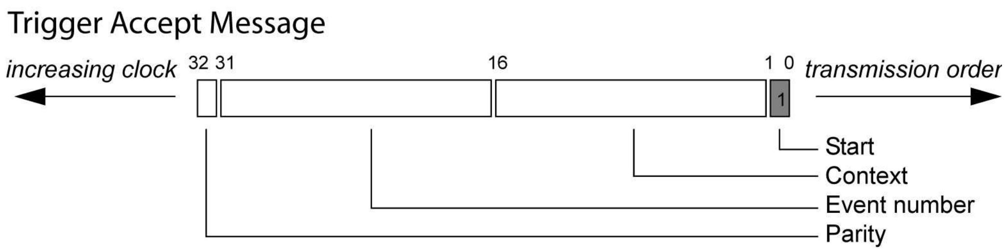
References

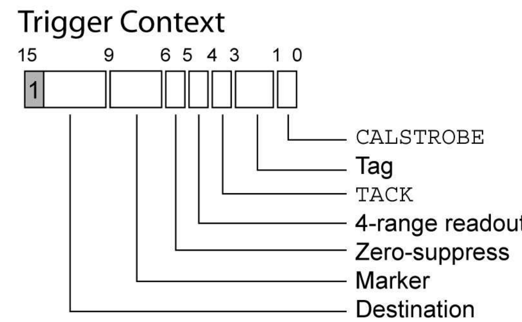
- GEM
  - LAT-TD-01514 GEM Programming ICD
- TEM
  - LAT-TD-00605 TEM Programming ICD
  - LAT-TD-01550 GTCC Specification and ICD
  - LAT-TD-01549 GCCC Specification and ICD
- CAL
  - LAT-SS-01973 GCRC Design Specification
  - LAT-SS-01972 GCFE Design Description
- TKR
  - LAT-SS-00170 GTRC Specification
  - LAT-SS-00169 GCFE Specification

Quick word about the GEM

- Recall, there are 8 separate inputs to the GEM
  - ACD (usually a veto), CNO
  - TKR 3-in-a-row, CAL LO, CAL HI
  - Periodic, Solicited, External
- Results in 255 different trigger combinations
- There are 16 separate trigger “Engines”
  - Each defines a different trigger “line”
    - Zero-suppress, CALSTROBE, Marker, Prescale, etc.
- GEM Scheduler allows each of the 255 trigger conditions to be mapped to one of the 16 trigger engines.
- Almost completely random example:
  - When overlaying two triggers like TKR and EXT, one can readout the TKR triggers normally, then apply a prescale and turn off zero-suppression for the EXT.

Tower Readout Overview





- **Trigger Accept Message (TAM) Arrives at TEM**
- **TEM Common Controller (GTIU) decodes the Trigger Context**
- **This information is stored in the GCCC FIFOs**
  - **From one it is included in the TEM event contribution, the other 3 are discarded**
- **GTIU coordinates the latching and readout of the data**
- **Data arrives from the detectors at the Cable Controllers (CC) and is processed and stored in FIFOs**
- **The GTIU then creates the TEM event contribution from the data in these FIFOs and forwards it to the Event Builder (EBM)**

Tracker Readout 0

- There are 3 lines which the TEM uses to control TKR readout
  - Trigger Acknowledge (TACK)
  - Command (For the Read Event command)
  - Token
- Buffers
  - 4 events GTFE
  - 2 events in GTRC (each programmable up to 64 hits)
  - 5 FIFOs in TEM for each GTCC
    - Diagnostic FIFO (64 entries deep)
    - Error FIFO (128 entries deep)
    - TOT FIFO (64 entries deep)
    - Data FIFO (128 entries deep)
    - Summary FIFO (64 entries deep)

Tracker Readout 1

- No coincidence that the first 3 bits of the TAM are CALSTROBE and TAG
  - If CALSTROBE is clear, then the only information needed to readout the TKR is which FE buffers to use (this is the TAG)
- Before the rest of the TAM is decoded (actually it waits for the TACK delay), the GTIU sends the Trigger Acknowledge (TACK) on the trigger line to the TFEs.
  - 4 bits: Start bit followed by the TAG and parity
- Upon receipt of the TACK, each GTFE latches it’s hitmap into the appropriate buffer (as specified in the TAG)
- Then the read event command is issued to the GTRCs
  - Causes the hitmaps to be extracted from the GTFE in each layer-end, and the addresses (up to MAX_HITS) to be stored in one of the two GTRC event buffers.
    - Which buffer is fixed by the LSB of the GTFE buffer address
    - The readout begins at the near GTFE and proceeds to the far
    - When the maximum number of hits are reached, readout stops
    - GTFE buffer is not “freed” yet as the GTRC does not report when this readout is complete

Tracker Readout 2

- After the Read Event command is sent, the GTIU token signal is sent to the first TRC on each cable.
  - 3 bits: Start Bit, GTRC buffer, Parity
- GTCC then receives the data from each GTRC in turn and fills the GTCC FIFOs as appropriate
- The GTIU is responsible for asserting BUSY to the GEM when the TKR is unable to buffer another event
  - It keeps track of how many buffers are occupied in the GTFEs and GTRCs
  - It keeps track of the "almost full" flags on the GTCC FIFOs
    - It is important to remember that the GTCC FIFOs are filling and emptying as events are being triggered, we should expect the number of words in the FIFOs to fluctuate based on trigger rate and backpressure.

If one were to limit the maximum number of hits in a GTRC buffer to 14 (max hits of 126 per GTCC) with the goal of eliminating FIFO overflows, one would have to set the "almost full" flag of the Data FIFO to generate back pressure whenever it contains 3 or more words.

This would negatively affect the TKR deadtime.

Calorimeter Readout 0

- There is only one line that controls CAL readout
  - Command Line
- Buffers
  - Data from CFE and CRC are buffered/deconvoluted in GCCC
  - FIFOs in TEM for each GCCC
    - Diagnostic FIFO (64 entries deep)
    - Error FIFO (64 entries deep)
    - Negative Data FIFO (128 entries deep)
    - Positive Data FIFO (128 deep)
    - Summary FIFO (64 deep)

Calorimeter Readout 1

- The GTIU sends a read command through the GCCC to the GCRC
  - Command tells GCRC if trigger is for 1 or 4 range readout
- Data bits are read out in a special format (see LAT-SS-01973) and reassembled in GCCC.
- Also log ends are reunited by “crossing over” from opposite sides of the TEM (So that each GCCC effectively reads out both ends of 2 layers.)
- It is the GCCC which performs zero suppression, if required by the trigger context
- The GCCC then appropriately fills the FIFOs
- There is no event buffering in the CAL, so while readout is taking place, the GCCC ensures that the TEM asserts its BUSY line to the GEM

The TEM event contribution

- The construction of the TEM event contribution begins when all of the enabled Cable Controllers (GTCC and GCCC) have the “not empty” flag set on their Summary FIFOs
- First the Trigger information is extracted from the appropriate GCCC Data FIFO and the Event Summary is formed
- This is followed by the CAL contribution
  - Log accepts
  - Log Data (either single or 4-range)
- Then there is the TKR contribution
  - TKR accepts
  - Strip Addresses
  - TOTs
- If the diagnostic bit is set, then a Diagnostic contribution is added
- Last of all is any Error contribution
- Each word collected from the appropriate FIFO, is serialized, and sent to the EBM (That is, if the EBM is not asserting backpressure.)

Summary

- Let's not forget that the GEM is highly configurable (not just in the ways that allow it to be "timed in")
  - Example:
    - We can take non-zero suppressed pedestals in the same run as zero suppressed cosmics
- There will be compromises made in the configuration of the TEM (and the dataflow system as a whole)
  - Example:
    - Choosing FIFO almost full levels to optimize deadtime vs. GTCC FIFO overflows
- The Dataflow system is buffered and dynamic
  - The Testbed is an imperfect model of this system, but may provide insight into the performance of the instrument
  - We will likely not have the final answers before we have seen the LAT in on-orbit conditions