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# Requirements for Year 2009 TCU

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This document establishes the requirements for an upgraded STAR Trigger Control Unit (TCU). The primary reason for this upgrade is to allow more simultaneously-running triggers at STAR. Secondary reasons include a requirement for more bits in the user-accessible selection process and an increased number of independent detectors. The new TCU must be compatible with existing DSMI input and TCUI output to allow using the new TCU prior to implementing a new TCD system.

Notable similarities to previous TCU versions:
1. The token handling logic remains identical
2. The VME interface remains as similar as possible to the existing version, given the modifications due to hardware & firmware changes.

Notable changes from previous version:
1. Change: **Preceded / Followed** - No longer require preceded / followed logic.
2. Change: **Limitations** – The following limitations will be increased
* 8 detector groups – new limit set by action word length : will be ≥ 16
* Prescale value range increased to >26 bits
3. Change: **Logic** – The state-machine concept is altered, and we now will issue a trigger whenever any specified combination of input bits has a prescale value of 1. This means that a crossing may have more than 1 valid trigger condition.

Definitions:
1. Trigger: a specified combination of physics bits and detector-LIVE bits and pre-scale conditions
2. Physics bits: bits that originate from fast detectors, primarily from the DSM tree
3. Detector-live bit: bit to assert when a detector is ready to be triggered, the so-called Live bit.
4. Action word: one word for each trigger: a bit-mask specification of each detector that must respond to this trigger, accompanied by a 4-bit trigger command, a 4-bit daq command, and a 12-bit token.
5. RS == RHIC strobe: this is the 9.4 MHz system clock at STAR.
6. TCD == Trigger-Clock Distribution system

Brief description: The TCU will take input bits, presumably but not necessarily from the DSM tree, and Live status bits from the detectors, and it will generate a level0 trigger for STAR. Any combination of input and Live bits can define a trigger. Any number of triggers (up to at least 50) may be simultaneously satisfied. The trigger command must be sent to the detectors specified in the action word for this trigger within 1.5 microseconds of the occurrence of the triggering interaction. For crossings when there is no trigger, the TCU will distribute other commands from its stack, such as abort or accept commands.

We use 128 input bits and 128 output bits in our current model, (128 on P3, 64 on P2, 64 on front panel) with their meaning fully programmable. These may run at multiples of the RHIC clock, increasing the I/O count accordingly.

## TCU Requirements

1. Requirement: **Format** - The TCU must be a 9U VME board.
Justification: Easy integration with existing trigger system.

2. Requirement: **Data Input** - The TCU must be able to accept at least 128 input bits.
Justification: To remove existing constraints on what triggers may be implemented and to support detector and trigger upgrades for years to come.

3. Requirement: **Detector-Live Input** - The TCU must accept independent input bits representing each of the non-trigger detector system's LIVE/BUSY status.
Justification: No trigger may be issued to any detector while it is dead.
Status: we intend to implement at least 16 detector LIVE bits in a manner that allows expansion.

4. Requirement: **Input Standard** : A single standard will be selected for routing bits into and out of the TCU – most likely LVTTL – allowing for multiple RS frequency operation.
Justification: Want simple interface, consistent with current trigger standard. Note that a single ended standard allows us to use more pins as bits.
Status: We expect to employ a 3-slot backplane-overlay to bring data into the TCU from a DSMI, and put it out to the TCD through a TCUI, with a copy available for a spy board.

5. Requirement: **Speed** - The TCU must accept input data and produce a trigger decision based on its input every tick of the 9.4 MHz RHIC clock.
Justification: Every RHIC clock represents a possible collision.

6. Requirement: **Latency in TCU**: The TCU must distribute a trigger within 2.5 RS of receiving the 128 input bits.
Justification: The 1.5 microsecond limit allows 260ns latency in TCU. This is also required to keep timing the same as the current system.

7. Requirement: **Supported Triggers** – The TCU must support at least 50 simultaneous running triggers.
Justification: To support star operations.

8. Requirement: **Internal BUSY** - The TCU must generate an internal BUSY state of either 0 or a single fixed duration for each detector to cover the time it takes between the issuing of the trigger and the raising of that detector's external busy signal.
Justification: No trigger may be issued to any detector while it is dead. We want the delay to be a fixed value to minimize confusion, since the TCD can be programmed for any delay length for each detector.

9. Requirement: **Trigger Independence** – The behavior of a trigger should be fully defined by the input bits (physics + Live bits) presented to the TCU. This criterion must remain true for each trigger individually, no matter how many, or which other triggers are specified.
Justification: This is necessary to ensure unbiased triggering.

10. Requirement: **Detector Action** – If an L0 trigger condition is met, each detector in the trigger's action word must be sent the command identified with that trigger. Since multiple trigger conditions may be met in a single crossing, a hierarchy of commands must be imposed to resolve conflict.
Justification: To support triggers with differing detector requirements

11. Requirement: **Detector Selection** - The set of detectors reacting in any bunch crossing must be the logical "OR" of the action words of each satisfied trigger, or the action word associated with a queued command.
Justification: The detector requirements are part of the specification of a trigger.

12. Requirement: **Token Based Resource Management** - The TCU will manage the resources of the entire trigger system by tagging events with one of 4095 tokens. Tokens are taken from the FIFO whenever a command is issued to the detectors. The depth of the token FIFO is 4096. A token may not be reused until the event has been aborted or stored by DAQ.
Justification: Existing trigger protocols must be maintained.

13. Requirement: **Prescale** - The TCU must be capable of prescaling each defined trigger independently from a maximum of 10 MHz down to less than 0.1 Hz, ($2^{27}$=1.28x$10^{8}$).
Justification: The only way to control the detector deadtime is to manage the Level0 trigger rate.

14. Requirement: **Halt** – A nearly-bullet-proof mechanism must be implemented for ensuring that the DSM data read out by the DSM CPUs is not stale.
Justification: Data is saved in the DSM circular input buffers for 7 ms after it is written. A scheme must be in place to ensure that the <0.01% of the data is not stale.
Status: we use software scheduling to ensure this now, because we do not demand notification from each CPU when it has sent its data to L2.

15. Requirement: **Output to Detectors** - When the TCU issues a trigger or other command it must distribute information to the trigger system. This includes providing the trigger command, daq command, and token to the TCD fanout. It also includes making the same information, as well as a list of triggers and detectors fired, and the current DSM buffer address available over VME so that other trigger components may be notified via the trigger network.
Justification: The existing trigger protocol must be obeyed.

16. Requirement: **Command Distribution** - A mechanism must be provided to distribute commands via the VME interface for events in the system.

Justification: We employ a 4bit trigger command (trg-cmd) and a 4 bit daq command (daq-cmd). These are sent to the detectors whenever they appear on the command FIFO, which has a depth of at least 4096 to match the token FIFO. Commands are placed on the CMD-FIFO in association with a Level 0 trigger, or from the queue of secondary commands awaiting distribution for crossings which do not generate a Level 0 trigger, , such as abort and accept commands. The abort and accept decisions are made by other trigger components and routed via VME to the TCU for distribution.

17. Requirement: **Null Event** - If the current event is not triggered, and there are no other commands queued for distribution, the TCU must actively send zeros to all the non-trigger detectors.
Justification: If the TCU does not actively send zeros, the detectors may fire erroneously.

18: Requirement: **Output to Scalers**: 64 bits must be available for scaler input, with the bits defined in software.
Justification: Want to count correlated detector conditions with trigger conditions in various combinations.
Status: expect these to be available on front panel

19. Requirement: **Interface**: Communication between the TCU and the detectors and other outside components (RCC, RAT, etc) must be driven through an interface card. The pinout for this board must be compatible with the existing TCUI (interface card).
Justification: to maintain flexibility and eliminate drivers from the TCU design. We need to maintain compatibility to allow staging of the new hardware.
Status: The TCU will place a single copy of the output on the VME backplane. An interface board will take these and drive them to a TCD distribution system being designed by Tonko.

20. Requirement: **VME Specification** – VME standards should be respected:
* Polling the event fifo during VME downloads should not lock the crate
* The TCU should respond unconditionally to the SYSreset line by performing a power-on reset which includes configuring all FPGAs.
* The board must not interfere with VME power or communication lines
Justification: To eliminate the necessity to power-cycle the VME crate on errors and maintain VME standards compatibility.
Justification: need to respect VME standards and eliminate need for power cycling to reset.

21. Requirement: **Counters**: The TCU must keep a count of each occurrence of each defined trigger, counting the occurrence of the physics bits and the LIVE bits separately, as well as in combination.
Justification: This unit must allow calculation of cross sections for different triggers.

22. Requirement: **Start/Stop control from RCC**: The TCU must obey the RCC for starting and stopping operation.

Justification: Need to maintain synchronous operation with trigger electronics.

23. Requirement: **Configure in <60 sec**: The TCU must fully configure at run start in less than 1 minute.
Justification: beamtime requires that the trigger configure in under 60 sec.

23. Requirement: **Configure at Reset**: The TCU must re-configure on sysrest.
Justification: Want to configure all non-run-specific portions to speed run start-up configuration.

25. Requirement: **Front Panel**: The front panel should have, at least,

    1) LEDs - Run/Load (green/yellow), token FIFO mt (red), Halt (red)
    2) lemo's - trigger out, clock out, trigger in

Justification: ease of trouble-shooting

26. Requirement: **TCU input in data stream**: The TCU must place its input and output bits into the data stream for any triggered event. It must also put the DSM address of the triggered data into the data stream. It must also place a bitmask in the data stream indiciating which triggers had a prescale of 1 for this event.
Justification: we need to be able to reconstruct why an event was triggered.

27. Requirement: **Input and Output memories:** The TCU needs to have enough memory to save all of its input and output data (and maybe an intermediate stage) from 64k crossings. A register-selectable option to suppress NULL crossings must be implemented to allow the memory to store a longer time period. The output memory must also be configurable to operate as input to the TCD for tests.
Justification: need to be able to debug and test the board.