



ProtoDUNE SiPM Signal Processor Interface between SSP and timing system

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Introduction

This is a draft document describing the implementation of the firmware of the SSP on the date shown above, provided for discussion purposes only. This is neither a final specification nor a formal user's manual and the information provided herein should not in any way be considered formal documentation of the SSP.

General concept of the firmware

The SSP implements the "timing endpoint" firmware as provided by ProtoDUNE collaborators. A four-bit SCMD "trigger type" value and the SCMD_V strobe are decoded. Each "trigger type" value, when asserted by the timing system, generates a one-clock-tick internal strobe. Counters for each "trigger type" are provided. This strobe enters a programmable delay line whose output is considered the "command begin". The "command begin" also triggers a programmable digital one-shot to create a delayed signal referred to as the "command end". Software has full control over the length of the delay line and the timeout of the digital one-shot. Each of these 32 internal signals is connected to four logic blocks to generate GATE, EVENT, TRIG and SPILL signals as shown in Figure 1.

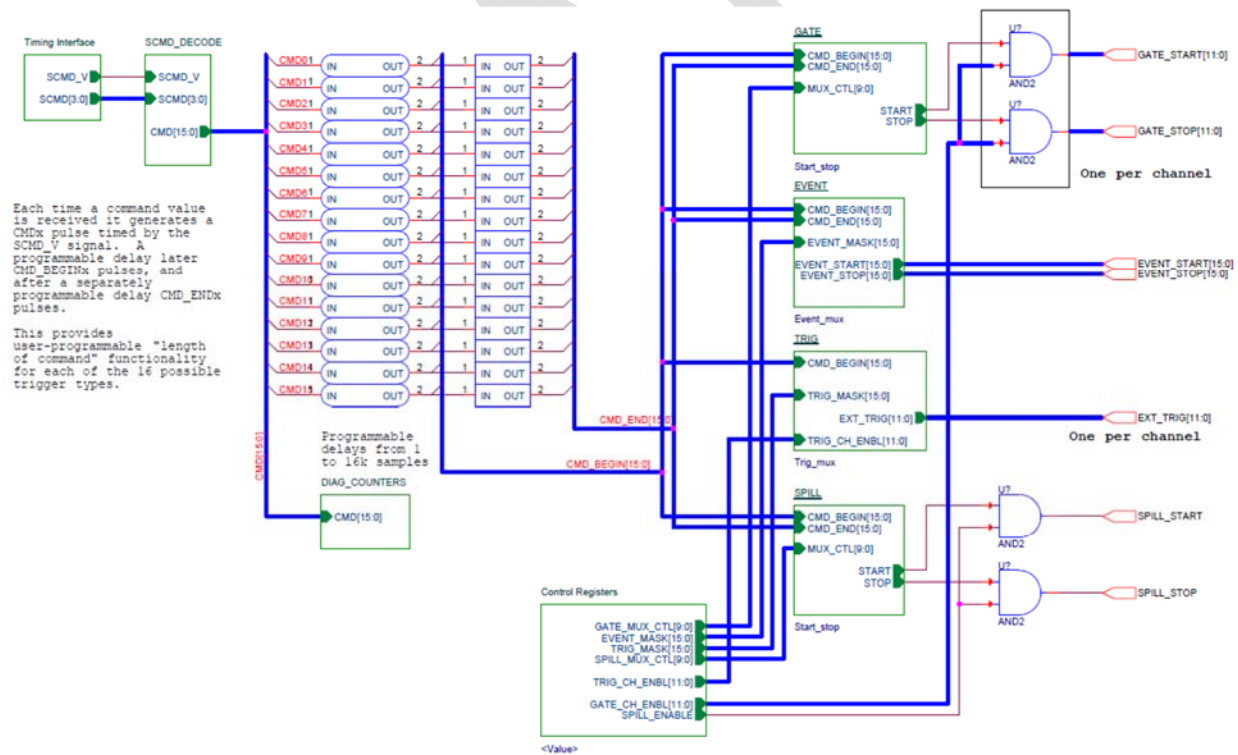


Figure 1 - block diagram view of SSP message response firmware

Operation of the GATE, EVENT, TRIG and SPILL blocks

In general, the logic blocks are multiplexers that allow software to map which command(s) will generate the signals indicative of the various actions. There are, however, some slight differences between them. The SSP presumes that the GATE, EVENT and SPILL are conditions that will persist for some amount of time, but do not in and of themselves modify whether the SSP generates a data record. Instead, the SSP uses these conditions to modify the readout of records created by the discriminator logic:

- The GATE signal may be used to select regions of time, controlled by messages from the timing system, during which data records are thrown away and not sent to the BoardReader. This optional functionality is intended to allow the exclusion of known-bad events detrimental to DAQ performance at known times, such as short periods of time at the very beginning or end of a spill or when known sources of noise are energized.
 - The GATE function is applicable on a channel-by-channel basis.
- The EVENT signals may be used to mark data records that may have occurred during a specific time period as belonging to a specific sort group. The EVENT signals pass through to the header of the SSP data for use by event building software. The general intent of EVENT signals is to provide a method of marking records after the records have been captured but before the records are sent to the BoardReader – a post-trigger.
 - The EVENT function is global across the SSP.
- The SPILL signal may be used to select regions of time during which the amount of waveform data associated with any record is different from records obtained at other times. The SSP will implement two separate waveform readout length registers to support this. The presumptive use of this feature would be to have records with significant waveform data during the beam spill, but to limit records outside the beam spill to just the header, or to very little waveform, to control overall readout bandwidth.
 - The SPILL function is applicable on a channel-by-channel basis. If SPILL is disabled for a given channel, the readout length for that channel will be the “in spill” length.

The TRIG condition, unlike the others, may be used to force the creation of new data records at times when the internal leading edge discriminator is idle. The intent of the TRIG condition is to provide a mechanism by which “background” or “pedestal” data records may be collected when no edge is present to fire the discriminator logic.

Details of implementation

The GATE and SPILL blocks are identical. Multiplexer control registers allow the user to select any of the 32 CMD_BEGIN or CMD_END signals as the START, and any of the 32 CMD_BEGIN or CMD_END signals as the STOP. This flexibility allows the SSP to use a single command from the timing system to indicate the start of a condition (e.g. SPILL) with a programmable window based upon the one-shot value, or to use two different timing system commands as SPILL_START and SPILL_STOP. Overall enable/disable controls are provided to allow the GATE and SPILL conditions to be completely disabled.

The EVENT block provides 16 start/stop signals, one per “trigger type” message, with an enable for each message type from a control register. All 16 bits are passed to the header of the data record, allowing any data record to be marked by any or all of the message types. The EVENT marks are applied to the **first** record (from either internal discriminator or TRIG) that passes through after the EVENT mark is set. Subsequent records that pass through the SSP after the first are **not marked**. If no record passes through before the stop for the given EVENT mark is received, the mark is not applied to any event.

The TRIG block does not create a time window, but instead merely masks the 16 CMD_BEGIN pulses to select which subset of trigger types are to generate an external trigger. The bus of external trigger signals are not subject to the programmable “P” delay that is applied to the internal discriminator. By appropriate adjustment of the TRIG function delay relative to the “P” delay differences the TRIG may be aligned as desired with respect to normal discriminator events. This may be used to measure the trigger formation time of the system when using TRIG messages derived from the TRIG_OUT of the SSP. As waveform data is processed, the external trigger signals are ORed with the leading edge discriminator that is based upon the waveform data values. Sections of waveform are selected for readout if either the leading edge discriminator fires or any unmasked CMD_BEGIN arrives. By allowing selection of multiple trigger type codes as the “external discriminator”, the experiment may define one trigger type code as a regularly occurring, background pedestal measurement while simultaneously defining some other trigger type code to force capture at other times (e.g. calibration, external cosmic ray, etc.).

Selection of trigger type codes for various functions

The SSP aims to be completely generic such that the mapping of which trigger type code should be associated with any given function (or *functions*) can be left to software. Software should exercise care when setting which trigger type codes are active for each function. While it is possible to have any given code active in more than one function, multiple-use codes are harder to debug, maintain and document. The desired intent of the multiplexing logic of the SSP is to allow for flexibility during ProtoDUNE to add or modify trigger type codes.

Interaction rules between different conditions

- The TRIG overrides the GATE function. The SSP always responds to the TRIG function, with only internal discriminator records blocked by the GATE.
- The TRIG overrides the SPILL function in the sense that every record generated by TRIG will have the waveform length associated with “in spill” records, even if the TRIG occurs outside the spill.
- EVENT is simply a mark applied to any records that occur while EVENT is active, and thus has no interaction with the other functions.
- GATE and SPILL are independent of each other.

Overall System Timing Considerations

As noted previously for the TRIG function, the programmable “P” delay imposed upon the internal discriminator signal is not applied to any of the GATE, SPILL, EVENT or TRIG functions. Thus the combination of the delay that can be applied to each function, in concert with the value of “P”, provides an adjustable window of time where the functions may be applied relative to the waveform-based discriminator. As currently configured the “P” delay can be set from 0 to 1023 waveform samples (0 – 6.82us). When combined with the 0 – 109.21us delay range that can be applied to the functions themselves, the functions (or, equivalently, the messages from the timing system) may occur anywhere from 109.21us before to 6.82us after the discriminator firing.

The possibility exists to increase the 6.82us value if needed, but this requires a firmware change.

Delay settings versus timestamp values

The timestamp value recorded for internal discriminator firings is the timestamp *at the moment the discriminator fires*, and is not modified in any way by the value of “P”. The timestamp value recorded for records selected by the TRIG command will be the timestamp *when the external TRIG is applied to the channel* and thus is again independent of the value of “P” but completely dependent on the delay applied to the TRIG function. The “P” buffer is used solely to provide a delay to compensate for formation of the GATE, SPILL, EVENT or TRIG functions and in no way affects timestamps.