HINS Clock Event Definitions and Initial Set-up

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Introduction

There are three fundamental timing rates important to HINS Linac systems operations.

1) The ion source rate which needs to be steady and constant for stable ion source operating temperatures.
2) The RF system pulse rate which may be less than the ion source rate, initially due at least to modulator charging power supply limitations.
3) The accelerated beam rate which we allow to be set to a sub-harmonic of the RF rate.

A unique clock event is defined for each of these three fundamental system rates. These events will have independently selectable repetition rates and adjustable delays from the fundamental 10 Hz event of the clock system. The philosophy is to provide common and adjustable event references for systems linked to each of the fundamental rates.

New Rep Rate Generator hardware is expected to be available in summer 2007. Descriptions and definitions in this note assume the availability of the new hardware and items that depend on it are noted in italics.

Planned Clock System Implementation

The HINS accelerator in Meson will initially operate with nine clock events. Six events, $A9-$AF, are triggered directly by the Rep Rate Generator hardware; of these, four are fixed rate and two variable rate events. These six events are synchronized with the fundamental 10 Hz rate of the clock system (power line frequency divided by six) and each occurs at its respective rate within microseconds of the corresponding 10 Hz event. The remaining three events, $A6-$A8, are triggered by programmable delay timers individually referenced to one of the $A9-$AF events. The rate of any event may or may not be different from any other event except that the two variable rate events are inherently coupled (*until new Rep Rate Generator hardware is installed*).

Event Definitions

The event definitions are made as follows:

$AF – 10 Hz Event
- fixed 10 Hz line-locked clock event (one-sixth of power line frequency)
- triggered by GPIP Clock Generator

$AE – 5 Hz Event (*with new Rep Rate Generator only*)
- fixed 5 Hz clock event
- triggered by Rep Rate Generator hardware 2 μs after corresponding $AF

$AD – 2.5 Hz Event (*new Rep Rate Generator only*)

- fixed 2.5 Hz clock event
- triggered by Rep Rate Generator hardware 4 µs after corresponding $AF

$AC – "Rate M" Event

- selectable by "Rate M" thumbwheel on Rep Rate Generator to 0.1, 0.2, 0.5, 1, 2, 5, 10 Hz
- *selectable to 0.2, 0.5, 1, 2, 2.5, 5, and 10Hz with new Rep Rate Generator*
- triggered by Rep Rate Generator hardware 6 µs after corresponding $AF

$AB – "Rate N" Event

- COUPLED TO "RATE M" with present Rep Rate Generator!!!
- selectable by "Rate N" thumbwheel on Rep Rate Generator to "Rate M" rate divided by 1, 2, 5, 10, 20, 50, or 100
- *selectable to 0.2, 0.5, 1, 2, 2.5, 5, or 10Hz decoupled from "Rate M" with new Rep Rate Generator*
- triggered by Rep Rate Generator 8 µs after corresponding $AF

$AA – 1 Hz Event (*with new Rep Rate Generator only*)

- fixed 1 Hz clock event
- triggered by Rep Rate Generator hardware 10 µs after corresponding $AF

$A9 – 0.1 Hz Event

- fixed 0.1 Hz clock event
- triggered by Rep Rate Generator hardware 12 µs after corresponding $AF

$A8 – Ion Source Event

- triggered by Ion Source Event Trigger delayed timer channel
- referenced to any Rep Rate Generator hardware triggered event

$A7 – RF Event

- triggered by RF Event Trigger delayed timer channel
- referenced to any Rep Rate Generator hardware triggered event

$A6 – Beam Acceleration Event

- triggered by Beam Event Trigger delayed timer channel
- referenced to any Rep Rate Generator hardware triggered event

It is expected that the $A8 Ion Source Event will be referenced to the 10, 5, or 2.5 Hz event ($AF-$AD respectively), the $A7 RF event referenced to the $AC "Rate M" Event, and the $A6 Beam Acceleration Event referenced to the $AB "Rate N" Event.

Ion source referenced systems are to be timed relative to the $A8 event, RF referenced systems relative to the $A7 event, and beam referenced systems relative to the $A6 event.

"Start of Beam" Definition and Event Setup

The klystron modulator(s), ion source, LLRF, and possibly other systems require triggers as much as several milliseconds in advance of "Start of Beam" time. To accommodate these requirements and to provide that all systems monitoring clock events can know precisely when to expect beam, the time of "Start of Beam"[1] is formally defined to be 5000 microseconds (μs) after the respective $A6 Beam Acceleration Event. Additionally, the nominal time of the $A6 Beam Acceleration Event shall be 5000 μs after the corresponding $AF 10 Hz Event.

This implies that the nominal "Start of Beam" time occurs 10,000 μs after the corresponding $AF 10 Hz Event. For diagnostic and system studies purposes, the "Start of Beam" may be moved relative to the $AF event by changing the $A6 Beam Acceleration Event trigger delay; nevertheless the "Start of Beam" shall remain 5000 μs after the $A6 event itself. Delays for the $A8 and $A7 event triggers will need to be set as required relative to the $A6.

Trigger delays to generate the $A8 Ion Source Event and the $A7 RF Event are somewhat arbitrary, since most system triggers have subsequent programmable delays from their respective event. The $A8 and $A7 event trigger delays should be ≥100 μs so these events are well separated from the fixed rate events and yet small enough to allow systems to take advantage of the time until "Start of Beam".

RF System Timer Assignments and Example of Initial Settings

The following assumes the nominal "Start of Beam" time, 10,000 μs from the corresponding $AF event, and a 500 μs delay of the $A7 RF Event from the $AF.

The klystron pulse transformer rise-time is assumed to be 400 μs, superconducting cavity RF rise-time is assumed to be 500 μs, and these two are assumed to be sequential with no overlap. Therefore, the modulator flattop must be attained 500 μs in advance of "Start of Beam", i.e. by 9500 μs relative to the corresponding $AF event.

Nominal delays are shown in the table below for a 1 millisecond beam pulse starting at the nominal 10,000 μs "Start of Beam" time. Modulator pulse width setting must be beam pulse length plus transformer rise plus cavity RF rise = 1.9 ms. Relative to the $A7 event, things occur at these times: modulator trigger at 5350, center of modulator pulse at 9550, beginning of video pulse flattop and beginning of RF power at 9550 – pw/2 + 400 = 9550-950+400 = 9000, and beginning of cavity RF flattop at 9500. With $A7 set to 500 after $AF, cavity RF flattop begins at 10,000 relative to $AF as required.

[1] To be unambiguous at the microsecond level, "Start of Beam" for any machine cycle is defined as the time at which the front edge of the beam pulse exits the MEBT Chopper.

VME Crate 8-Channel Delay Timer Assignments and Initial Settings

Channel #	Assignment	Reference Event	Nominal Delay	Nominal Width
Channel 0	Modulator Trigger	$A7	5350 µs	10 µs
Channel 1	Forward Power RF Interlock Gate	$A7	9000 µs	Desired RF Pulse Width
Channel 2	Reverse Power RF Interlock Gate	$A7	9500 µs	Desired RF Pulse Width - 500 µs
Channel 3	RF Interlock Digitizer Trigger	$A7	8900 µs	10 µs
Channel 4	RF Gate	$A7	9000 µs	Desired RF Pulse Width
Channel 5	$A7 RF Event Trigger	$AC	500 µs	10 µs
Channel 6	N/A	TBD		
Channel 7	Scope Trigger	$Ax	User choice	10 µs

Timing Requirements from Systems Experts

Modulator Timing Requirements Per Chris Jensen

The modulator trigger pulse sent from the control system (1us pulse width or more) starts the bouncer circuit ringing and the CENTER of the modulator output pulse is fixed at roughly 4.2 ms (need to verify) after the trigger pulse. The modulator output pulse width variable is set locally or by the modulator interlock computer, NOT by the timing system. The modulator pulse width setting needs to be 400 microseconds greater than the desired video pulse flattop length to account for pulse transformer rise time and this additional 400 us is not centered but added to the beginning. For example, a video pulse flattop of 3 ms requires the modulator pulse width setting to be 3.4 ms and the start of the flattop relative to the modulator trigger will be at 4.2 ms + 0.4 ms - 0.5 * PulseWidthSetting, e.g. 4.2 ms + 0.4 ms - (3.4 ms/2) = 2.9 ms.

To keep start of modulator pulse flattop fixed in time when modulator pulse width is changed, the modulator trigger must be changed by an amount that is one-half and the same sign as the change in pulse width. For example, a pulse width increase of 1000 µs calls for a 500 µs later trigger time.

Ion Source Timing Requirements

Chuck Schmidt claims that ion source timing requirements can be accommodated by an ion source trigger 5 milliseconds in advance of expected time of start of beam.

Low Level RF Timing Requirements

Brian Chase requested up to 10 milliseconds advance timing before “Start of Beam” to accommodate possible pulse-by-pulse active reference line phase measurements.