CUSTOMER TRIGGERING CAPABILITY FOR THE HERMES III ACCELERATOR

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INTRODUCTION

This paper describes the hardware changes made to the triggering systems of the HERMES III accelerator at the Simulation Technology Laboratory (STL) at Sandia National Laboratories, New Mexico. The HERMES III accelerator is a gamma ray simulator producing 100kRad dose per shot with a full width half max pulse duration of ~25 nanoseconds and averages six shots per day. The HERMES III accelerator is operated as a "work for others" and for many years our customers positioned their device under test (asset) near the x-ray source and monitored the device operation while HERMES III was charged and fired. However, during the last few years some customer assets have required the accelerator x-ray pulse output occur at a pre-determined time with respect to the operational sequences of their assets thereby requiring these users either initiate the triggering of the HERMES III accelerator or we provide a means to time sync our accelerator with their external systems.

Over the last 30 months the HERMES III data acquisition system (DAS) and accelerator trigger systems have undergone two significant trigger system upgrades. The first upgrade, due to budget constraints, used existing DAS hardware and software; however by changing equipment layouts and configurations together with archiving the appropriate timing information we were able to time sync the DAS triggers and digitizers' time bases [1]. Integral to this upgraded DAS trigger system was a single DAS trigger source originating solely from the HERMES III operator. The second upgrade involved replacing all legacy trigger systems with commercial off the shelf (COTS) equipment that was configured in a modular fashion allowing for DAS expansion [2]. Again, integral to the DAS trigger system is a single trigger source; however we created a separate second trigger system enabled by the HERMES III operator that our customer can access to trigger both the accelerator and DAS systems so the customers can meet their trigger and time syncing requirements. This time synchronization of the HERMES III accelerator with the customer asset is a recent and significant development for users whose assets "survivability" requirements dictate HERMES III x-ray source irradiations occur at specific times. Also, this approach enables quick (between H3 shots) irradiation exposure time adjustments allowing asset performance to be quantified for numerous and specific exposure times with respect to asset operation.

The HERMES III accelerator is a high energy, high radiation producing device subject to DOE rules and regulations and (of course) safety is of paramount importance. Adding a customer trigger capability requires caution and restrictive features. The purpose of this paper is to present the main DAS and the separate second trigger (SST) systems, their operational behavior, and their requirements and limitations. The paper will outline the generalized steps a customer should take so their asset is irradiated at the correct asset operational time, and it also provides a couple of example experimental setups we have employed for time syncing the trigger of the HERMES III accelerator with external systems. Due to the sensitive nature of some customer setups, the examples given will be generalized but still informative.

MAIN DAS TRIGGER CIRCUIT AND SEPARATE SECOND TRIGGER (SST) SYSTEM

The HERMES III (H3) accelerator physically occupies a volume ~ 24 meter wide x 31 meter deep x 5 meter tall containing 400+ current and voltage probes throughout its electrical power flow. The H3 main screen room records 95% of these probes signals using ~ 65 digitizers mounted in 12 equipment racks. This RF shielded enclosure is ~ 50 meters from the H3 x-ray source resulting in unique probe to digitizer signal path lengths. The latest upgrade to our main DAS and accelerator trigger system is shown in figure 1. In this figure we see that DG535#1 is the "top level" trigger generator and it triggers both DG645 #1 and DG645 #2 devices, each containing eight (8) outputs that drive a 40 volt pulse into 50 ohms. Each required DG645 output is copper cabled to a rack mounted 10-way trigger splitter containing 10 equal length output cables with each cable terminating at a scope trigger input. As shown in the figure, we defined the rising edge of the DG535 #1"To" front panel output signal as the "local T-Zero" reference point. This reference has a rising edge less than 5 nanoseconds and its ease of access for the dozens of measurements is advantageous. We measure the time delay from the T-Zero reference to a single scope trigger in each rack and archive the value appropriately into the DAS information file. By making all 10-way splitter cables in each rack the same length this measured delay value is valid for all scopes within each rack. For expandability, the unused DG645 #2 outputs E thru F can be used to trigger other racks of digitizer or if we need more than 4 racks we can purchase and then add device DG645 #3 in parallel with the other two units. DG535 #1 is triggered from the summer circuit with inputs from the MARX pre-fire detection circuit and from the separate second trigger system. The MARX pre-fire detection circuit will output a trigger signal if any one of the ten MARX capacitor banks pre-fire. Of note, the DAS operator can perform numerous screen room trigger tests to prepare the DAS digitizer systems for accelerator shots without an HERMES III operator by locally triggering DG535 #1 and not adversely affecting the DAS time bases or the trigger lines leading to and from the summer.

As stated earlier, the HERMES III accelerator is a high energy, high radiation producing device subject to DOE rules and regulations and safety is of paramount importance. Adding a second trigger system that the customer can access requires a lot of caution and restrictive features. Our separate second trigger (SST) system meets two important requirements. First, to prevent an early customer trigger signal from triggering the accelerator when it's not ready to fire we required a trigger system that can only be enabled by the HERMES III operator. Second, for the "no trigger signal from the customer" event, we required our system contain an imbedded backup command trigger and this backup command trigger be generated no longer than 3 seconds after the SST is enabled. The SST system is shown in figure 2 and requires an external trigger input 5 volts into 50 ohms. In this figure we see that the HERMES III operator triggers device DG535#U1 which in turn enables DG535#U2 via its front panel C/D output. The user command trigger is input to a 2-way type summer whose output triggers device DG535 #U2 which in turn triggers the main DAS and the accelerator. The backup trigger source is derived from DG535 #U1channel # A and is input to the 2-way summer for triggering the DG535#U2 which triggers the main DAS. Of note, this SST system is now utilized for all accelerator tests, however for accelerator tests without a user trigger source we reduce the "wait after enable" time from 3 to ~0.1 seconds and rely on the SST's embedded backup trigger. This reduces stress on the HERMES III accelerator capacitors and the operators. The addition of this second trigger circuit inserts ~ 90 nanoseconds into user command trigger path delay due to the through-put delay of "DG 535 # U2". Additional trigger delays are also possible dependent upon the type and placement of the user equipment to be used for creating the user command trigger. The SST system allows users access to trigger the HERMES III accelerator and provides a means for time syncing the local HERMES III time base to external systems.

CUSTOMER TIME SYNCHRONIZATION AT HERMES III UTILIZING THE SST SYSTEM

Here we present an example pertaining to customers with assets requiring the customer both remotely "start" the asset operational sequence and then some time later fire the HERMES III accelerator so that the time of accelerator output radiation is time synced to the asset "start" operation. Obviously, the time syncing precision for this type of process is not great but this procedure has been necessary for some customers. This type of operation requires the customer be aware of the time lag between the asset startup and the desired asset irradiation so they correctly time their actions while the accelerators systems are charging.

For every HERMES III accelerator downline test the operator is required to charge the master trigger amplifier (MTA), the MARX trigger generator (MTG), the laser and the ten MARX capacitor banks. The MARX banks take the longest to charge (~215 seconds) and the accelerator charging sequence is timed so all systems are full charged ~5-10 seconds before the MARX banks are ready. While the MARX banks are charging the operator broadcasts the MARX charge voltage in 10 kilovolt increments. After MARX bank full charge, the operator announces "Charge complete, Arm, Disconnect" while simultaneously engaging relay switches that arm the accelerator and disconnect the charge line. This is followed by the countdown "3..2..1" and the operator presses a button sending the enable signal to the SST system. Total time elapsed from MARX full charge to enable is ~ 4 seconds.

In this type of example the customer will typically have already started the asset "start" operation and the customer is now ready to fire the accelerator. In order to assist the customers determine when they should "start" their asset, the following table of MARX charge time and voltages for our HERMES III MARX capacitor bank is given. Note: The MARX bank power supply charges with the bank capacitors with a constant charge current resulting in a constant MARX bank charge rate of 577.8 volts per second.

HERMES III MARX bank Charge voltage (KV)	MARX bank Charge time (seconds)
0	0
10	17.3
20	34.6
30	51.9
40	69.2
50	86.5
60	103.9
70	121.2
78	135

Note: The HERMES III charging system may soon be updated resulting in a different charge rate. Customers are encouraged to ask operating personnel as needed.

GPS TIME SYNCHRONIZATION AT HERMES III UTILIZING THE SST SYSTEM

As an example of the utility of the SST trigger system, a test series was performed whereby the firing of the HERMES III accelerator was time synced to the satellite Global Positioning System clock. This was accomplished using a GPS antenna, an antenna booster, a time and frequency GPS Controller, a trigger generator and some fiber-optic trigger transmitters and receivers.

This circuit is shown in figure 3 and is detailed as follows:

1. A GPS antenna signal is boosted and input to the GPS Receiver Controller "GPS Antenna" input.
2. A long delay time occurs while the HERMES III accelerator is prepared and charged.
3. The HERMES III operator sends a command signal to the GPS Receiver Controller "Arm" input and the HERMES III "Enable" signal is simultaneously sent to the SST system.
4. The GPS controller outputs GPS synced triggers at 1 pulse per second (1 PPS).
5. The 1 PPS signal is input to a fiber optic transmitter and the optical signal is transmitted over fiber.
6. The fiber terminates in the H3 main screen room at an optical receiver.
7. The optical receiver signal is input to the STT as the user command trigger signal and triggers the HERMES III accelerator.
8. Note 1: The time delay from the GPS Receiver Controller 1 PPS output signal to our T-Zero reference was measured to be ~ 600 nanoseconds.
9. Note 2: HERMES III x-ray burst occurs at T-Zero + 3200 nanoseconds.

DIESEL GENERATOR TIME SYNCHRONIZATION AT HERMES III UTILIZING THE SST SYSTEM

A second example illustrating the use of the SST involves a test series in which the firing of the HERMES III accelerator was time synced to the zero crossings of the 60 Hertz 120 VAC power output from a diesel generator. This was accomplished using a diesel generator, an extension cord, a user designed "Zero crossing detector" trigger box, a trigger generator and some fiber-optic trigger transmitters and receivers.

This circuit is shown in figure 4 and is detailed as follows:

1. The diesel generator power output circuit breaker is engaged powering an extension cord.
2. The extension cord power is input to a "Zero Crossing Detector" (ZCD) box.
3. The ZCD box outputs a 60 Hertz pulse train into a DG535 trigger generator ("ZCD dg535").
4. A user selectable delayed output from ZCD dg535 trigger generator output drives a fiber optic transmitter and the optical signal is transmitted over fiber.
5. The fiber terminates in the H3 main screen room at an optical receiver
6. The optical receiver signal is input to the STT as the user command trigger signal. Note: this will not yet trigger the HERMES III accelerator because the HERMES III operator enable signal has not been sent.
7. A long delay time occurs while the HERMES III accelerator is prepared and charged.
8. The HERMES III operator sends the "Enable" signal to the SST system.
9. The SST system will now output a trigger signal that is ultimately synced to the Zero Crossing Detector and by extension the diesel generator.
10. Note 1: The time delay from the ZCD dg535 trigger generator to our T-Zero reference was measured to be ~ 1500 nanoseconds
11. Note 2: HERMES III x-ray burst occurs at T-Zero + 3200 nanoseconds.

RESULTS AND SUMMARY

Customer feedback for this triggering capability has been positive and we will be implementing something similar for the SATURN accelerator. Every HERMES III accelerator test requires the operator record a shot time; we have found the GPS timing system of interest and are examining how to incorporate this GPS clock permanently so that accelerator shot time is synced with the GPS clock.

Hermes "Main DAQ" Trigger Circuit

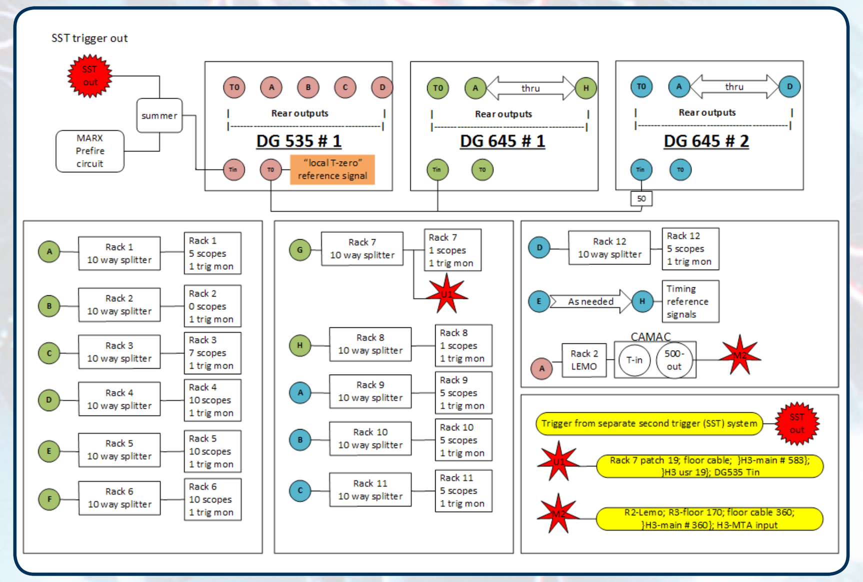

Figure 1: HERMES III main DAS trigger system

Hermes III Separate Second Trigger (SST) System

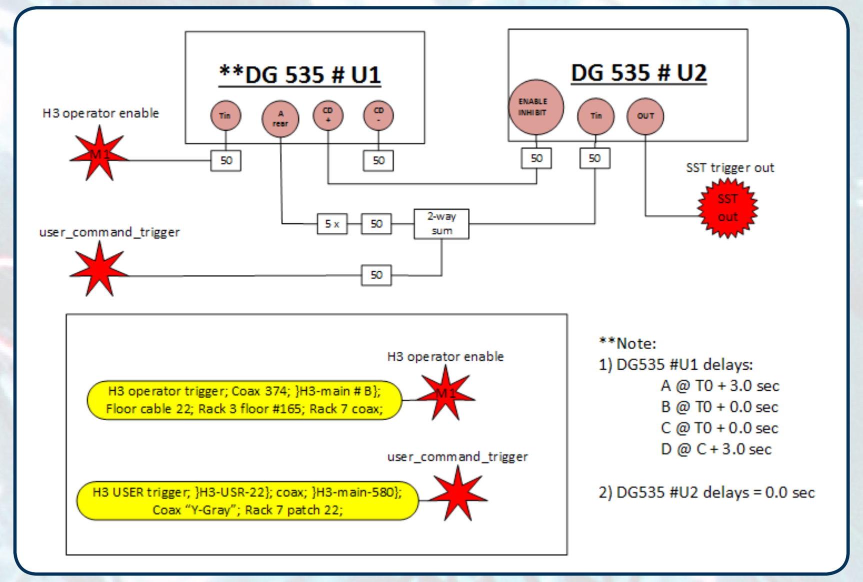

Figure 2: Separate second trigger (SST) system

GPS Time Synchronization at Hermes III

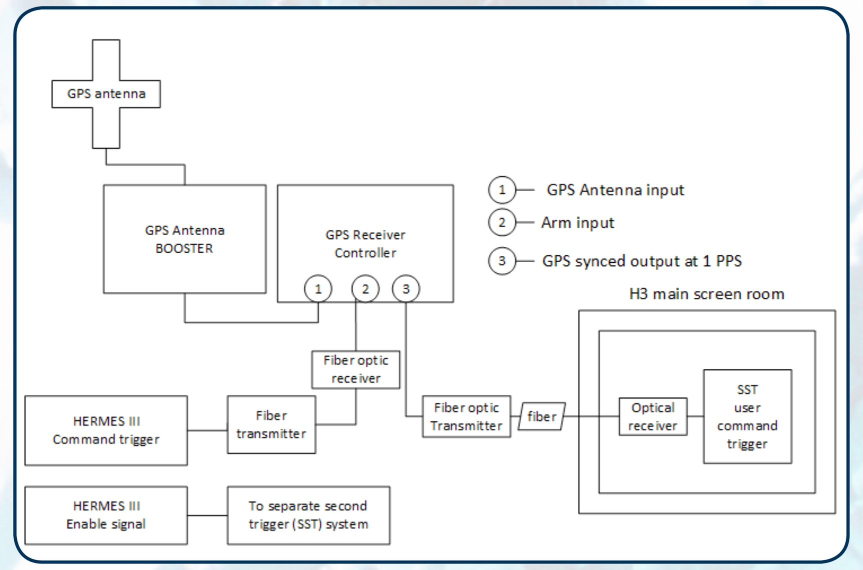

Figure 3: Global Positioning System time synchronization

Diesel Generator Time Synchronization at Hermes III

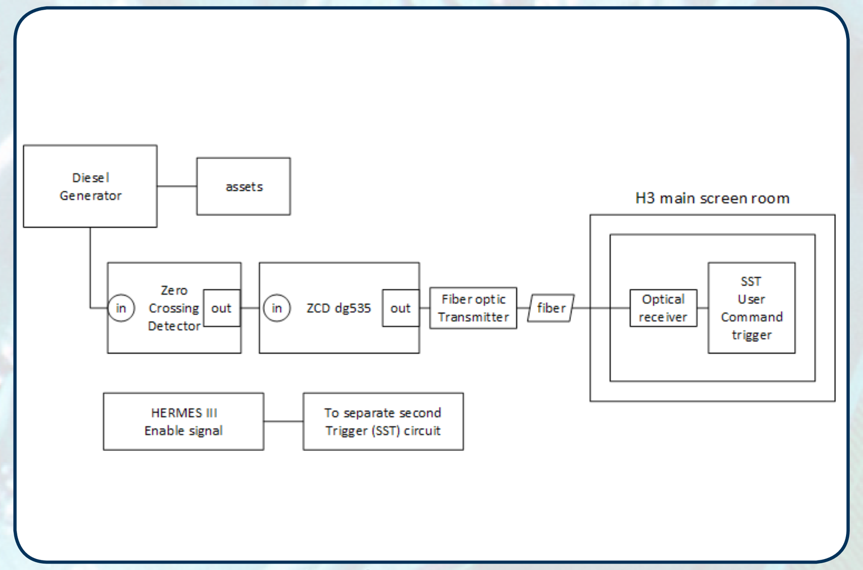

Figure 4: Diesel Generator time synchronization

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