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TRIGGER SYSTEM CHANGES FOR THE HERMES III ACCELERATOR*

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Abstract

This paper describes the hardware changes made to the triggering system of the HERMES III accelerator at Sandia National Laboratories, New Mexico. The HERMES III accelerator is a gamma ray simulator producing 100 kRad dose per shot with a full width half max pulse duration of approximately 25 nanoseconds and averaging six shots per day. For each accelerator test, approximately 400 probe signals are recorded over approximately 65 digitizers. The original digitizer trigger system employed numerous independent legacy signal generators resulting in non-referenceable digitizer time bases. We detail our efforts to reference the digitizer time bases together using a modular and scalable approach with commercial-off-the-shelf components. This upgraded trigger system presently measures a maximum digitizer trigger time spread of less than two nanoseconds across the 65+ digitizers.

This document details the hardware changes, provides a summary of the accelerator charging process, presents "one-line" trigger system diagrams and summarizes the times of interest for a typical HERMES accelerator shot.

I. INTRODUCTION

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, utilized existing DAS hardware and software; however, by changing the equipment layouts and configurations, together with archiving the appropriate timing information, we time synced all DAS triggers and digitizer time bases to a common reference [1]. The second upgrade involved replacing all legacy trigger systems with commercial off-the-shelf (COTS) equipment and configured in a modular fashion allowing for DAS expansion. Integral to both upgrades we defined a time reference "location" for all digitizer trigger times and we installed a single "Main" trigger generator for triggering the HERMES III accelerator and all digitizers. During the second upgrade we also added a separate second trigger system, enabled by the HERMES III operator, that our customers may access providing a means for HERMES III customers and users to safely trigger the HERMES III accelerator. This separate second trigger system is described in reference [2] and will not be detailed here.

After implementing the changes outlined here, the digitizer trigger time variation across 12 racks of digitizers is less than 2.0 nanoseconds and all DAS digitizer trigger amplitudes are 3.0-volts (1.5 volts into 50 ohms). Previously, digitizer trigger amplitudes varied with some triggers as low as 0.15 volts, resulting in sporadic digitizer pre-trigger events and, by consequence, shot delays. This replacement of the legacy equipment with COTS, making all digitizer amplitudes uniform and reducing digitizer trigger variation, is a recent and significant improvement for the HERMES III trigger system.

II. HARDWARE AND EQUIPMENT MODIFICATIONS

The hardware, equipment, and software changes can be broken up into 5 areas.

A. DG-535 as Main Trigger

The number of independent trigger systems for triggering all data acquisition system (DAS) digitizers was reduced from three to one. Originally, the main screen room digitizers were split into two systems, and the user screen room digitizers were on a third system. Now, one Stanford Research Systems Model DG-535 (labeled "DG–535 #1" in figure 1) device is configured at the "top" of our trigger system allowing the DAS operator to trigger all digitizers from this one instrument. Previously, the DAS operator needed to pause the DAS computer program, manually initiate various triggers, and then resume program run. As part of this upgrade a DG-535 software driver was created allowing the DAS operator to software trigger the system if needed.

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B. DG-645 as Rack Triggers

The numerous legacy trigger generators triggering the individual digitizers were replaced with two SRS DG-645 delay generators. These 645's are each triggered from the main DG-535 #1. Each DG-645 trigger generator outputs eight separate high voltage outputs using positive 30-volt logic (15 into 50 ohm) going high for 100 nanoseconds. Each output is copper cabled to a rack of DAS digitizers. The present HERMES DAS setup requires 12 racks so the two DG-645s accommodate our present DAS requirements while providing four spares. This upgrade increases the confidence in our system because the legacy equipment was not repairable and the companies were out of business.

C. Rack Trigger Splitters as 10 Digitizer Triggers

We replaced the unique daisy chaining of trigger lines with a modular design to include a single 10-way trigger signal splitter (Mini-Circuits model ZFSC-10-1+) within each digitizer rack. Physically our digitizer racks never contain more than 10 digitizers so a 10-way splitter is well suited to our needs. The splitter input signal originates from a DG-645 high voltage logic output providing a consistent 3.0-volt (1.5 into 50 ohms) trigger amplitude signal to all rack digitizers. Previously, many digitizer trigger signal amplitudes were as low as 0.15 volts - requiring low digitizer trigger thresholds which sometimes resulted in a digitizer pre-triggering during accelerator charging operations. This pre-trigger event would require the DAS operator to initiate an "Abort Shot" request so that the DAS system could be reset. Also, the DG-645 high voltage logic signal rise time of 4 nanoseconds is ≈5X faster than their replacements helping to reduce the digitizer trigger start time variations.

D. Definition and Measurement of "T-zero" Reference

For ease of access and convenience we defined the rising edge from DG-535 #1 T0 output signal (figure 1) to be the DAS T-zero timing reference. Then the time delay between this T-zero reference and any other digitizer trigger input can easily be measured. Because every racks trigger splitter has 10 equal output cable lengths, the time delay for one DAS trigger input is valid for all 10 scopes within that rack. We perform this type time delay measurement for all DAS scope racks and refer to this measurement as the digitizer time-of-fire. The digitizer time-of-fire value is input to the shot header for use later when time shifting of digitizer signal data is required.

E. Pre-fire Circuit

We added a Marx pre-fire detection circuit in parallel with the HERMES III Operator trigger so the top-level DG-535 #1 will trigger from either a HERMES III Operator Trigger signal or a Marx pre-fire event. This allows the digitizers to trigger and capture waveform data if any of the 10 Marx banks prefires occur. This assists the HERMES III operators troubleshoot machine problems.

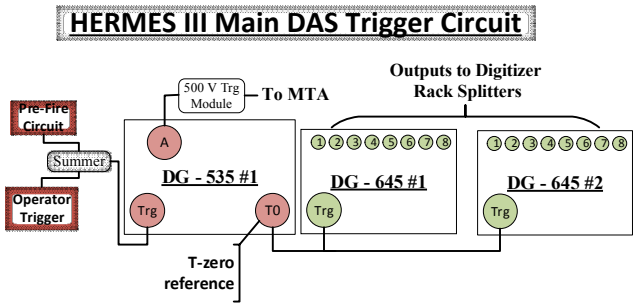

Figure 1. HERMES Main DAS Trigger Circuit

III. Measured Data Acquisition Time Synchronization

For each HERMES III accelerator shot, we record one signal from each rack mounted 10-way trigger splitter, providing for us a method to monitor all DAS digitizer trigger signal timings. For each accelerator shot, we measure the time when each DAS trigger signal amplitude equals 20% of its peak value (i.e.; 20% of 1.5 volts = 0.30 volts). From these 12 timing values, we subtract the minimum time from the maximum allowing us to calculate the maximum "time spread" of these trigger signals. For example, for HERMES III shots 10420 thru 10430, the time spreads are shown in Table 1. For these 11 shots, the average time spread measured 1.402 nanoseconds with a standard deviation of 95 picoseconds.

Table 1. HERMES III 12-Digitizer Trigger Time Spread

H III Shot #	12-Digitizer Trigger Time Spread (ns)
10420	1.393
10421	1.451
10422	1.445
10423	1.441
10424	1.386
10425	1.420
10426	1.522
10427	1.320
10428	1.446
10429	1.159
10430	1.440
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Mean (nsec)	1.402
Std dev. (nsec)	0.095

IV. MACHINE TIMING

There are four triggered systems within the HERMES III accelerator: Master Trigger Amplifier (MTA), Marx Trigger generator (MTG-West & MTG-East), Marx banks and the laser trigger systems. The Marx system, containing 10 Marx banks, is the most energetic requiring approximately 130 seconds to reach its standard operating voltage of 78 kilovolts. The HERMES III operators typically engage the MTG, MTA, and laser charging supplies while the Marx charge voltages have reached 43 kV, 60 kV, and 70 kV, respectively. These start times allows these said systems to reach their respective full charge within ~5 seconds prior to the Marx banks reaching their full charge. When the Marx banks are fully charged, the operator calls out "STOP charge" and "disconnect charge relays" while simultaneously engaging appropriate relays. This is followed by the audible "3-2-1" countdown whereby the operator initiates the accelerator trigger signal.

This operator trigger signal is sent via copper coaxial cable to the main DAS screen room and triggers the Main DAS trigger circuit. This triggers for the DAS digitizers and also outputs a 500 volts trigger for the HERMES III Master Trigger Amplifier (MTA) system. The MTA then triggers both the West and East Marx trigger generators and the laser trigger system. The West and East MTG's then trigger Marx banks 1 thru 5 & Marx banks 6-10, respectively. The Marx banks discharge into Intermediate Storage capacitors containing laser triggered gas output switches. The HERMES III accelerator contains 2 MTG systems each triggering 5 Marx banks. Each Marx bank charges 2 Intermediate storage (IS) capacitors and each IS discharges into 4 coaxial pulse forming lines (PFL) terminating at cavities with 4 inputs. Thus, we have 1 MTA, 2 MTG's, 10 Marx banks, 20 IS's, 20 gas switches, 80 PFL's and 20 cavities. A simplified layout of this trigger system is shown in figure 2.

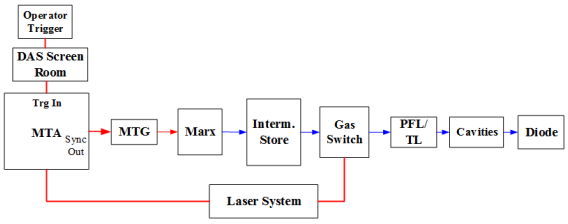

Figure 2. HERMES III Trigger Chain.

For HERMES test # 10322 the accelerator power flow time of arrival within various machine sections is shown in Table 2.

Table 2. HERMES III 10322 Timing

Event	Time Delay (ns)	Comments
T-Zero	0.00	By definition
Main digitizer triggers	151	12 rack avg.
User screen room triggers	771	Trigger bus out
MTA	950	Marx trigger amp.
MTG-West	1547	Marx trigger (west)
MTG-East	1530	Marx trigger (east)
Marx output	1894	10 bank avg.
Laser start	2710	Laser trigger
Intermediate Store	2835	20 line avg.
PFL Oil	2868	80 line avg.
PFL Water	3014	80 line avg.
TL	3042	80 line avg.
Cavity 1-4	3077	4 cavity avg.
Cavity 5-8	3088	4 cavity avg.
Cavity 9-12	3092	4 cavity avg.
Cavity 13-16	3107	4 cavity avg.
Cavity 16-20	3117	4 cavity avg.
SCD-Ref	3182	X-ray output

V. SUMMARY

This latest upgrade is a significant improvement for the HERMES III trigger system that:

- Adds capability for the customer to trigger the HERMES III accelerator.
- Ensures less than 2 ns time spread across all 65 DAS digitizers.
- Eliminates digitizer pre-trigger events.
- Decreases dependency on legacy trigger equipment in favor of modularity and maintainability.
- Synchronizes DAS data channel time bases.

VI. REFERENCES

[1] S. K. Coffey, et al., "Hardware and Software upgrades for the Saturn Data Acquisition Triggers and Time Base, " Proceedings of the 20th IEEE International Pulsed Power Conference, Vol. 1, pp. 775-784, (2015).

[2] S. K. Coffey, et al., "Customer Triggering Capability for the HERMES III Accelerator," 34th Annual HEART Technical Interchange, Late News Poster PB.14.