TRIGGER SYSTEM CHANGES FOR THE HERMES III ACCELERATOR*

Sean K Coffey, Barbara Lewis, John Sedillo and Diego Salazar
Sandia National Laboratories
PO Box 5800 MS-1106
Albuquerque, NM 87185-1106

2017 IEEE International Pulsed Power Conference
Brighton, UK
June 18-22, 2017

Introduction

Over the last 30 months, the HERMES III data acquisition system (DAS) and accelerator trigger systems have undergone two significant trigger system upgrades. During our first upgrade, due to budget constraints, we implemented interim software changes to synchronize our existing legacy DAS trigger generators [1]. During our second upgrade, all legacy trigger systems were replaced with commercial off-the-shelf (COTS) equipment and arranged in a modular fashion to facilitate DAS expansion.

Highlights

- The COTS trigger output rise times are approximately 5x faster than their replacements, reducing the total time variation in our 65 DAS digitizers' time bases from (roughly) 8 to 1.5 nanoseconds.
- The DAS scope trigger amplitudes have been increased to 4.0 volts. Previously, the amplitudes were as low as 0.10 volts, resulting in sporadic DAS scope pre-trigger events and, by consequence, shot delays.
- A separate, second trigger system has been added for customer access. This additional trigger system allows a customer to trigger the HERMES III accelerator (with limitations) and is further discussed in reference 2.

Hardware and Equipment Modifications

- *Main Trigger:* We eliminated three independent trigger systems for triggering the data acquisition system (DAS) with a single "top" level generator for triggering all sub-systems (Fig 1: "DG 535 #1", Stanford Research Systems (SRS) model DG535). Prior to this change, the independent trigger systems were derived from machine diagnostics making it difficult to time sync the entire DAS system.

- *Sub-triggers:* We replaced the numerous legacy trigger generators with two SRS DG-645 delay generators (Fig 1: "DG 645 # 1" and "DG 645 #2"), each equipped with eight individual 40 volt (50 ohm) outputs. The DG-645's outputs are cabled to a rack mounted trigger splitter. Our DAS system contains 12 racks of scopes providing this trigger system with four spare DG 645 outputs.

- *Trigger splitters:* Each scope rack contains a Mini-Circuits model ZFSC-10-1+ ten-way signal splitter providing 4 volt scope trigger signals to 10 scopes (max). The 10 scope trigger cables are equal in length, ensuring that, for each rack, the scope trigger signals arrive simultaneously.

- *Define "local T-zero" reference, measure, and archive:* We defined DG 535 #1's front panel T-zero output signal as our "local T-zero" timing reference (Fig. 1 yellow highlight). We measure the time delay between this signal edge and each scope trigger input signal and archive this appropriately into the DAS database. The DAS program later time shifts the scope time bases when processing the HERMES III accelerator shot data.

- *Pre-fire circuit:* We added a MARX pre-fire detection circuit in parallel with the HERMES III command trigger so top level DG 535 #1 will trigger from either a HERMES III Operator ready to fire signal or a MARX pre-fire event.

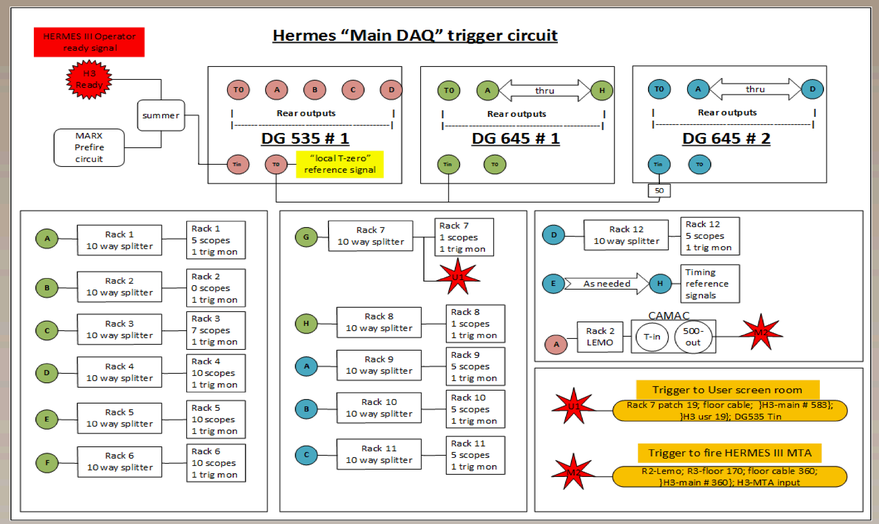

Figure 1: HERMES Main DAQ trigger circuit

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 review the timings of all scope triggers. For each accelerator shot, we measure the time when each signal amplitude equals 20% of its peak output (i.e.; 0.8 volts for 4.0 V_{peak}). From these 12 timing values we subtract the minimum value from the maximum to give a "time spread" value. The time spreads for HERMES III shots 10420 through 10430 are shown in Table 1. For these 11 shots, the average time spread was 1.402 nanoseconds with a standard deviation of 95 picoseconds.

H3 Shot #	12 scope trigger time spread (nsec)
10420	1.393
10421	1.451
10422	1.445
10423	1.441
10424	1.386
10425	1.42
10426	1.522
10427	1.32
10428	1.446
10429	1.159
10430	1.44
-------	----------
Mean	1.402
Std-dev	0.095

Table 1: HERMES Shot # vs 12 scope trigger time spread

Note:
- For a Tektronix model TDS 3054 oscilloscope, the external trigger input adds 3.8 ns delay to trigger path.
- The SMA signal input coupling adapters on a Tektronix model TLS 216 scope add 2.3 ns to the signal path.

Machine Timings

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

Table 2: HERMES III 10322 machine timings

H3 # 10322 Event	Time delay (nanoseconds)	Miscellaneous Info
T-Zero	0.00	
H3 main scope triggers	151	12 rack avg.
H3 user screen room trigger	771	Trigger bus out
MTA trigger	950	Master Trig Amp
MTG-West	1547	Marx Trig (west)
MTG-East	1530	Marx Trig (east)
Marx output	1894	10 bank avg.
Laser start	2710	Laser trigger
Inter Store out	2835	20 IS out avg.
PFL Oil	2868	80 line avg.
PFL Water	3014	80 line avg.
TL	3042	80 line avg.
Cav 01 – 04 out	3077	4 cavity avg.
Cav 05 – 08 out	3088	4 cavity avg.
Cav 09 – 12 out	3092	4 cavity avg.
Cav 13 – 16 out	3107	4 cavity avg.
Cav 16 - 20 out	3117	4 cavity avg.
SCD-REF	3182	X-ray out

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 oscilloscope pre-trigger events.
- Decreases dependency on legacy trigger equipment in favor of modularity and maintainability.
- Synchronizes DAS data channel time bases.

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, 2015, pp. 775-784.

[2] S. K. Coffey, *et. al.*, "Customer Triggering Capability For The HERMES III Accelerator" 34Th Annual HEART Technical Interchange, Late News Poster PB.14.