Operation of the SPEAR III Kicker System

Chris Pappas
## SPEAR III Kicker System
### Requirements & Specs.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>K1</th>
<th>K2</th>
<th>K3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Energy</td>
<td>3.3 GeV</td>
<td>3.3 GeV</td>
<td>3.3 GeV</td>
</tr>
<tr>
<td>Bend Angle</td>
<td>2.2 mrad</td>
<td>1.2 mrad</td>
<td>2.2 mrad</td>
</tr>
<tr>
<td>Magnet Length</td>
<td>1.2 m</td>
<td>0.6 m</td>
<td>1.2 m</td>
</tr>
<tr>
<td>Magnet Aperture</td>
<td>60X34 mm</td>
<td>60X34 mm</td>
<td>60X34 mm</td>
</tr>
<tr>
<td>Magnitude $\mathbf{B}$</td>
<td>20 mT</td>
<td>22 mT</td>
<td>20 mT</td>
</tr>
<tr>
<td>Magnetic Gain</td>
<td>8.7 $\mu$T/A</td>
<td>8.7 $\mu$T/A</td>
<td>8.7 $\mu$T/A</td>
</tr>
<tr>
<td>Current</td>
<td>2381 A</td>
<td>2619 A</td>
<td>2381 A</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>20 kV</td>
<td>10 kV</td>
<td>20 kV</td>
</tr>
<tr>
<td>Rise/Fall Time</td>
<td>&lt;375 ns</td>
<td>&lt;375 ns</td>
<td>&lt;375 ns</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>&lt;750 ns</td>
<td>&lt;750 ns</td>
<td>&lt;750 ns</td>
</tr>
<tr>
<td>PRF</td>
<td>10 Hz</td>
<td>10 Hz</td>
<td>10 Hz</td>
</tr>
</tbody>
</table>
Schematic of K2 Modulator
Magnet Cross Section

- HV Feeds
- Bus
- Image Current Return
Output Current & IGBT Voltage

C1-1

Collector Voltage

Cable Current

Volts

Amps

Seconds
B118 Racks 16-18 Layout

- SRS Trigger Generators
- AC Breakers
- Allen Bradley PLC
- Current Monitor Patch Panel
- Emergency Off
- K1 Modulator
- K2 Modulator
- K3 Modulator
- HVDC Power Supplies
K2 & K3 Modulators
IGBT Driver

- Resistor
- Capacitor
- Core
- IGBT & Gate Driver
Gate Drive Pulse
Timing Delays

SPEAR 3 KICKEr SYSTEM TIMING Fig 2

- System Delay K1 or K2 = Btime +85nS + Channel Delay +500 pS + 3200 pS + 581nS + Time of Flight
- System Delay K3 = Btime +85nS + 2000pS +85nS + Channel Delay +500 pS + 3200 pS + 581nS + Time of Flight
- Time of Flight = 265ft * 1.5nS= 397.5nS

Beam time trigger from control room

Kicker Magnet

CT signal

85nS SRS DG 535

T 0 A B A B C D C D

32nS to KX

397nS

58nS

32nS to KX

2nS

.5nS

85nS
Timing Error Diagram

Trigger from SRS

82 ms blanking pulse

Generate timing error if SRS pulse occurs in blanking pulse

Trigger from SRS

5 MHz asynchronous clock

Generate timing fault if more than 3 5 MHz clock cycles occur within SRS pulse width
# Programming the Output Voltage

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Magnet Current</td>
<td>Amps</td>
</tr>
<tr>
<td>N</td>
<td>Number of Cells</td>
<td></td>
</tr>
<tr>
<td>$V_o$</td>
<td>HVPS Output Voltage</td>
<td>Volts</td>
</tr>
<tr>
<td>Z</td>
<td>Modulator Impedance</td>
<td>Ohms</td>
</tr>
<tr>
<td>$M_g$</td>
<td>Magnet Gain</td>
<td>Tesla/Amp</td>
</tr>
<tr>
<td>$M_l$</td>
<td>Magnet Length</td>
<td>meters</td>
</tr>
<tr>
<td>$V_g$</td>
<td>Voltage Gain</td>
<td>Tesla-meter/Volt</td>
</tr>
<tr>
<td>$G_{dw}$</td>
<td>Digital Word Gain</td>
<td>Tesla-meter/bit</td>
</tr>
</tbody>
</table>
Programming the Output Voltage

• Modulator output current

• Beam Kick

• Voltage gain of modulator
• The 3000 V supply is controlled by a 0-10 VDC reference which is programmed by a 16 bit word.
• Digital word gain (Tesla-meter/bit)

\[ I = 2N \frac{V_0}{Z} \]

\[ K = M_g M_l I \]

\[ V_g = 2N \frac{M_g M_l}{Z} \]

\[ G_{dw} = 0.18N \frac{M_g M_l}{Z} \]
# Table of Gains

<table>
<thead>
<tr>
<th>Kicker</th>
<th>Voltage Gain</th>
<th>Digital Word Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1</td>
<td>$1.55 \times 10^{-5}$</td>
<td>$1.4 \times 10^{-6}$</td>
</tr>
<tr>
<td>K2</td>
<td>$7.73 \times 10^{-6}$</td>
<td>$0.71 \times 10^{-6}$</td>
</tr>
<tr>
<td>K3</td>
<td>$1.55 \times 10^{-5}$</td>
<td>$1.4 \times 10^{-6}$</td>
</tr>
</tbody>
</table>
PLC Chassis

- Input/Output Modules
- Power Supply
- AC Breaker
- Interlock Indicators
- Local Interface
- CPU Module
Local Control Interface
Operation on Local Mode

**TURN ON**
- Select the kicker you want to run.
- Press the Reset button.
- Press 200 V Enable.
- Press HV Enable.
- Press HV ON button.
- Turn Pot to desired voltage.

**TURN OFF**
- Press HV OFF button.

**Note.** When controller is powered up all LEDs light for 2 seconds for a lamp test.
Troubleshooting in Local Mode

- Check Breakers in Rack 18 and in the PLC chassis.
- Make sure the PLC is in RUN mode.
- Check to see that all INTERLOCK indicators are illuminated.
- Make sure the EMERGENCY OFF button is not depressed.
- Make sure that the pulse width is less than 1 μs, and the PRF is less than 10 Hz.
- Check the LED indicators on the trigger distribution board and the PLC interface board.
Fault Indicator LEDs

PLC Interface Board

- P.S. Under Voltage
- Cell Fault
- Trigger Error
- Reset
- Trigger Enable

- Main Trigger Present
- HV Ready
- Core Reset Permit
- O.C. / IGBT Failed
- Gate Trigger
PLC Interface Indicators

- **P.S. Under Voltage.** Indicates the 15 VDC power supply on the trigger distribution board is not working.
- **Cell Fault.** Could indicate a shorted IGBT, failure of a gate drive, or trigger distribution board.
- **Trigger Fault.** Indicates a PRF of greater than 10 Hz, or pulse width of greater than 1.1 µs.
- **Reset.** Indicates that the system is being reset from a previous fault.
- **Trigger Enable.** Indicates the SRS is properly programmed, and the high voltage is enabled.
Indicators on Trigger Distribution Daughterboards.

- **Main Trigger Present.** Indicates that triggers are present on the distribution board.
- **HV Ready.** Indicates the 200 VDC supply is on.
- **Core Reset Permit.** Not used.
- **O.C./IGBT Failed.** Indicates a shorted IGBT or blown switch on the distribution board.
- **Gate Trigger.** Indicates gate pulses are preset at the IGBT.
Operating in REMOTE mode with RSLogix5000

- Resetting the Kicker (Main Routine Rung 1).
Enable 200 VDC with RSLogix5000

• Remote Subroutine Rung 10
HV Enable with RSLogix5000

• Remote subroutine, Rung 11.
Remote HV ON with RSLogix5000

- Remote subroutine, Rung 12.
Voltage Programming with RSLogix5000

- Remote Routine Rungs 13, 14 & 15.
Remote TURN OFF with RSLogix500

- Remote routine, Rung 19.
Safety

• Turn off all Breakers before servicing using kicker ELP.
• Back doors are interlocked.
• Front panels are NOT interlocked.
• Grounding sticks are located inside the back doors on each modulator.
HV Grounding

Grounding Post