Technical Specification
PROTOTYPE CHOPPER PULSERS

Los Alamos National Laboratory

1. GENERAL DESCRIPTION

1.1. Introduction

1.1.1 This specification document covers the design and fabrication of two pulsers to be used to drive a meander-line deflector in a particle-accelerator beamline. The two pulsers are identical except for the polarity of their outputs.

1.2. System Requirements

1.2.1 The pulsers shall function in the system depicted in Figure 1. Each pulser puts out an identical pulse trains driving a 50±2 Ω, matched-impedance system. The output amplitudes are adjustable from <500 v to at least 3000 v. Nominal outputs are 2500 v. Each pulser delivers a maximum of 3600 watts average power.

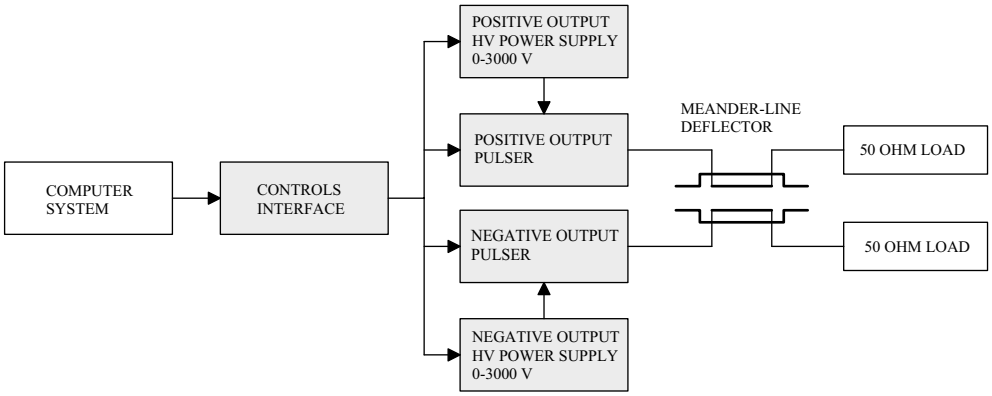

Figure 1. Simplified block diagram of the chopper system. Systems described herein are shown in gray.

1.2.2 The high voltage power supplies may be integral to the pulsers or separate units. A timing system (not shown) drives each pulser with the required output pattern.

1.2.3 A computer system shall interface to the controls interface via TTL-level binary controls and analog inputs.

1.2.4 All circuits shall be solid state.

2. ELECTRICAL PERFORMANCE

2.1. Output Voltage

2.1.1 Each pulser shall deliver a maximum of 3000 volts and be continuously adjustable between 500 and 3000 volts. Lower output voltages are acceptable. One unit shall deliver positive output voltages and the other shall deliver negative output voltages.

2.1.2 The load impedance to be driven is 50±2 Ω.

2.2. Output Pulse Timing Modes

2.2.1 A diagram of the required output pulse train is shown below in Figure 2.

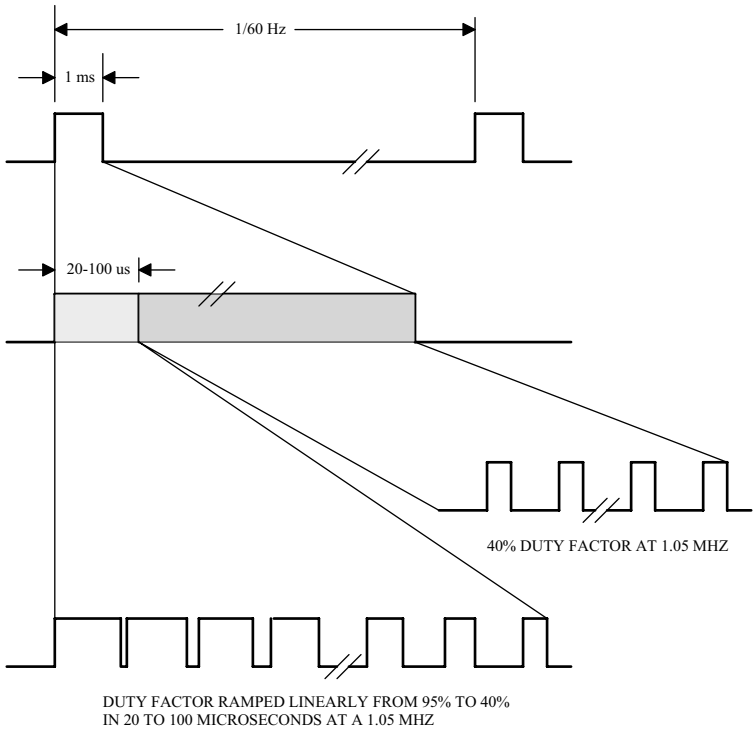

Figure 2. Output pulse structure required from the pulsers. This graphic is for illustrative purposes only and not to scale.

2.2.2 Each pulser puts out a train or burst of pulses, referred to as the macropulse, for a period of approximately 1 millisecond. The macropulse is chopped at a 1.05 MHz rate. The average duty factor during the macropulse is approximately 33%. Each individual pulse at the 1.05-MHz rate is referred to as a millipulse. The millipulses vary in width from as long as 953 ns to as short as 300 ns. The macropulse is repeated at a 60-Hz rate.

2.2.3 The duty factor during the first 20-100 μs of the macropulse varies linearly from 95% down to 33%.

2.2.4 The macropulse described above shall be able to be produced at any rate from single-shot to 60 Hz (i.e. single shot, 0.1 Hz, 1 Hz, 10, Hz. Etc.).

2.2.5 Additional modes include generating a single pulse with a duration of from 100 ns to 953 ns at a rate from single-shot to 60 Hz, and the generation of macropulses of any duration from 20 μs to 1.1 ms as described above.

2.3. Output Pulse Characteristics

2.3.1 The maximum droop in output voltage over any macropulse described above shall be 2% for load impedances of 50±2 Ω.

2.3.2 The maximum pulse rise time and fall time of either polarity of output pulses as measured from 10% to 90% (or 90% to 10%) for load impedances of 50±2 Ω, shall be as required to meet the following requirement 2.3.3.

2.3.3 The maximum pulse rise time and fall time of either polarity of output pulses shall be less than 10 ns as measured from 1% to 90% (or 90% to 1%) for load impedances of 50±2 Ω.

2.3.4 The maximum ringing about the zero output level shall not exceed ±1% of the peak output voltage for load impedances of 50±2 Ω.

2.3.5 For output voltages between 2000 and 3000 the maximum overshoot shall be <10% of the requested output pulse voltage and be of a duration less than 5 ns for load impedances of 50±2 Ω. At output levels between 500 volts and 2000 volts the overshoot shall be <25% of the requested output pulse voltage.

2.3.6 The maximum level of ringing on the pulse top shall be < ±5% for the first 20 ns and < ±2% thereafter.

2.4. Fault Protection

2.4.1 The pulsers and power supplies shall be protected against shorting at the pulser outputs. The pulser and power supply circuits shall survive when operated continuously under these shorted-load conditions without damage. When a fault occurs, the systems may automatically shut off for a period of time not to exceed 1000 ms. Recovery from a fault shall be automatic. It is understood that shorting of a load at a distance greater than a few feet from the pulser output shall probable destroy the output stages.

2.4.2 The pulsers shall be internally protected from an unexpected shorting of the output FET switches such that no damages occur to other circuits except for fuses.

2.4.3 The design of the high-power portions of the pulsers and power supplies shall be such that the stored energy is <3000 joules. This stored energy will be isolated from the output through a series switch, and will be discharged at power-down or during a fault condition through dump resistors. The capacitor bank may be housed in a separate rack-mounted enclosure.

2.4.4 The pulse generators will be protected against over-current, over-voltage and repetition frequencies in excess of 1.05 MHz. The macroplulse width and repetition frequency will be limited by the pulser's internal control circuitry.

2.5. AC Power

2.5.1 Available power source for high-voltage, high-power supplies: 3 phase, 208 VAC, 30 A.

2.5.2 The input power shall be configured 5-wire WYE with a neutral and earth ground.

2.5.3 Available power source for pulsers (if built w/o internal high voltage supplies): 120 VAC, 20 A.

2.6. Listed Equipment

2.6.1 The pulsers shall be designed and manufactured to personnel safety and protocols appropriate to high voltage, high power electronic systems.

3. CONTROLS and INTERFACE

3.1. Front Panel

At least the following user controls, monitor, and interface connections shall be available on the front panel(s). Labels are suggested, but may be determined by the manufacturer.

3.1.1 "Local / Remote" key switch, used to select "Local" (front panel control operation) or "Remote" (operation via the rear panel connections) and remote control system. This switch selects between front panel and rear panel output level control. The key shall be removable in either position.

3.1.2 "Output Voltage Adjust" Potentiometer or keypad, used to adjust the high voltage output level when operating in local mode (has no effect in remote operation mode).

3.1.3 "Output Voltage" numeric indicator with at least 1-volt resolution, indicates output voltage of the high voltage power supply (absolute accuracy shall be < ±2 %).

3.1.4 "Control Power" On/Off key switch (with lighted indicator), used to energize all control and monitoring functions within the pulser without energizing the high-voltage power supply. The key shall be removable in either position.

3.1.5 "HV AC Power" On/Off switch, key desirable, with lighted indicator, turns on the primary AC power to the high voltage power supply. This switch would be located on the power supply if separate from the pulser chassis. Note that this is independent of the "Local/Remote" control.

3.1.6 "HV Output Enable" momentary push button (with lighted indicator) or equivalent. Active only in "Local" mode. When asserted, the high-power components are energized and the pulser is ready to fire when it receives a trigger pulse. This control is located on the pulser chassis. If a separate HV power supply is used, this control shall control the power supply via a connection on the back panels of the two chassis. This control is inactive when any detected fault is present.

3.1.7 "HV OFF" push button (with lighted indicator) or University approved equivalent. Active only in "Local" mode. When asserted turns off the high voltage power supply output. This control is located on the pulser chassis. If a separate HV power supply is used, this control shall control the power supply via a connection via the back panels of the two chassis.

3.1.8 Latching status indicators for internal modulator functions and internal faults such as water flow, over temperature, timing pattern error, etc. When the fault is cleared, such as water flow resuming, the pulse system resumes normal operation, but the appropriate fault indicator remains latched on. Any fault turns off the high voltage power supply output. One status indicator shall be for an external interlock.

3.1.9 "Fault Reset" momentary push button to reset the latched status indicators.

3.1.10 "Run Permit Status" indicator. On when pulser and HVPS are on, HV output enabled, no faults existing and HV power supply output is within ±5% of the control set point. When run permit output on rear panel is high, "Run Permit Status" indicator is on and high voltage pulses shall be generated if triggered. Any condition detected, which will lead to lack of output pulses, abnormal output pulses or imminent failure shall drop run permit to a low state.

3.1.11 "Trigger Monitor," type "SMA" connector for monitoring the "Trigger Input" mounted on the rear panel. This 50Ω TTL-level output shall be buffered from the rear input such that the pulser operation is completely independent of the termination impedance of the monitor.

3.1.12 No incandescent lamps are to be used as indicators.

3.2. Rear Panel

At least the following connections, interlocks, and signals shall be incorporated. All binary I/O and analog I/O signals to be within the same multi-pin connector. Connector type to be agreed upon between vendor and LANL. Labels are suggested, but may be determined by the manufacturer.

3.2.1 "HV Pulse Output" type "N" connector. (changed to 7-16 DIN)

3.2.2 Water connections, if required. To be determined with vendor.

3.2.3 AC power connection(s). To be determined with vendor. An EMI filter shall be incorporated in the AC input circuit.

3.2.4 "Trigger Input," type "SMA" connector, input impedance 50 Ω, <0.4v = low, >2v = high.

3.2.5 "External Interlock" type Lemo K-lock connector, external short, or TTL low required for HV output and run permit to be enabled.

3.2.6 "High Voltage Control" analog input signals, differential amplifier input, input impedance ≥ 10 kΩ, common-mode rejection from DC to 100 Hz ≥ 60 dB, 100 to 1 kHz ≥ 45 dB, 1 kHz to 100 kHz ≥ 30 dB, differential bandwidth < 30 Hz. Input voltage range, 0-10 VDC corresponding to 0 to 3000 volts on the high voltage power supply.

3.2.7 "Local/Remote" readback, binary TTL output, TTL high for remote operation, TTL low for local operation.

3.2.8 "High Voltage Enable" binary TTL level input, TTL high enables high voltage, TTL low disables high voltage. Active only in remote operation mode.

3.2.9 "High Voltage Readback," analog output, 500 Ω or less output impedance, 0 to 10 volts corresponding to 0 to 3000 volts from high voltage power supply. Absolute accuracy shall be < 2% or better when driving 100 kΩ or greater.

3.2.10 "Output Current Readback," analog output, 500Ω or less output impedance, 0 to 10 volts corresponding to 0 to maximum current available from high voltage power supply. Absolute accuracy shall be < 2% or better when driving 100 kΩ or greater.

3.2.11 "Interlock Status" binary TTL level outputs. Multiple outputs, one for each monitored interlock function (water flow, over temperature, external, Etc.) High level for status ok, low level for fault condition.

3.2.12 "Fault Reset" binary TTL level input, high resets latched fault indicator lights on front panel.

3.2.13 "Run Permit" output, Lemo K-lock connector. TTL level, 100-Ω output impedance, high level for system nominal, low level for output disabled condition.

3.2.14 "Aux. 1," type "BNC" feedthrough connector, spare, no internal connection.

3.2.15 "Aux. 2," type "BNC" feedthrough connector, spare, no internal connection.

4. MECHANICAL

4.1. Configuration and Size

4.1.1 The positive and negative output pulsers, shall be independent subsystems, both physically and in operation.

4.1.2 The high voltage power supplies may be separate self-contained units, or may be incorporated in the pulser chassis.

4.1.3 All chassis shall be designed for rack mounting in a standard 19" rack. All chassis shall include high-quality slide mounts.

4.1.4 Each complete pulser, including power supply and energy storage, shall be contained within a maximum of 38.5" height.

4.2. Weight

The weight of each pulser with its power supplies shall not exceed 200 lbs.

4.3. Altitude

The pulsers shall operate within specifications at an altitude of from sea level to 7300 ft.

4.4. Temperature Range

The modulator shall operate within specifications at a temperature range of 60 to 95 °F ambient air temperature.

4.5. Humidity

The modulator shall operate within specifications over a relative humidity range of 15 to 80 percent.

4.6. Cooling

4.6.1 Water cooling (de-ionized water) is available at up to 4 GPM per pulser, 120 psig supply, and about 20 psig return. The cooling-water temperature range is 60 to 90° F, and the resistivity ranges from 1 to 4 MΩ-cm. Interlocks shall be included to detect inadequate flow rates or excessive water temperature.

5. MISCELLANEOUS

5.1. Reliability/MTBF

5.1.1 These pulsers are to be used in a facility operating 24 hours per day. The design of these systems shall be such as to reasonably expect that the mean time to failure (MTBF) be in excess of 25,000 hours for the pulsers and power supplies, assuming no external load faults. No compromises in design shall be made which would lead to questionable lifetime or reliability.

5.1.2 It is likely that some load faults will damage the pulser output circuits. The pulsers shall be designed such that the mean time to repair (MTTR) them from such failures is no more that four hours. LANL may require such spare circuits and assemblies for the future upon delivery of the pulser.

STATEMENT OF WORK
PROTOTYPE CHOPPER PULSER

LOS ALAMOS NATIONAL LABORATORY

1. GENERAL

1.1 The vendor shall provide specification-compliant turn-key pulsers and power supplies for use at the Los Alamos National Laboratory.

1.2 The vendor shall provide the necessary labor, equipment, and tools necessary for the design, fabrication, testing and shipping of the modulators. Vendor shall use suitable loads for testing and development, such as Bird Electronics model 8329-300 with BA-300-115 high-power 50-Ω loads. These loads will be provided by LANL on request.

2. SCHEDULE

2.1 No later than 3 weeks ARO, a preliminary schedule showing milestones and expected due dates is due to University Procurement Specialist.

2.2 No later than two weeks prior to acceptance testing, the vendor shall provide University Procurement Specialist with a detailed acceptance testing procedure, which details how the tests will demonstrate specification compliance.

2.3 Vendor to quote best delivery. Acceptance testing shall begin at the vendor's facility. It is expected that the preliminary acceptance testing shall last up to 3 days—calendar time.

2.4 Within two weeks after acceptance, the modulators shall be ready to ship from the vendor's facility to LANL.

3. DELIVERABLES

3.1. Hardware

3.1.1 Two (2) complete, assembled, tested, and specification-compliant pulsers.

3.1.2 Two (2) complete high voltage power supplies (in not integral to pulsers).

3.2. Documentation and Reports

3.2.1 Schedule of progress and any preliminary schedules as needed.

3.2.2 Front panel layout for approval.

3.2.3 Rear panel layout and connection list and diagram for approval and interface verification.

3.2.4 Owner's manual including maintenance and calibration procedures, parts lists, and complete as-built electrical schematics.

3.2.5 Acceptance test data and specification verification documentation.

4. TESTING

The vendor shall allow University personnel, or its designees, access inside the vendor's facility (with ten business days notice) to inspect, coordinate or monitor work or testing related to this purchase order.

4.1. Acceptance Testing

4.1.1 Acceptance testing shall be performed at the vendor's facility according to the above referenced schedule. LANL expects to have personnel present at these tests.

4.1.2 The vendor shall provide instrumentation and control signals sufficient to verify that the modulator meets the technical specifications. LANL shall retain the option to provide the pulse-pattern generator and/or oscilloscope to be used during test. Bird Electronics model 8329-300 with BA-300-115 high-power 50-Ω loads shall be used during acceptance testing (provided by LANL). The vendor shall certify that the instrumentation exceeds the measurement requirements. The following tests are to be performed:

- ❑ operation at specified output voltage levels
- ❑ operation at specified risetimes and falltimes
- ❑ operation at specified macropulse pattern rate
- ❑ testing of interlocks and controls
- ❑ fault generation and recovery tests
- ❑ burn-in period of a minimum of 24 hours at rated maximum output voltage and repetition rate with the system meeting all the technical specifications at the end of the period with no adjustments.