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A SPARK-PROTECTED ION-SOURCE CONTROL AND MONITORING SYSTEM AT 1.5 MV*

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Summary

The Heavy Ion Fusion Program at Argonne National Laboratory utilizes a 1.5-MV Xe ion preaccelerator. Reliable beam transport requires accurate measurements and precise control of various ion-source parameters. This paper discusses the use of a multiplexed fiberoptic data-transmission system and low-cost digital stepper motors for control functions. Techniques are discussed which allow TTL and CMOS semiconductor circuits to survive the destructive sparks which can occur in the 1.5-MV preaccelerator.

Facility

The Penning type ion source[1] is operated in a pulsed mode. Xenon gas is pulsed into the source where a discharge electrode initiates and sustains the plasma current. Precise control and measurement of filament current, plasma current, gas pulse voltage, and discharge electrode voltage is essential for consistent beam properties. The control and monitoring system utilizes fiberoptic cables[2] for high voltage isolation. Low cost digital stepping motors[3] are used for ion source parameter control. Eventual x-ray darkening of the fiberoptics bundles necessitates that digital communication be used exclusively. High voltage terminal power is provided by a shaft isolated 3 Φ 800 Hz generator. The 1.5 MV preaccelerator[4] is inside a pressurized vessel of SF_6. Fiberoptic electronics access is improved by using a ground end optical feedthrough plate. This allows all ground potential electronics to be outside the pressure vessel for easy access.

Real Time Controls

Precise timing of Xe gas pulses and discharge electrode drive required two dedicated fiberoptic links. These links transmit on/off type commands. Optical receivers in the HV terminal control electronic switching of appropriate power supplies (see Fig. 1). Power supply output levels are controlled by digital stepping motors which are discussed later. Figure 1 shows Xe gas and discharge electrode pulse control systems. Both links are controllable in pulse width and are precisely timed by a crystal controlled timer not shown.

Ion Source Parameter Control

Source filament current, plasma ignition voltage, plasma sustaining voltage, and Xe gas pulse voltage must be set accurately. This is accomplished by setting the various power supply outputs which drive electronic switches shown in Fig. 1. Each supply is powered through a variable autotransformer (variac). Geared down digital stepper motors are used to rotate the variacs, thereby controlling power supply output. Gear box reduction was chosen for torque multiplication and step angle resolution of the output shaft. These particular motors have a basic step angle of 15°, the gearbox reduces this to 12 minutes of angle.

When applied to a high quality variac, this step resolution is much finer than the winding separation. Operational tests have proved this scheme more than adequate for ion source tuning. Variac winding pitch essentially limits incremental changes of power supply output to 0.7 percent of maximum. To fully utilize stepper motor precision, the power supplies could be controlled with electronic regulators. Then, ten-turn precision potentiometers could be utilized for regulator control. Stepper motors would be fitted with ten-to-one gearbox reduction and used to rotate the potentiometers. This configuration gives an incremental position accuracy of 0.042 percent over the potentiometers ten-turn range. These stepper motors offer high-holding torque which eliminates coasting effects. A single integrated circuit package[3] is available for driving the motors. Interfacing to the driver is easy, as TTL level pulses control both shaft speed and direction. Four sixteen-channel multiplexers are utilized to control stepper motors and send ion source parameter data to the operator. Figure 2 shows the basic multiplexing system employed. The synchronizing clock runs at 1250 Hz which allows each multiplexer port to be addressed every 12.8 ms. At this rate, the stepper motors rotate fast enough to run a variac to full output in 20.3 seconds. Ion source data, multiplexed and transmitted to the operator at the stated clockrate, gives instantaneous response to power supply changes for smooth digital readout response.

Multiplex System

Figure 2 shows the basic control and monitoring system. Sixteen channel multiplexers/demultiplexers are used in synchronous operation for stepper motor up-link commands and ion source parameter down-link data transmission. Synchronization is comprised of four BCD clock lines that are transmitted to the HV terminal using fiberoptics. The system diagram is simplified in that the ion source and associated power supplies are not shown. Instead, one stepper motor and power supply are presented. The basic technique of measuring steady state and pulsed parameters is given.

Pushing the "raise" button for stepper motor #1 causes a pulse train to be transmitted and appear at port #0 at the HV terminal demultiplexer. The first pulse to appear sets a flip-flop that determines direction of motor rotation. The motor continues to step at the multiplexing rate until the button is released. Pushing the "lower" button results in port #1 ouput clearing the flip-flop making the motor run in reverse. This system allows fine adjustment of power supplies as the motors can be single stepped with no coasting problems. All critical dc voltages and currents are scaled and applied to the 7506 analog multiplexer for frequency conversion and transmission back to the operator. Pulsed parameters are applied to follow-and-hold amplifiers which are updated during each beam pulse.

The follow-and-hold amplifiers are triggered to update from either the Xe gas pulse, or source discharge pulse optical receivers (see Fig. 1). Trigger pulses derived from these optical receivers are delayed an appropriate amount to insure the pulsed parameter is stabilized before holding the data. Follow-and-hold amplifier data is applied to the 7506 down-link multiplexer inputs. Multiplexer inputs are scanned and applied to a precision voltage-to-frequency converter. Step input settling time of a voltage-to-frequency converter is inversely proportional to the lowest

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frequency in the transition. In this system, only positive voltages are considered so the lowest converter frequency occurs at zero volts. The minimum frequency was chosen to be 10 kHz. Dynamic range is reduced because of the offset, but it is crucial that the frequency conversion be completed during the system clock pulse width of 0.80 ms. The multiplexed, frequency modulated pulse train drives an optical emitter for transmission through the "data down-link" fiber-optic cable. In the control room the signal is converted back to voltage levels and demultiplexed. The 4706 frequency-to-voltage converter is adjusted to cancel out the 10 kHz frequency offset discussed earlier. Demultiplexed source data is stored in follow and hold amplifiers which drive digital readout displays. These amplifiers are addressed in synchronism with the system clock.

Spark Protection

Up to 500 J of stored energy is dissipated when high voltage breakdown occurs. Peak currents flowing through the HV terminal during breakdown are a function of spark duration, but certainly run 5,000 to 10,000 A. Inside the HV terminal, where delicate electronics are housed, discharge current path inductance can develop thousands of volts. Clearly, a single ground point inside the HV enclosure must be established to avoid differential ground transients. All control and monitoring grounds need to be tied to this single attachment point. A 30 kV line isolation transformer was used to decouple the 800 Hz, 3 ϕ generator ground. Digital stepper motors had to be located at various positions within the enclosure. Short Delrin insulating shafts were used to couple the motors to the variacs. The motors were mounted on insulators to avoid multiple ground paths. This gives each motor a single ground reference inside the electronics crate. Semiconductor junctions must be protected from inrush voltages during HV breakdown. CMOS, TTL, and transistor circuits have solid state protectors[5] on all inputs and outputs that communicate with long signal leads. These protectors respond in less than 5 ns to large transients without damage. Voltage clamp levels are chosen on the basis of signal amplitudes and breakdown limit of the device to be protected

Acknowledgement

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References

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2) Augat, Inc., 33 Perry Ave., Attleboro, Mass. 02703, Family I Data Link Components.

3) North American Philips Controls Corp., Cheshire, Conn. 06410. No. K82639 - P2 Stepper Motor. Stepper motor IC driver series 5AA1027.

4) "A High Intensity 1.5 Megavolt Heavy Ion Preaccelerator for Ion Beam Fusion", J. M. Watson, et al., IEEE Transactions on Nuclear Science, Vol. NS-26, No.3, June 1979, p. 3098.

5) MCG Electronics, Inc., 160 Brook Ave., Deerpark, N.Y. 11729.

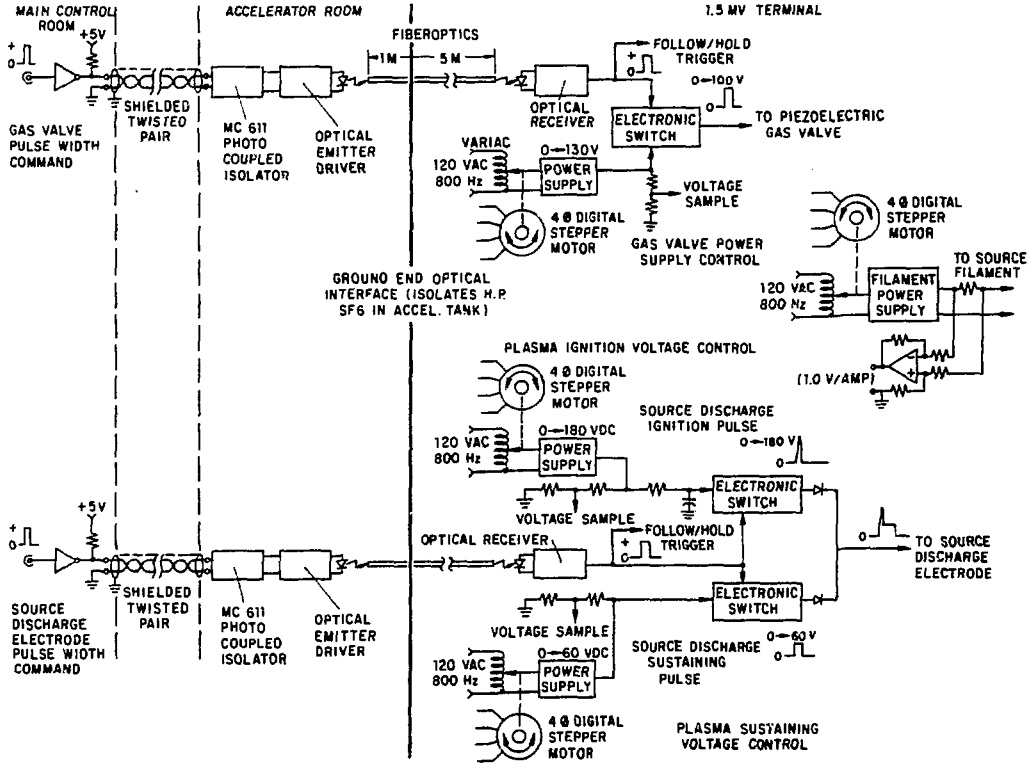

Fig. 1 Real Time Controls

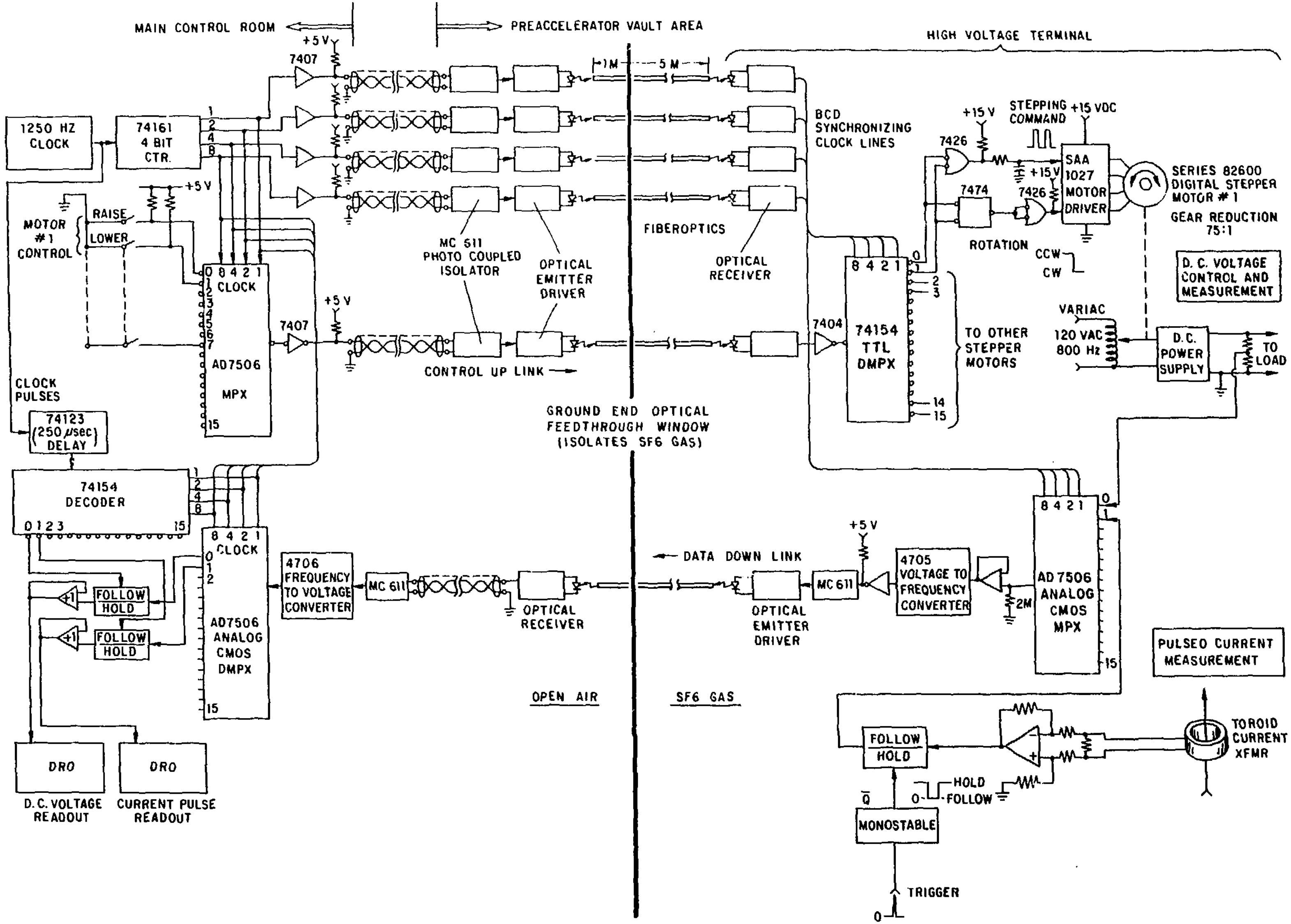

Fig. 2 Multiplexed Motor Control and Source Monitoring System

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