DATA TRANSMISSION ACROSS HIGH VOLTAGE INTERFACES VIA LIGHT LINKS*

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Summary

Computer control/monitoring of the LAMPF injector requires data to be transmitted to and from the ion source in the high voltage head. These data must be digitized for computer use as is done throughout the rest of the accelerator. The A/D converter, interfacing instrumentation equipment, and control logic are placed in the head. Signals are transmitted across the 750 kV interface to and from the high voltage head through 5 light links. Four are used to replace insulated rods and strings for data and control. One transmits the pulse signal to the ion source. The system should operate at computer speeds; therefore, rise and fall times for pulse transmission of data must be less than 200 ns. The pulse width is 800 ns with a 50% duty cycle. The ion source pulse requires the same rise time but the pulse width must extend to 1.5 ms. This paper describes the system and reports the test results on a system designed to meet these specifications. The modification of the system to provide linear transmission of fast waveforms is discussed.

Introduction

The light links described in this paper were designed to provide lines of communication between the central control computer and the information and control transducers at the ion source in the head of the injectors for the Los Alamos Linac. The control system has been described in some detail by Harold S. Butler in his paper entitled "Computer Control of the Los Alamos Linear Accelerator," presented at this conference.

Light Link Specification

Four lines running between the Computer Interface Unit (CIU) and each of the modules are used to communicate with the Remote Information and Control Equipment (RICE). A fifth line carries the command to pulse the RF power and ion source as demanded by the master pulser control unit (Fig. 1).

The transmission of the data to and from the RICE consists essentially of a burst of pulses on two lines. On the timing line, these pulses are 1.75 μs apart (pulse repetition rate is approximately 570 kilopulses/second with a 50% duty cycle). The control line carries the information to the RICE unit using an NRZ (nonreturn-to-zero) code. This means that any given pulse may be as short as 1.75 μs or nearly as long as the complete burst on the timing line (more than 20 μs). The information carried on the data line to the CIU is quite similar to that found on the control line. It is pulsed out of the RICE unit onto the line in serial form by the pulses carried on the timing line.

The fifth line carries the master pulser signals to the ion source pulser. The computer may vary the output of the master pulser from one pulse period or 1.75 μs to 1790 μs.

The transmission system must handle pulses as short as 800 ns or as long as 1.8 ms. In order to make the SNR high, the signals transmitted on these control lines have an initial amplitude of 10 V. Pulse delay characteristics of the system are important because of the length of the machine and the distances over which the pulses must be transmitted; however, the additional delay introduced by the light link will be relatively easy to compensate. The rise and fall times of the pulses being transmitted should not be restricted by the rise and fall time of the system used to transmit the signals to the head. A rise time of less than 200 ns was selected as the target value.

Since the use of a light link appeared to offer advantages from both cost and simplicity standpoints, several infrared sources and detectors were purchased and tests run on them. Most other light devices, while attractive from the gain standpoint, were too slow to handle pulses of less than one μs. The General Electric LED-11 infrared source and the EG&G SD-100 photodiode were selected as the pair to be used in the prototype. Curves for the LED-11 with the lens in place show a power output of about 0.8 mW at approximately 300 ma of drive.

The receiver specifications give a sensitivity of 0.25 μA/μW. If all the emitted radiation were received, we would expect a current of 200 μA from the receiver. Attempts to design a system which would handle a 40 dB light loss resulted in a receiver which was judged a bit too complex; therefore, a receiver threshold current of 10 μA was chosen.

Transmitter

A schematic diagram of the transmitter is shown in Fig. 2. The ratio of the input resistors, R_1 and R_2, is used to provide an adjustable control

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to compensate for variations in the amplitude of the input signal. This signal may range from approximately one volt to several tens of volts. R_5 and R_6 are selected to provide a gain of approximately four through Q_1. The output voltage of Q_1 is then applied to the base of Q_2. Q_2 and R_7 form a voltage-to-current transducer; therefore, the current through CR_1 is independent of the characteristics of CR_1. (CR_1 is the LED-11 galium arsenide infrared source.) R_1 and R_2 are selected to provide approximately 300 mA peak current flow through CR_1. R_8 is a one ohm resistor used to sense the photodiode for check out of the unit.

When the transmitter is used for pulse transmission, R_4 is not installed. With R_4 absent, the two transistors are in the off mode when no pulse is present. The presence of the pulse switches both transistors on. R_4 is chosen to provide a dc offset which moves the transmitter operating point into the linear range of operation. The output of the transmitter then becomes linear with respect to the amplitude of the input signal over a fairly wide range. (If the input signal is dc or very low frequency, the power dissipation of the output transistor and the photodiode go up. Sufficient cooling must then be provided to prevent destruction of these devices.)

Receiver

Figure 3 is a schematic diagram of the pulsed light receiver. CR_3 is an EG&G SD-100 infrared photodiode coupled directly to the base of the first stage of the amplifier Q_1. Q_1 and Q_2 are used as a linear amplifier with feedback provided through R_3 to stabilize the dc operating point of the pair. A combination of R_7, C_1, and C_2 increases the high frequency gain to broad-band the pair. L_1 provides some additional peaking.

The output of this pair of transistors is coupled through C_3 to the next pair. The first pair uses negative feedback for stabilization. The second pair uses positive feedback to operate in a switching mode. When the input signal exceeds the level determined in part by the value of R_{16}, Q_3 is turned on. The signal couples from Q_3 through R_{10} and C_6 to Q_4 turning this transistor on. The rising voltage across R_{12} is fed back to the base of Q_3 as positive feedback and causes the pair to switch on in approximately 20 ns. Since Q_4 is driven into saturation, the output impedence of the amplifier is very low. This low impedence allows the amplifier to drive a 75 ohm load to very nearly the supply voltage value.

Both the transmitter and the receiver use a printed circuit board with a ground plane as the common connection to the power supply. Filters have been provided in the positive side to reduce transmission of the fast current changes through the power system. Since the load impedence as seen by capacitor C_3 swings from relatively low value when Q_3 is turned on to a relatively high value when Q_3 is off, CR_1 has been added to provide a rapid discharge path for C_3 when the pulse is terminated.

Assembly and Test Results

Figure 4 is a photograph of the transmitter-receiver combination. The lens has been provided with a threaded mounting for proper focusing of the infrared beam. A cover is slipped over the outside of the mounting hardware to provide shielding both for radiation from the high current pulses and external coupling into the receiver. This system was set up with a separation of approximately 6 ft between the transmitter and receiver. Figure 5 shows the transmitter input pulse on the upper trace and the receiver output pulse on the lower trace. One pair of traces shows the response for a short pulse; the other pair, the response for a relatively long pulse. Both sets of output traces were taken at the end of 100 ft of RG-59U coax cable terminated in 75 ohms. The fast trace shows a small "glitch" near the center of the pulse top. This was found to be due to a slight mismatch in the cable termination.

One system has been assembled and put into operation to control the high voltage head on an electron acceleration experiment. This uses a manual control panel to replace the computer and operates at approximately a 35 kilopulse/s rate with pulse widths of the order of 17 µs. The system operates in essentially the same manner as described above; however, the command busy signal is not used. Separation between the transmitter and receiver is approximately 8 ft. The transmitters and receivers are mounted in a row with a spacing of approximately 3 inches between centers. No problem was experienced with cross talk between any of the transmitters or receivers. The alignment was considerably less of a problem than had been anticipated. No readjustments have been necessary.

A second receiver (Fig. 6), using linear integrated circuits, has been completed and breadboarded. Linearity and response tests have not been completed although preliminary tests show a bandwidth of the overall system in excess of 1 MHz.

Acknowledgments

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[1] On loan from EG&G, Inc., Las Vegas, Nevada.

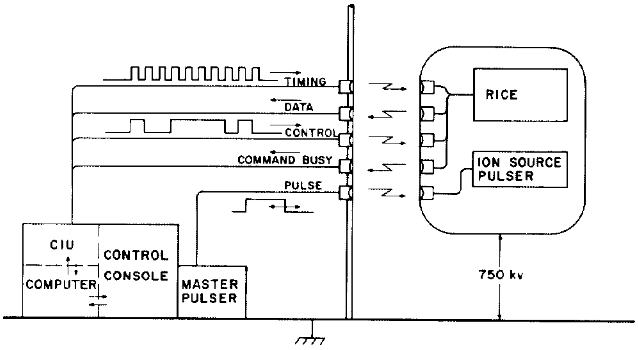

Fig. 1. Simplified diagram of computer—Ion source communication links.

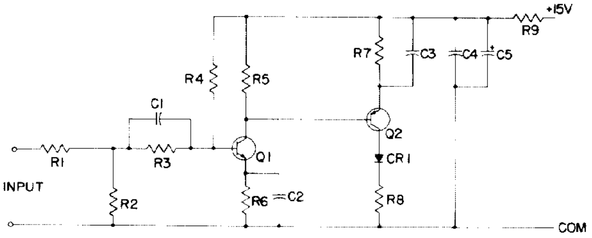

Fig. 2. Light source driver.

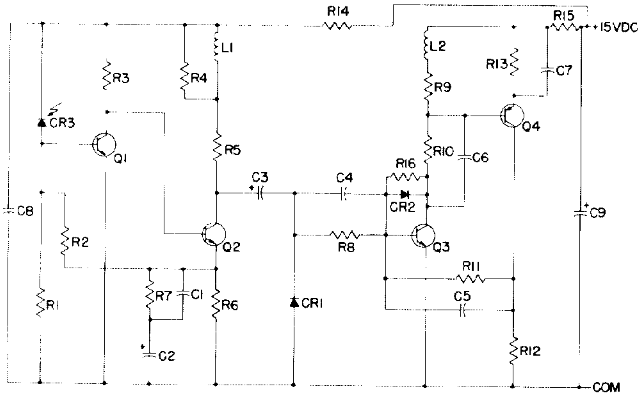

Fig. 3. Light receiver amplifier.

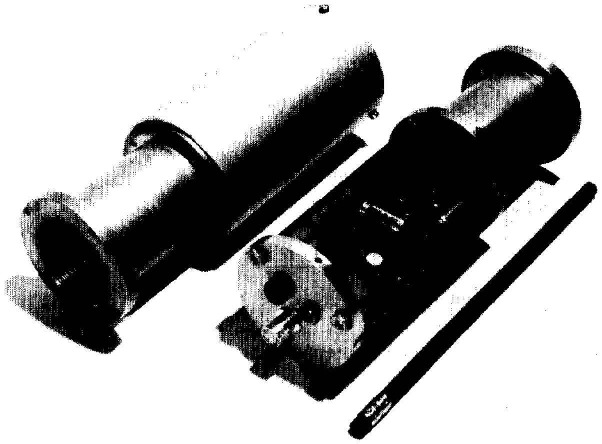

Fig. 4. Transmitter and receiver set.

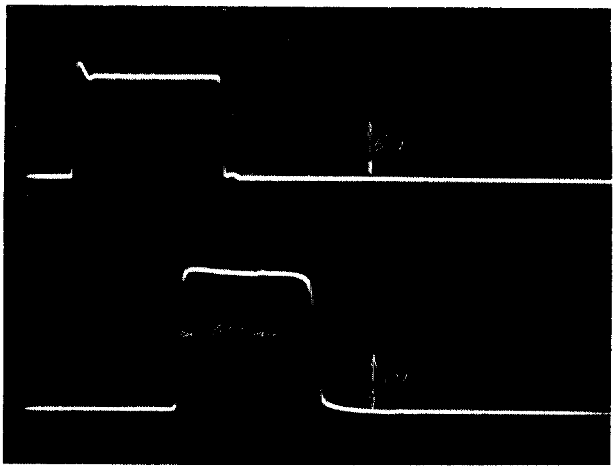

Fig. 5a. System response to short pulses.
Upper trace—input
Lower trace—output

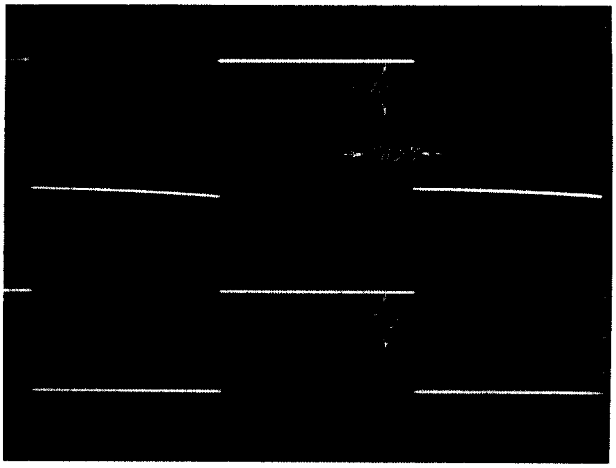

Fig. 5b. System response to long pulses.
Upper trace—input
Lower trace—output

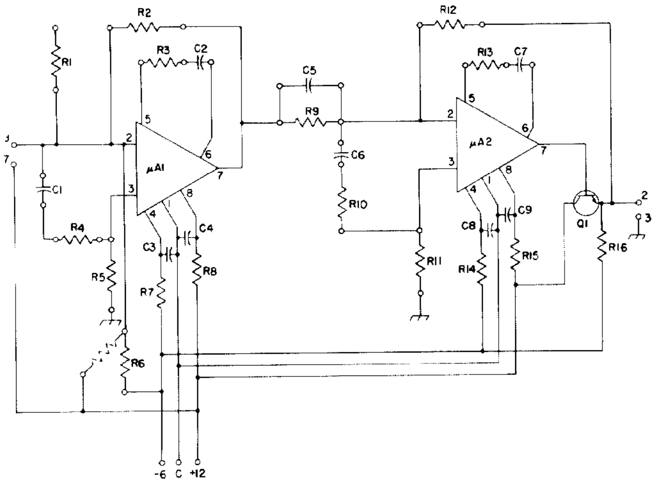

Fig. 6. Linear receiver amplifier.