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An Optically Coupled High Voltage Isolation Amplifier

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OAK RIDGE NATIONAL LABORATORY

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ABSTRACT

A common and persistent problem in modern instrumentation is the observation and recording of small signal waveforms that are removed from ground by very high voltages. Examples of this are the instrumentation of neutral particle injectors used in controlled thermonuclear research and the construction of safety breaks for air core toroidal devices.

To overcome this problem a very high voltage isolation amplifier was designed. It employs analog-to-digital conversion with serial data transmission on a fiber optic cable.

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1. INTRODUCTION

A common and persistent problem in modern instrumentation is the observation and recording of small signal waveforms that are removed from ground by very high voltages. Examples of this are the instrumentation of neutral particle injectors used in controlled thermonuclear research and the construction of safety breaks for air-core toroidal devices.

A technique used at the present time is a floating oscilloscope that is remotely viewed or photographed. This technique has obvious disadvantages in the areas of safety and convenience.

To overcome these problems, a very high voltage isolation amplifier was designed. It employs analog-to-digital conversion with serial data transmission on a fiber optic cable. A similar system[1] designed at Oak Ridge National Laboratory (ORNL) uses voltage-to-frequency (VF) conversion and optical transmission but suffers from a common problem with VF converters. The response time is a function of signal level. For very slowly changing signals this does not pose a great limitation but for pulsed signals, such as those encountered in tokamak devices, a uniform response time is highly desirable.

2. DESIGN SPECIFICATIONS

A system was required that would isolate a 0-10-V signal superimposed on a 150-kV dc voltage. Power for the system was available at the high voltage level through isolation transformers. The isolation amplifier was to have unity gain and a sample rate of four points per millisecond. In one application the output was going to be fed to a computerized data acquisition system that had a sample rate of two points per millisecond. A resolution of 1 part in 256, i.e., 8 bits, was considered acceptable. The linearity was to be at least as good as the resolution.

3. CIRCUIT DESCRIPTION

The system designed to meet the above specifications consists of a signal processing amplifier and transmitter that float at the high voltage level, a receiver that is at ground potential, and a fiber optic cable connecting them.

Figure 1 is a schematic diagram of the transmitter with its gain setting preamplifier A1. The transmitter consists of an 8-bit analog-to-digital converter (ADC), a Universal Asynchronous Receiver/Transmitter (UART), and some timing logic. The ADC's parallel digital output is connected to the Transmit Buffer Register (TBR) inputs of the UART. The UART converts these data to a serial form and adds start and stop bits that are recognized by the receiver. The UART is the speed limiting device in the system, and the one used here is a state-of-the-art complementary metal-oxide-semiconductor (CMOS) device. A characteristic of

CMOS devices is that their maximum operating speed increases with power supply voltage. This device has a maximum clock frequency of 6.4 MHz when operated at 10 V. Since each bit requires 16 clock pulses the throughput rate is approximately 40 kHz, which exceeds the base requirement by a factor of ten. However, if better than 0.5% resolution were required, a major speed sacrifice would have to be made.

An LC oscillator is used as the clock for the UART. High frequency stability is not necessary due to the characteristics of the UART; the transmitter and receiver clocks need to be within only a few percent of the same frequency.

The transmitter is assured of running at its maximum speed through the use of a timing circuit made up of two monostable multivibrators (U2A and U2B). One of them (U2B) issues a convert command to the ADC when the TBR of the UART is emptied. The other (U2A) issues a TBR load command to the UART when the ADC has completed its conversion. In this way they form a ring oscillator. Q2 and its associated components form a power-on reset to insure oscillation when power is applied.

The output of the UART is connected to an emitter-follower transistor that drives a Motorola MLED930 infrared light-emitting diode.

Figure 2 is a schematic diagram of the receiver, which operates in a manner similar to the transmitter. A PIN3D diode manufactured by Universal Detector Technology is used as the photodetector. After amplification and shaping the received data are fed to the receiver section of a UART where they are converted to parallel form. A digital-to-analog converter reconverts this digital word back to an analog signal. No timing logic is necessary in the receiver as the UART's output data remain valid until a complete new word is received.

The fiber optic cable used to connect the transmitter and receiver is a multifiber bundle (Corning 5013). It has a high numerical aperture which assures noncritical coupling. Its moderately high attenuation was not a problem since short lengths (<20 m) were used. BNC connectors, modified[1] as shown in Fig. 3, were used to connect the fiber optics to the transmitter and receiver.

4. SYSTEM PERFORMANCE

The system described above was constructed, tested, and found to meet or exceed all design specifications. Its gain can be varied to accommodate signal ranges other than 0-10 V, and its offset adjustment allows the system to handle bipolar signals. Transmissions along lengths of fiber optic cable up to 10 m have been entirely error free. Worst case nonlinearity for the system is 1/2 Least Significant Bit (LSB) for the ADC and 1/2 LSB for the DAC or 1 LSB overall. System performance is shown in Figs. 4 and 5. This isolation amplifier has proven itself to be quite useful and could find application wherever isolated grounding is required.

ACKNOWLEDGMENTS

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REFERENCES

*Research sponsored by the Department of Energy under contract with Union Carbide Corporation.

[1]R. E. Wright, *Optical Telemetry Control and Data Transfer System*, Proc. 7th Symp. on Eng. Prob. of Fusion Research (1977), IEEE 77CH1267-4-NPS.

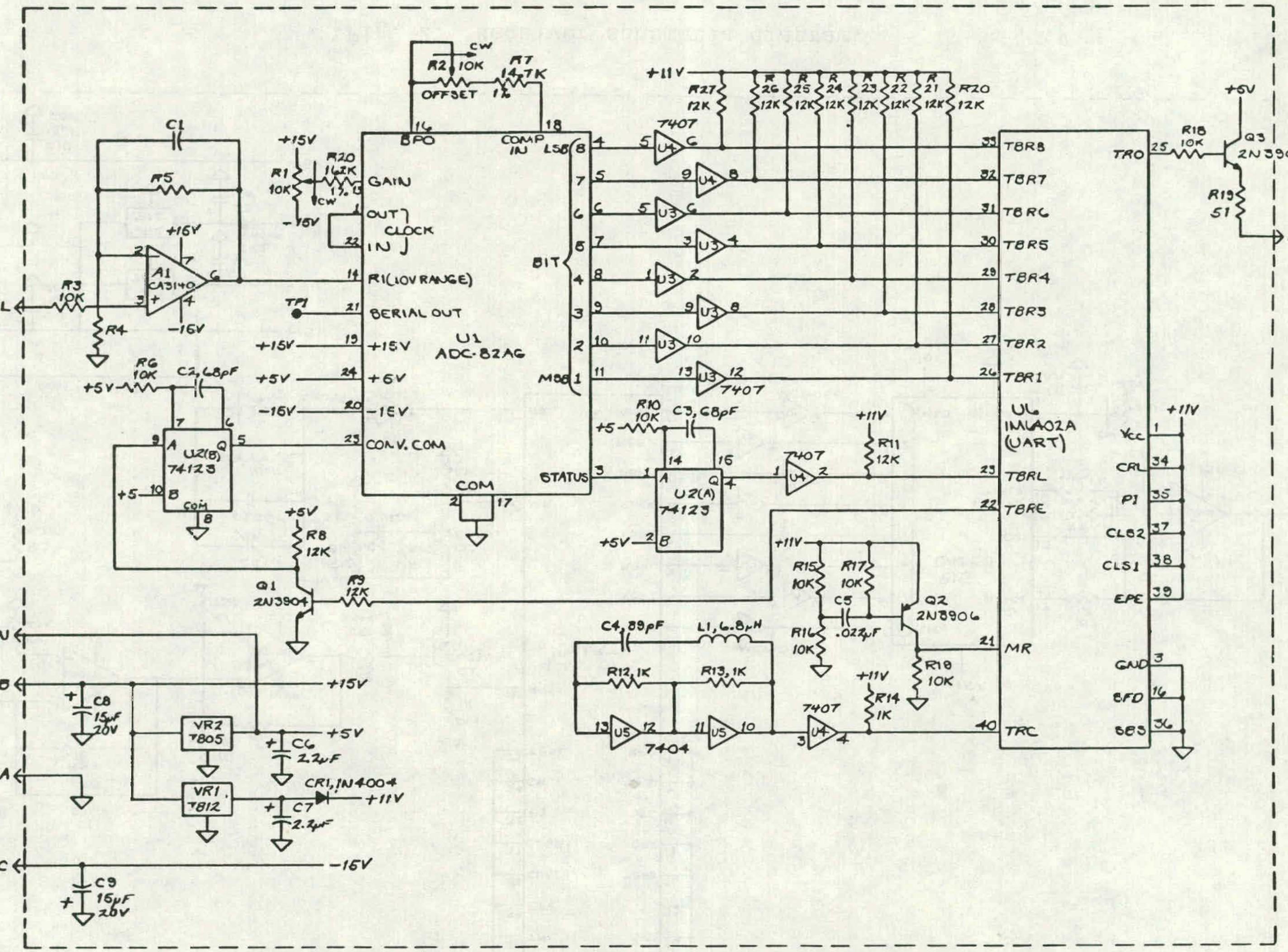

Fig. 1. Transmitter schematic diagram.

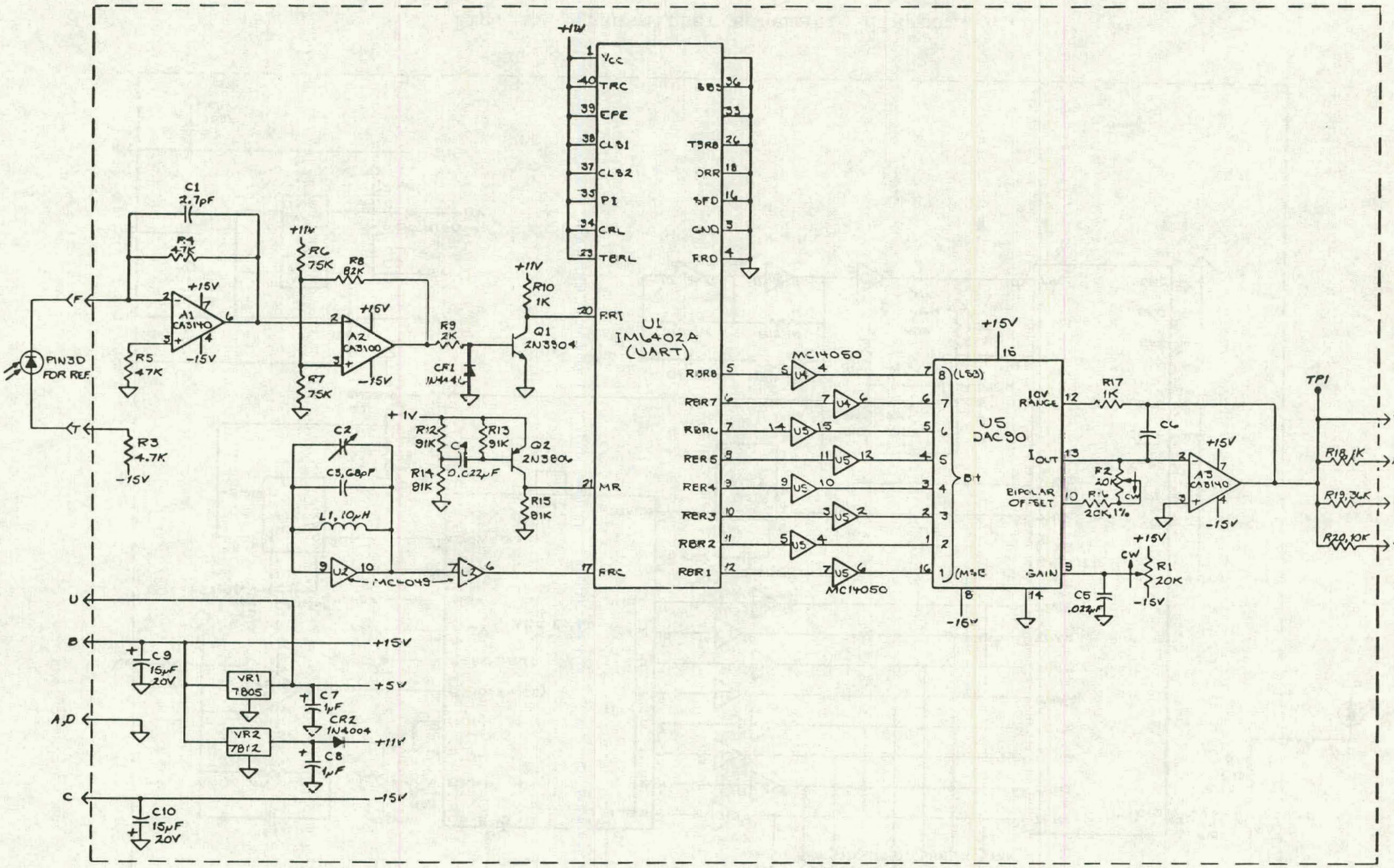

Fig. 2. Receiver schematic diagram.

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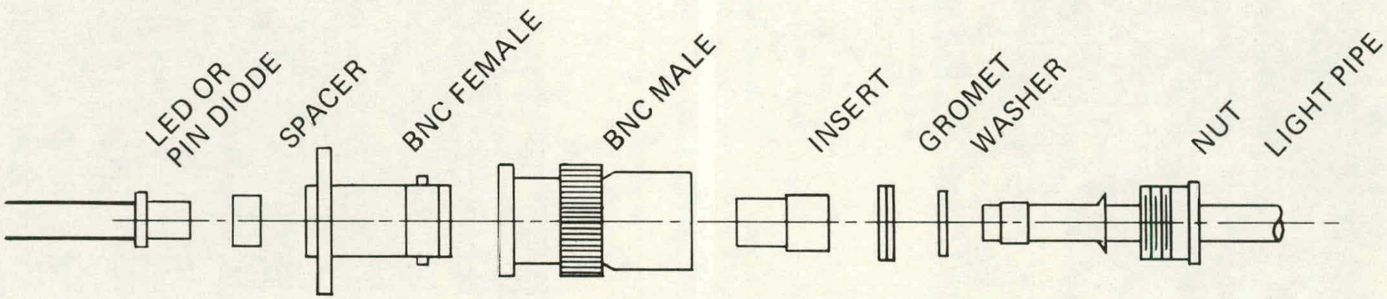

Fig. 3. BNC connectors modified for fiber optics.

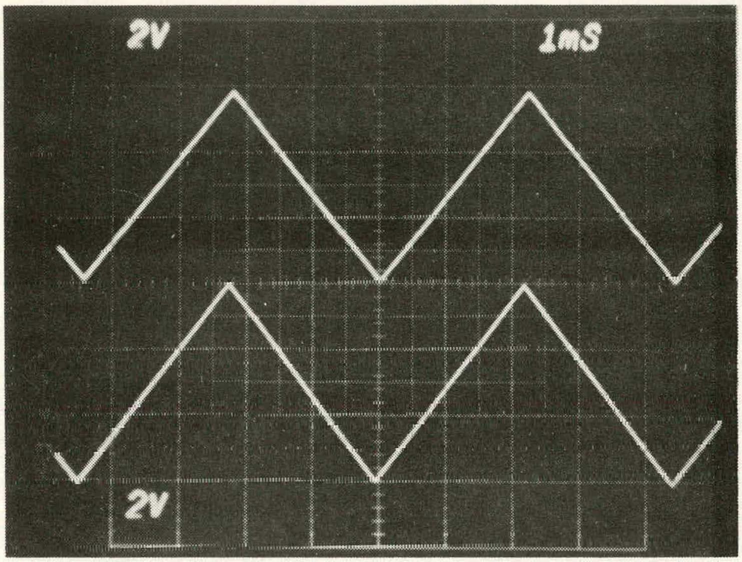

Fig. 4. Oscillogram of input (bottom) and output (top) waveforms.

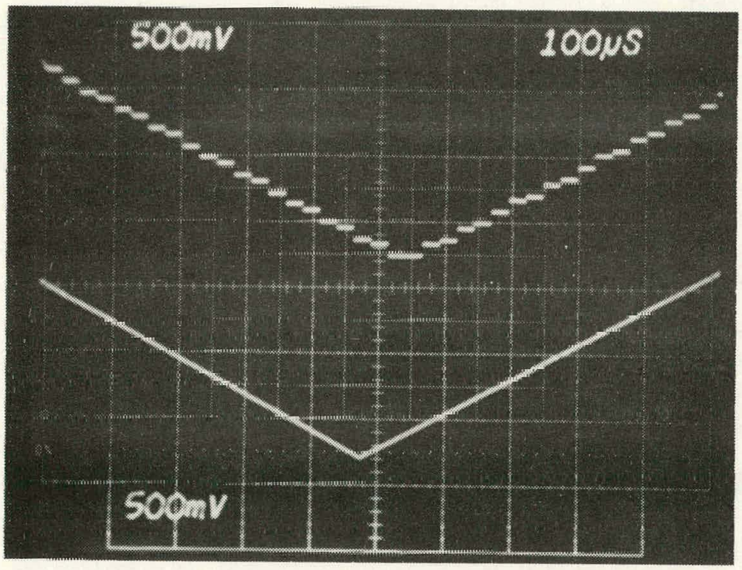

Fig. 5. Enlarged oscillogram of input and output waveforms.

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