LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

1

LA-UR--89-3298

DE90 002444

NOV 0 6 1989

TITLE: REMOTE CONTROLLED SIGNAL CONDITIONER AND FIBER OPTIC DATA LINK SYSTEM DEVELOPMENT FOR CPRF

AUTHOR(S): L. S. SCHRANK, L. D. CAUDILL, A. HABERSTICH, K. A. KLARE, AND W. A. REASS

SUBMITTED TO IEEE
KNOXVILLE, TN
10/2-6/89

DISCLAIMER

MASTER

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

REMOTE CONTROLLED SIGNAL CONDITIONER AND FIBER OPTIC DATA LINK SYSTEM DEVELOPMENT FOR CPRF[†]

L.S. Schrank, L.D. Caudill, A. Haberstich, K.A. Klare, W.A. Reass

Los Alamos National Laboratory, Los Alamos, NM 87545

ABSTRACT

The ZTH reversed-field pinch to be installed in the Confinement Physics Research Facility (CPRF) will produce a significant ambient magnetic field. To avoid ground-loop and other electrical problems, the diagnostics in direct or possible contact with the experiment will be accessed through a fiber optic data way. The frequency-modulated analog links developed for this system have a bandwidth of DC to 100 kHz and a signal-to-noise ratio of better than 60 dB. The fiber optic transmitter units include a signal conditioner and a microprocessor controller. The conditioners can be configured as DC-coupled, low-noise differential amplifiers, or as high-gain, low-drift differential integrators with a very long droop time constant. Magnetic field pickup is minimized by balancing sensitive circuit areas to within 5 mm^2 in all three planes of the PC boards. The gain, offset, and integrator reset are controlled and monitored by the microprocessor, and their status is displayed on the front panel of the transmitter unit. The signal conditioner can be controlled locally, or by way of a fiber optic coupled control network. The system allows fast, convenient, noise-immune control of a large number of signal conditioners from a central host computer. By varying the offset, the computer can verify the operational integrity of the data links.

INTRODUCTION

Being an air-core device, the ZTH reversed-field pinch to be installed in the Confinement Physics Research Facility (CPRF) will produce a substantial ambient magnetic field.[1] The far field can be approximated by a dipole field with a magnitude of up to 0.03 T at a radius of 8.5 m from the center of the experiment. The presence of this field is a significant factor in the design of the interface between diagnostics and data acquisition system.

Time-varying magnetic fields can induce large potential differences between the diagnostics and the front end, as well as circulating currents in the diagnostics grounding system. These effects can, in turn, generate spurious signals on the diagnostic data path and, in extreme cases, damage to the diagnostics. The problem will be solved in the case of diagnostics well isolated from the ZTH experiment by using a single diagnostics grounding point and by avoiding ground loops. Thermocouples may be handled by fiber optic coupled programmable controllers. The following approach has been adopted for the other sensors.

Diagnostics in direct or possible contact with the experiment are grounded at the front end of the facility. To prevent ground loops, the diagnostics are otherwise isolated from each other and from the outside world by the use of fiber optic data links. Frequency modulated analog links with a bandwidth of 100 kHz ensure reliable operation.

The fiber optic transmitter units are located in the experimental hall at a radius >8.5 m from the front end to mitigate magnetic pickup by the electronics. The fiber optic receivers are installed in a remote data acquisition area. This data acquisition network has the added advantage of being immune to electromagnetic pickup and of pre-

† Work performed under the auspices of the US DOE

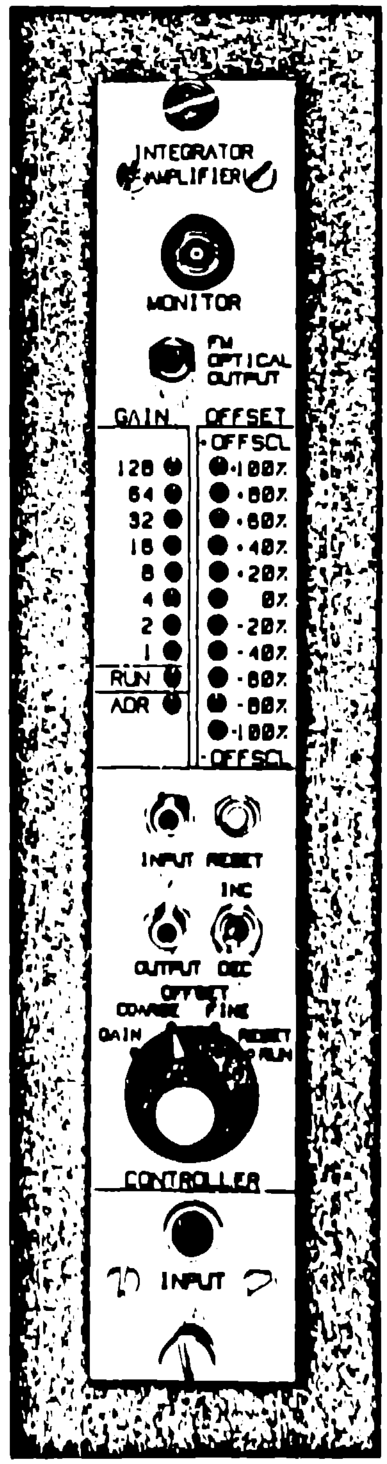

Fig. 1 Transmitter Unit Front Panel

venting noise propagation among the various areas of the facility. The transmitter units include a signal conditioner to match the characteristics of the diagnostics signals to the dynamic range of the links. The conditioner parameters are set and monitored by a built-in controller. Access to the controller from the user work stations is through a fiber optic control network and a host computer. Local access from the transmitter front panel is also available.

Automated verification of the gain and linearity of the data links will be performed by the host computer. An offset signal will be cycled through the data acquisition system, and the response checked for accuracy of gain and linearity.

DATA ACQUISITION NETWORK

The purpose of this network is to route the signals produced by the diagnostics to an area containing the data acquisition transient recorders as well as mixing and monitoring equipment. Analog links are used to provide on-line access to the data, for equilibrium control, for example. Frequency modulation ensures reliable gain and linearity.

The transmitter units incorporate the signal conditioners and controllers described below. The circuits are built on a single printed-circuit board mounted in a NIM-type plug-in unit. These units fit in special crates to ensure electrical isolation from each other and from the outside world. Power is provided by floating power supplies.

FIBER OPTIC LINK

The link operates with a carrier frequency of 750 kHz and a maximum swing of ± 250 kHz. An AD650BD chip is used as a voltage-to-frequency converter in the transmitter, and frequency-to-voltage converter in the receiver. Low-loss glass-core fiber allows communication over several hundred meters.

The link has an overall voltage gain of 1, and a dynamic range of ± 5 V. The bandwidth extends from DC to 100 kHz, with a signal-to-noise ratio of at least 60 dB. The linearity and gain errors are less than 0.2%. Temperature compensation techniques will be used to ensure a baseline stability of better than 0.2 mV/°C.

To achieve this low noise level with the minimum carrier frequency of 500 kHz, the receiver makes use of an active 9 pole Bessel filter.[2] This filter has an attenuation of 3 dB at 100 kHz and of 85 dB at 500 kHz. The filter introduces a delay of 7 μs in the signal. This delay will be taken into consideration in the data analysis.

SIGNAL CONDITIONER

The signal conditioner must be able to amplify the diagnostic signals by several orders of magnitude. Most of the electrical diagnostics signals must also be time integrated. The main elements of the conditioner are indicated in the block diagram of the transmitter unit shown in Fig. 2.

The input stage of the signal conditioner can be configured as a preamplifier or as an integrator. The input is differential in both cases to reject common mode electromagnetic pickup induced in the diagnostic lines. The gain of the preamplifier is preset during assembly at a value of 1 to 10. By careful matching of components, a common mode rejection ratio of 100 dB is achieved at the low frequency end. The ratio is reduced to 70 dB at 100 kHz.

The preamplifier is followed by 2 programmable gain amplifiers. These amplifiers have a combined gain of 1 to 128. The amplitude of the smallest full scale input signal is, therefore, 7.8 mV with a preamplifier gain of 10. The bandwidth of the signal conditioner exceeds 240 kHz in this configuration.

When used as an integrator, the signal conditioner must be able to integrate signals over a period of 5 seconds with minimal base line drift. This is accomplished with the circuit shown in Fig. 3. Use of an operational amplifier with an open loop gain greater than 135 dB and of low leakage integrator capacitors produces a droop time constant greater than 5,000 s.

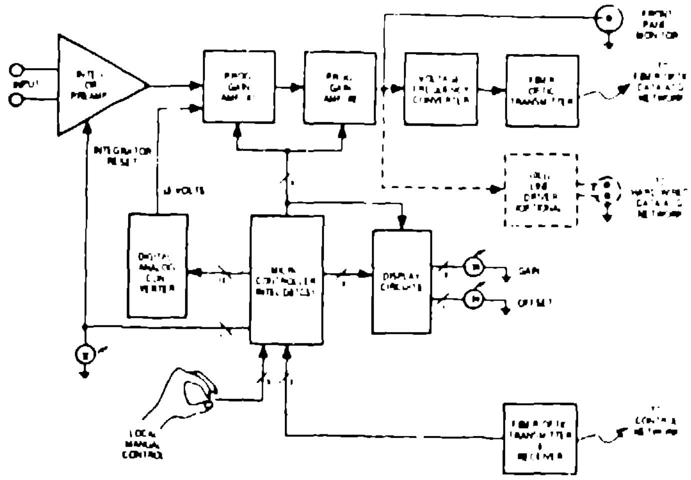

Fig. 2. Block Diagram of the Transmitter Unit

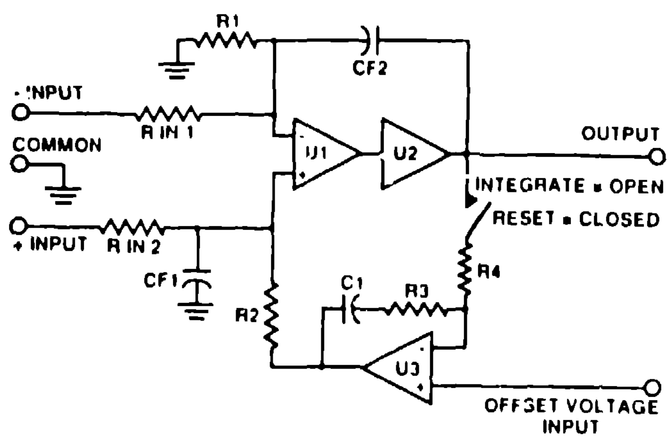

Fig. 3. Integrator Circuit.

The integrator circuit has a gain of 0.5 V/mV s. The overall gain of the conditioner in the integrator mode can, therefore, be varied between 0.5 and 64 V/mV s. By matching components, a common mode rejection ratio of 100 dB is obtained at low frequency. A ratio of 50 dB, at 100 kHz, is made possible by buffering the output of the operational amplifier U1.

The integrator is reset between shots to control the starting point of the integration. This operation is performed by U3. The base line of the input signal can be shifted, in the preamplifier or integrator configuration, by injection of an offset voltage produced by a D/A convertor.

The gain, offset, and reset parameters are set and monitored by an on board controller. The operation of this unit and the control network are described below.

The front panel of the transmitter unit is shown in Fig. 1. LED's display the status of the signal conditioner, and switches allow local access to the controller. This feature will be useful during the setting up of a diagnostic, for example. A connector is available to monitor the input to the voltage-to-frequency converter or, as an option, to drive a 100-Ω line. The differential output range, in the latter case, is ±1 V.

The printed circuit board is designed to minimize ambient magnetic field pickup. Use is made of a 3-layer board with the center layer used for the ground conductors. Input traces are laid out in a pattern analogous to a twisted pair. Unavoidable loop areas thus tend to cancel each other. An effective area of less than 5 mm^2, as referred to the input of the conditioner, has been obtained in all orientations of a prototype board. The anticipated spurious output signal will be less than 10 mV at maximum gain in the integrator configuration.

CONTROL NETWORK

The control system provides user access to a widely distributed array of signal conditioners. Up to 992 controllers can be connected to a host computer with 16 serial data ports. Star hubs (Fig. 4) with a subset of up to 62 controllers can be clustered as dictated by geographic requirements. All interconnections use fiber optic components for electrical isolation and noise immunity.

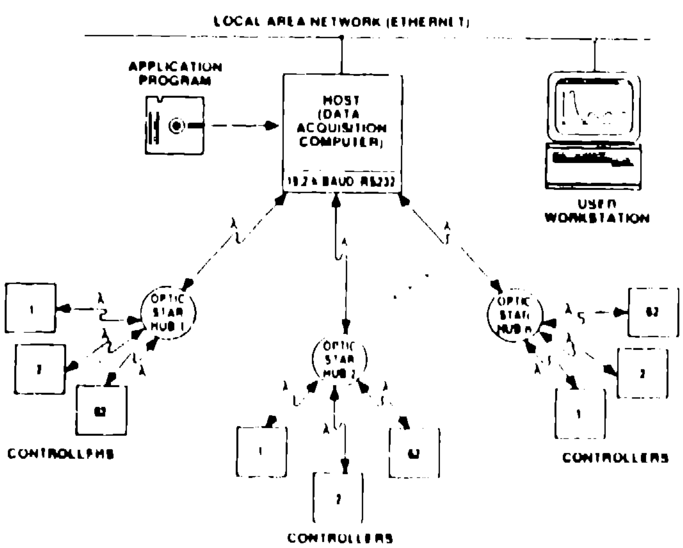

Fig. 4. Control Network.

The network and the user interactions are managed by a host application program. This application program, presently under development, may, for example, respond to a user request for gain information on "diagnostic number 125." The application program in this case will read serial port number 1, controller number 25 for its gain setting and return the information to the user.

CONTROLLER TASKS

The controller must respond to commands generated by the host computer and to demands generated from the front panel of the transmitter unit. Host computer commands (after parity and protocol checks) must be translated and used to set the signal conditioner parameters. The front panel demands are serviced at a high priority and allow immediate control of the signal conditioner. After adjustment of the signal conditioner parameters the controller outputs the updated front panel display and enters an idle mode. In this mode the controller tasks are reduced to maintenance of the watchdog circuit using its associated timer interrupt.

CONTROLLER HARDWARE

The primary hardware component is an Intel model 87C51 microcontroller. This microcontroller has been selected for its small size, low power consumption, and extensive set of on-board resources. These resources include a serial port for communication with the host, an erasable programmable read only memory for storage of the embedded program, input/output ports for connection to the signal conditioner, and interrupt support which allows responsive design of the controller program.

The block diagram of the controller (Fig. 5) shows the support circuits necessary to complete the controller/signal conditioner interface, the controller/local user interface, the controller host interface, and three "housekeeping" tasks.

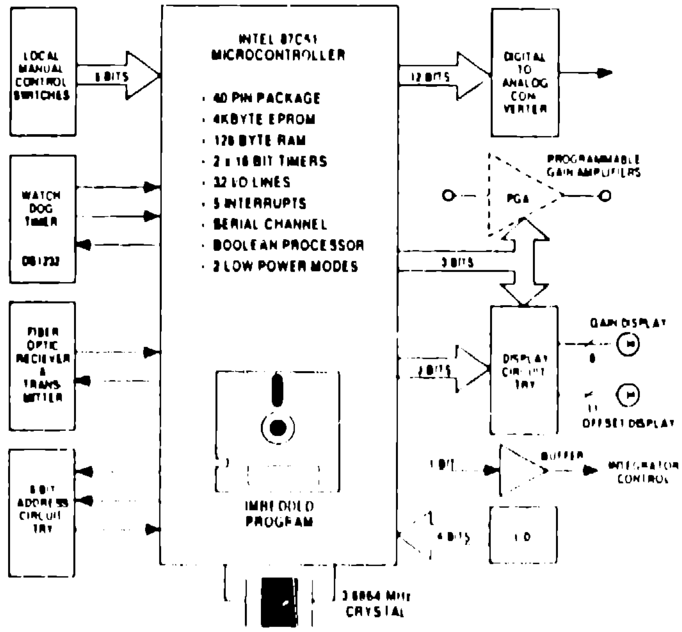

Fig. 5. Microcontroller and Support Circuits

The first housekeeping task is management of a watchdog timer. This circuit ensures that the embedded program is running and that proper control sequences are followed. The embedded program must periodically update the watchdog or suffer a partial reset to return the program to correct operation.

The second housekeeping task is to read the controller address. This 6 bit value is user selectable for addresses 1 to 62 and uniquely identifies a signal conditioner channel. The address is stored in internal memory during the initialize portion of the controller program and used to determine which controller responds to a host command.

The final housekeeping task involves a 4 bit identification code returned with the signal conditioner data in response to a host query. These I.D. straps are permanently set to identify signal conditioner parameters such as the integrator time constant.

EMBEDDED PROGRAM

The controller program must manage the on-board resources, interact with the support circuits, and maintain communication with the signal conditioner by following predefined rules. These rules result from the selection of a communications protocol and a hardware configuration.

The communications protocol defines the interchange of commands, status, and data between the host and the controller. Figure 6 shows the program flow chart which exercises control of the signal conditioners by following the protocol rules. The main program segment starts from reset, initializes resources, and enters the idle mode waiting for a command. Commands from the host generate a serial interrupt. This interrupt drives a second program segment which processes the host input and alerts the main program. The main program then exits the idle mode, executes the command, updates the front-panel display, sends a response to the host, and returns to the idle state. Parity and procedure error checks are performed on the arriving commands during execution of these two program segments. The status of these checks is returned in the response sent to the host.

Another interrupt signals that the front panel interface needs service. The manual control routine of Fig. 6 shows how the controller program acknowledges this interrupt and executes the local user command while supplying updated displays of gain, offset, and reset information to the front panel.

The timer routine uses two interrupts to manage the watchdog circuit. A timer interrupt establishes the watchdog update rate and the second interrupt (shown in the main program segment) forces a reset if the watchdog times out.

These interrupt driven code segments create a program which is responsive to the different real-time events which occur during the control of the signal conditioners. Asynchronous occurrences of host commands, front panel demands, and timer interrupts are processed reliably.

CONCLUSIONS

A fiber optic data link system has been developped for CPRF/ZTH diagnostics requiring electrical isolation from each other and from the outside world. Immunity to the magnetic field environment has been a prime consideration. The links have a bandwidth of DC to 100 kHz, and good linearity, signal-to-noise ratio and stability.

The data links include a signal conditioner capable of handling a wide range of diagnostics requirements. Remote setting of the conditioner parameters can be handled from the user work stations. Reliability is ensured by the choice of circuits, the choice of control procedures, and a provision for automated verification of the operational integrity of the system.

ACKNOWLEDGEMENTS

The authors wish to thank C. J. Buchenauer, T. L. Petersen, and R. W. Wilkins for stimulating discussions and helpful advice.

REFERENCES

1. C. F. Hammer and P. Thullen, "Confinement Physics Research Facility/ZTH: A Progress Report," Proceedings of the 13th Symposium on Fusion Engineering, Knoxville, TN, Oct. 2-6, 1989.

2. D. S. Humphreys, "Analysis, Design, and Synthesis of Electrical Filters," Prentice Hall (1970).

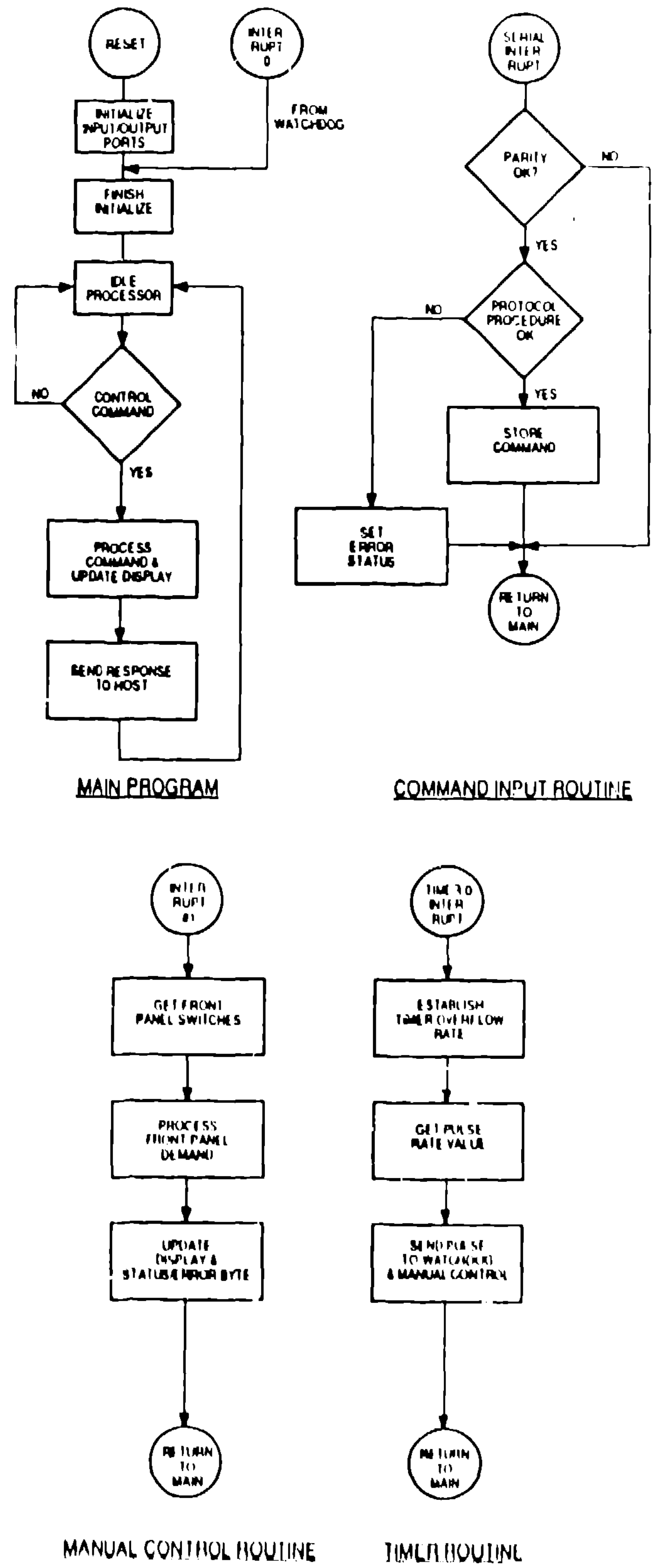

Fig. 6. Embedded Program Flow Chart