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FOUNDATION SYSTEM OF THE LOCAL CONTROL AND INSTRUMENTATION SYSTEM FOR MFTF

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SUMMARY

There are over 50 distinguishable systems in the Local Control and Instrumentation System (LCIS) of the Mirror Fusion Test Facility. It became clear that as much as possible a common hardware system or "foundation system" should be used. This "foundation system" consists of three major subsystems, the LSI-11 computer, the fiber optic communication links, and the CAMAC system. The LSI-11 computer includes a 32 K word memory, a serial interface that communicates with the supervisor computer, and the serial driver, which provides serial CAMAC protocols and the block transfer function. The fiber optic links are duplex-links of optical transmitters, receivers, and fiber cables. These links carry information between the LSI-11 computer and the CAMAC system, which are more than 200 m apart. The CAMAC system consists of one or more CAMAC crates, serial crate controller, and CAMAC modules, which are unique to each system. A transient recorder, for example, is a CAMAC module that will be used in the plasma streaming systems to record the streaming gun and magnet power supply waveforms. The digitized data are stored in the memory of the module and are transferred to the computer memory through the block transfer mode of the serial driver and the DMA port of the LSI-11 computer.

Introduction

The complexity of the Mirror Fusion Test Facility (MFTF) requires the use of local controls to transfer information between the system and the Supervisory Controls and Diagnostic System (SCDS) computers. These local controls fall within the area of the LCIS.

There are many systems in MFTF, such as start-up neutral-beam power supply systems, sustaining neutral-beam power supply systems, plasma streaming systems, magnet systems, vacuum systems, safety interlock systems, cryogenic plant systems, and experimental diagnostic systems. During the course of the preliminary design of the LCIS, it became clear that a common hardware system should be used in local controls of all systems of MFTF for reasons of economics, ease of maintenance, reduction of design effort, and timely completion of the LCIS installation. With these goals, the LCIS group is determined to provide a "foundation system" for local controls of all systems in MFTF.

System Description

In the LCIS design philosophy each of the systems consists of one part that is common to all systems and another part that is unique to the particular system or groups of systems. This common hardware, or "foundation system," consists of three major subsystems:

- Local computer system
- Fiber optic communication links
- CAMAC system

The LCIS is completed by adding selected modules to the "foundation system." These modules, either of inhouse design or commercially available, are selected to implement control and monitor functions of the system. A block diagram of the "foundation system" is shown in Fig. 1.

The installation location of the computer was an issue because of the hostile environment in the equipment area of Building 431. It was decided to locate the LCIS computers in the control room (Building 439) along with the SCDS computers. This placement puts a distance of up to 200 m between the LCIS computer and the hardware to be controlled in Building 431. For this reason, a high-speed serial transmission scheme such as the CAMAC serial system was selected as the most economical implementation of the communication link between the LCIS computer and the remote equipment. To eliminate electromagnetic interference and to provide ground isolation, fiber optic cables will be used for all links that enter the control room. An advantage incidental to locating the LCIS computers near the SCDS computers is that a multiwire serial line that is relatively short can be used to link the two computers. Thus the LCIS/SCDS computer communication protocol is simplified.

The LCIS operates in conjunction with and under the control of the SCDS computers. The local control computers are cold-loaded through the serial link with control programs that are stored on the SCDS computer disks. These programs run in the LCIS computers and communicate with the remote CAMAC over the two fiber optic links. The CAMAC serial crate controller receives messages, passes commands, and writes data to the modules on the CAMAC Dataway, and transmits status and read-data back to the local computer. At the end of a shot cycle, or on command, the local computer outputs data to the SCDS computer over the serial communication links.

Local Computer System

The LCIS computer system consists of the following:

- LSI-11 computer CPU
- 32 K word memory
- Serial line modem interface
- Serial highway driver interface (SHDI)

The computer selected for the LCIS is the LSI-11/2 manufactured by Digital Equipment Corporation (DEC), Massachusetts. The computer was selected as a result of a bidding process. The LSI-11/2 is a 16-bit microcomputer that can address up to 32 K word memory locations. However, the LSI-11 architecture reserves the upper 4 K word address space for user devices and peripherals leaving 28 K words of usable memory for programs and data.

The serial line modem interface is the DLV11-E supplied by DEC. It is used as an asynchronous serial line to communicate with the SCDS computer. The communication protocols between the SCDS and the LCIS computers are described in detail in Ref. 1.

In order to establish the link between the CAMAC serial highway and the local computer, a SHDI has to be designed. The decision to design a custom interface was based on lack of a suitable commercially

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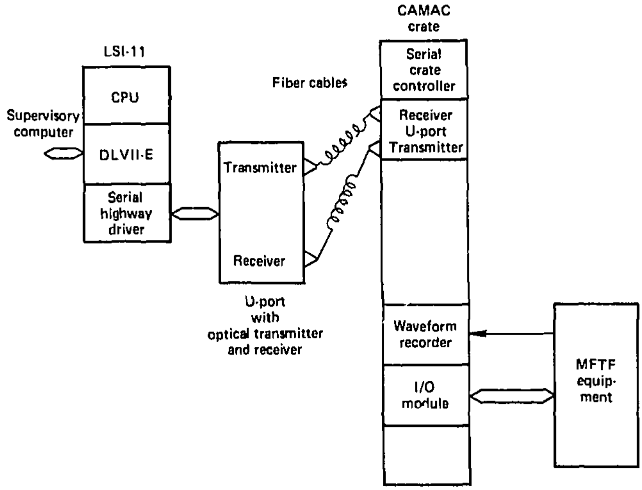

Fig. 1. Block diagram of LCIS foundation system.

available interface and the high cost of the standard method of implementing the serial highway with the LSI-11 computer.

The SHDI consists of two modules: the transmitter of double size and the receiver of quad size, directly plugged into the LSI-11 computer backplane. Having its own memory address, the transmitter is a data formatting device, which can accept CAMAC-oriented data from the Q-bus of the LSI-11. The transmitter converts the data to conform with the serial highway message protocol. Transverse and vertical message parties are generated as the data are ready to shift out serially at the D-ports. The transmitter generates a fixed number of Space bytes and then terminates the transaction by sending the End byte. It continues to send Wait bytes until another command message is executed. A modulated output of Bi-phase/Manchester code at a maximum transmission rate of 5 Mb/s is also provided.

The receiver module of the SHDI can perform two modes of operation:

- Program I/O reading and writing
- Block transfer with DMA reading

The program in the computer can write the buss address and word count for the block transfer mode (BTM), and controls in the control/status register—all of which are in the Receiver. It can read the receiver, the buss address and the word count when the BTM is set, reply messages, status flags, and LAM messages.

The Receiver provides both D-port inputs and modulated input of the Bi-phase/Manchester code where the NRZ data and clock are recovered. Each frame of input data is interrogated if it is a Wait byte, demand byte, data byte, or End byte. A Wait byte resets the receiving circuits and provides synchronization. A demand byte will be stored in the demand FIFO where an interrupt to the computer is generated. A data byte will be stored in the register. An End byte will raise a data-ready flag for the program I/O mode, or a DMA request line on the Q-bus of the computer for BTM. Transverse and vertical parties are checked. Any errors including work count zero when the BTM is set will trigger an interrupt in the computer and terminate the BTM.

Fiber Optic Links

The communication links between the LSI-11 computer and the remote CAMAC crate will be implemented with fiber optic links. Optical fiber cables offer several advantages over metallic cables:

- Immunity from electromagnetic interference
- Low attenuation and large bandwidth
- Electrical and ground isolation

The basic requirements for LCIS fiber optic links are:

1. Data rate maximum: 10 Mb/s NRZ (5 Mb/s bi-phase)
2. Length maximum: 300 m
3. Bit error rate: less than 10^{-9} at maximum data rate
4. Ruggedness: must survive pulling in conduit
5. Field termination capability
6. Single power source for the Transmitter and receiver
7. Cost effectiveness
8. Standard commercial product

During FY 78, a number of commercial fiber optic systems were borrowed for evaluation to determine applicability to MFTF systems. At that time, very few systems met the requirements mentioned above. The evaluation continued into FY 79 since fiber optics is a rapidly evolving technology, and system improvement and cost reductions are continually being made. During FY 79, several commercial fiber optic systems that met most of the requirements were purchased for evaluations. It is interesting to find that the requirements for LCIS fiber optic systems fall into the medium range application and that there are many of these systems available in the market that can be selected, especially fiber optic cable.

Because of the medium data rate and relatively short system length, the characteristics of the fiber optic systems fall into these general areas:

1. The transmitting light source is a light-emitting diode that can operate over a wide temperature range, has a long expected life, and offers greater long-term stability.

2. The light detector is a PIN diode that requires low bias voltage and thus creates less excess noise.

3. The emission-peak wave length of the light source is 820 to 850 nm.

4. The transmission medium is single, step-index fiber, which has the attenuation of less than 20 dB/km, core diameters of 100-250 μm and a numerical aperture of 0.22 to 0.4.

CAMAC System

The CAMAC system is the last major subsystem of the LCIS. Modules that are common to all systems include the serial crate controller, which regulates the traffic of the Dataway in the crate, and the U-port module, which provides conversion of signals between D-ports and Bi-phase/Manchester code multiplexing.

The actual interface to the equipment being controlled is provided by a set of CAMAC compatible modules. These modules will be commercially available and will be different for each system. However, using the same type of CAMAC modules in all systems has been encouraged. For instance, an inhouse-designed CAMAC module will be used to control and monitor certain power supplies of the start-up neutral-beam systems, sustaining neutral-beam systems, and plasma streaming systems. This module contains 24 bits of bidirectional data lines, 3 unidirectional control lines, and 5 unidirectional address lines, all of which are optically isolated.

Transient recorders that collect power supply waveforms will be different units among the systems of MFTF. The plasma streaming system will utilize a single-width CAMAC module of dual channel A/D with 1 K words of memory in each channel for recoding the current and voltage waveforms of its gun and magnet power supplies. The digitized data from each A/D are stored in the memory during the 10-ms shot time, and are transferred to the computer through th BTM of the SHDI at the end of the shot.

The sustaining neutral-beam system uses an 8 K word memory module because of the 0.5-s shot-time. The analog waveforms of its power supplies are digitized in the high voltage area and shift out serially through a fiber optical link into a register where the serial data are converted into parallel data and stored in the memory module. The data in the memory will be read by the computer through the BTM of the SHDI.

The LCIS computer system topology is different among the systems of MFTF. There are 24 sustaining neutral beam sources. Each source consists of five types of power supplies. Each set of power supplies is controlled and monitored by CAMAC modules in a CAMAC crate, which will talk to an LSI-11 computer. Therefore, there are 24 LSI-11 computers communicating with 24 CAMAC crates.

The plasma streaming system utilizes the structure of the multicrate technique. One LSI-11 will communicate with four CAMAC crates. Each crate will control and monitor 15 gun and magnet power supplies, occupying only 15 slots of the crate.

Conclusion

The "foundation system" of the LCIS is a simple and logical solution for providing controls for MFTF. None of this system is installed at this time; however, a prototype has been set up and used for the evaluation of fiber optic links and the testing of all inhouse-designed CAMAC modules.

Acknowledgments

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