GA-A--20604

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EIGHT CHANNEL – 16 BIT, BIDIRECTIONAL ANALOG TO DIGITAL MONITORING AND CONTROL SYSTEM

by

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This is a preprint of a paper to be presented at the 14th Symposium on Fusion Engineering, September 30–October 3, 1991, San Diego, California, and to be printed in the *Proceedings*.

Work supported by
Department of Energy
Contract DE-AC03-89ER51114

GENERAL ATOMICS PROJECT 3466
NOVEMBER 1991

GENERAL ATOMICS

EIGHT CHANNEL – 16 BIT, BIDIRECTIONAL ANALOG TO DIGITAL MONITORING AND CONTROL SYSTEM

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Abstract: The DIII–D tokamak facility is currently upgrading its electron cyclotron resonance heating (ECH) system. The new system is based on 110 GHz gyrotrons developed by Varian. As part of this upgrade, the superconducting magnet power supplies were required to be remotely controlled and monitored accurately. The 110 GHz gyrotron superconducting magnet has eight coils, that are energized by current regulating power supplies. An analog to digital (A/D) system was designed to allow remote coil current monitoring and power supply programing. The A/D system is an eight channel multiplexed, 16 bit, bidirectional, fiber optically linked, analog to digital telemetry system. Design concerns and trade-offs will be discussed as will the results of in system use.

Introduction

The 110 GHz gyrotron superconducting magnet power supplies are controlled and monitored by a 16 bit analog to digital (A/D) system. The system was designed to be accurate, compact, bidirectional, optically isolated and reliable. High accuracy is required, so a 16 bit system was chosen. Multiplexing was chosen to reduce its size and cost (16 bit analog to digital and digital to analog converters are expensive). The system also needed to be bidirectional because the power supplies need to be remotely monitored as well as controlled. For noise immunity, the A/D system needed to be optically coupled. The system will functionally be described and discussed in block format.

System Description

The Block diagram of the bidirectional A/D link is shown in Fig. 1. The 8 analog inputs of the A/D link are differential instrumentation amplifiers, with programmable gains. Highly accurate gains of 1, 10, or 100 (Using Amps internal gain resistors) can be selected by different jumper configurations. Any other gains greater than one can be achieved by a jumper configuration, and adjustment of an external pot. The 8 outputs of the instrumentation amplifiers are fed into a 8 to 1 analog multiplexer. The output of the multiplexer is fed into a 16 bit analog to digital converter. The converted 16 bit digital word is than latched in a bank of D–flip flops, and multiplexed into two 8 bit bytes (low byte & high byte). Each byte is loaded into a universal asynchronous receiver transmitter (UART), and transmitted serially over a quartz fiber optic link to a UART on the other board. The receiving UART checks the parity of the byte for a transmission error, if no error has occurred the low and high bytes are 1 to 2 demultiplexed and loaded into a 16 bit digital to analog converter. However, if an error occurs, a error signal is sent back to the transmitting UART over a fiber optic link, and the byte is retransmitted. A byte can be retransmitted up to three time, before the system is reset. The analog signal from the D/A is then analog demultiplexed, and stored in a sample and hold amplifier. All 8 of the analog signals are transmitted through the system in a similar fashion. After the last byte of the 8th signal has been acquired by the receiving UART, a framing signal is sent over the error light pipe link to the transmitter board, and the system is reset. The system than starts transmission at the 1st signal, and cycles its way through again to the 8th signal. The system is bidirectional, each board can transmit 8 analog signals and receive 8 analog signals. The receiving and transmitting circuitry on each board is independent of each other. Therefore, each board could be used separately as a receiver or transmitter.

System Dynamics

The system cycles from the 1st signal back to the 1st signal (refresh rate) in 16 ms. This refresh rate was more than adequate to meet our current application needs. However, the system could be easily modified to operate at a higher frequency. The system can be set up by different jumper configurations to operate plus to minus 5 volts or plus to minus 10 volts. The system is more accurate in the plus to minus 5 volt configuration. In an A/D system the best accuracy achievable is 1/2 the least significant bit. Therefore, higher accuracy is obtained with a smaller weighted least significant bit (5 volt configuration). The system is accurate and stable to the 15th bit. The A/D system is temperature stable, and it has not shown any tendency to drift with time.

System Application

The block diagram of the superconducting magnet control system is shown in Fig. 2. The magnet and the superconducting magnet power supplies during gyrotron operation are locked in an area called the vault. The vault is locked for personnel safety, due to high voltage (80 KV). During operation the currents in the coils of the magnet need to occasionally be adjusted to optimize RF produced by the gyrotron. The bidirectional A/D link was designed to allow the coil currents to be remotely monitored and programed safely. The monitoring and programing are accomplished from an area called the gyrotron control room. There are 8 externally programmable current regulating power supplies used to energize the coils of the superconducting magnet. Each power supply can be programed remotely, to achieve a current from ± full rated current, by a ±5 volt analog control signal. The power supplies are connected to the magnet coils through shunts. The shunt signals are fed into the A/D link in the vault, and are transmitted to the gyrotron control room A/D link. The coil currents are then displayed on eight 4 3/4 digit voltmeters. The meters can also display the power supply control signal voltages, by use of a switch control. The power supply control signal are fed into the A/D link in the gyrotron control room, and are transmitted to the vault A/D link. The control signals are then distributed to the magnet coil power supplies. The superconducting magnet system has been in use

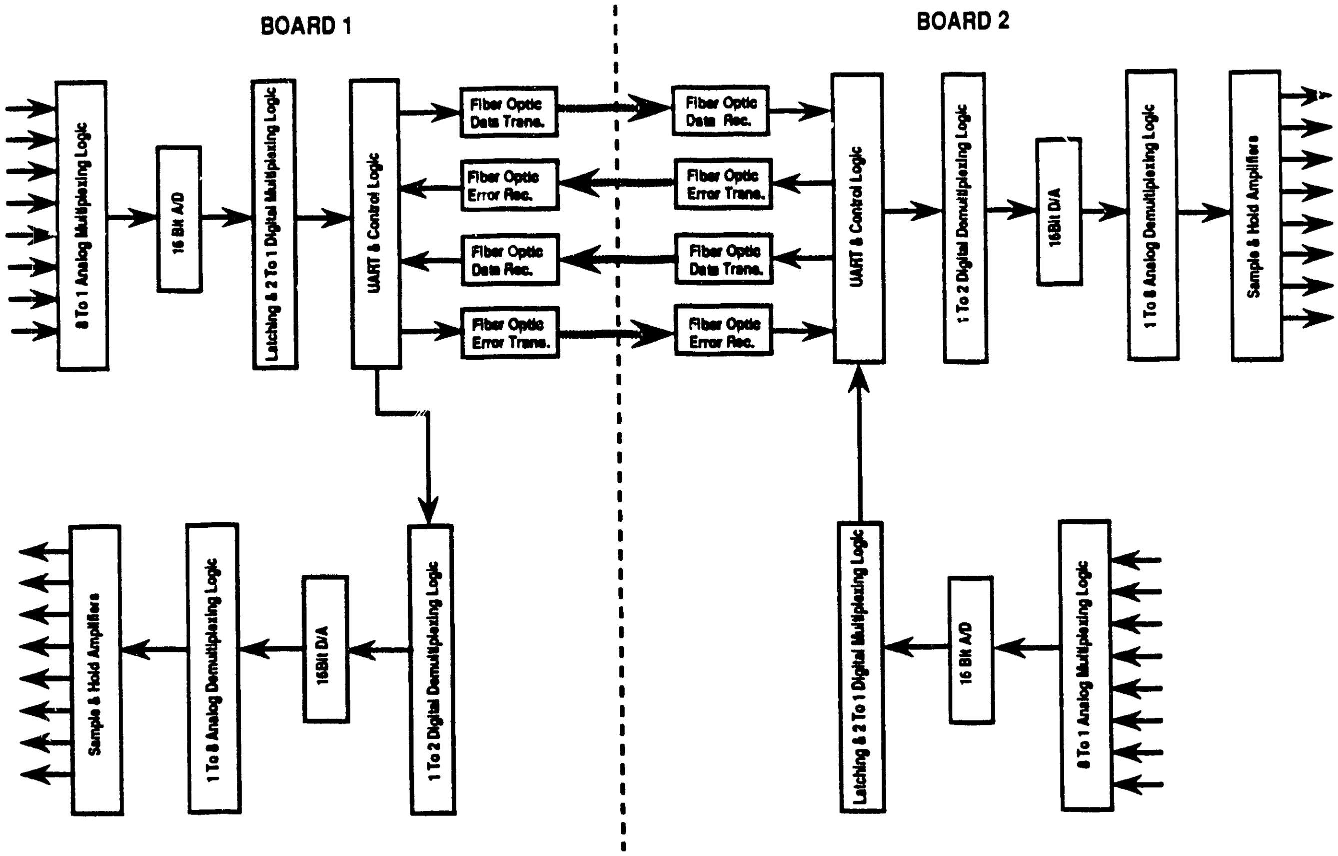

Fig. 1. Bidirection A/D Link

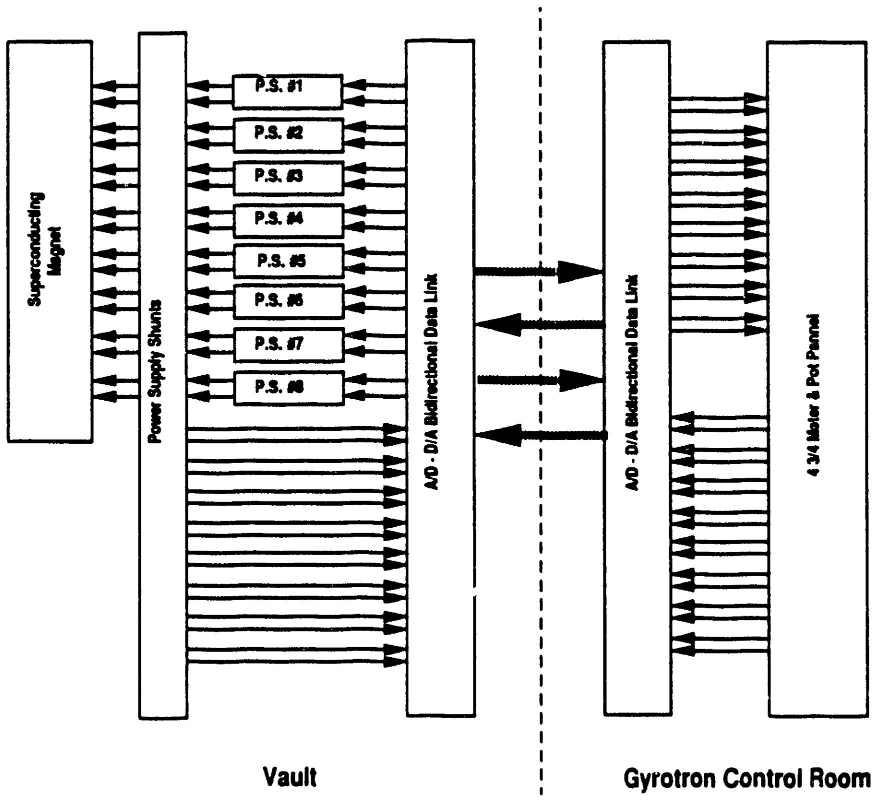

Fig. 2. Superconducting Magnet Control System.

for several months, and it has proven to be an accurate reliable system. The system has also proven to have a high repeatability (a power supply control signal level consistency corresponds to certain coil current). The superconducting magnet control system is essentially an open loop control system. However, in the future the control loop will probably be closed. It would be easy to use the coil current signals as a feedback mechanism to drive the power supply control signals. With the loop closed you could set a reference current and force the power supply signal to set and maintain indefinitely a coil current equal to the reference.

Future Applications

The A/D bidirectional data link is a very versatile telemetry control system which can be used for monitoring and/or transmitting analog signals. It can be used in open or closed loop control systems, and it can operate in a high voltage environment.

Acknowledgment

This work was sponsored by the U.S. Department of Energy under Contract No. DE-AC03-89ER51114.

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