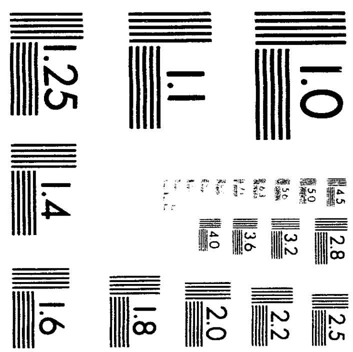
1.0
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DOE/ER/79124--T1

Technical Report: University of Wisconsin

June 30, 1993

Grantee: Don D. Reeder, University of Wisconsin - Madison

Grant Number: DE-FG05-92ER79124
Project Period:

Description of Equipment: Detector Development and Test Facility

1 Introduction

Following the ideas presented in the proposal to the DoE, we have begun to acquire the equipment needed to design, develop construct and test the electronic and mechanical features of detectors used in High Energy Physics Experiments. A guiding principle for the effort is to achieve integrated electronic and mechanical designs which meet the demanding specifications of the modern hadron collider environment yet minimize costs. This requires state of the art simulation of signal processing as well as detailed calculations of heat transfer and finite element analysis of structural integrity.

2 Status and Use

The Electronic CAD facility composed of four HP Workstations and a complete installation of Mentor-Graphics design software is operational. The high speed QMS laser postscript printer for generating B-size engineering drawings is also working. The distance measurement equipment based on laser positioning is in routine use. The mechanical CAD system is installed on an McIntosh Quadra color workstation using the commercial software package Microstation by the Intergraph corporation. The management control and scheduling system has also been installed on this platform and is in use.

3 New Projects

The initial activity to which the facility has been addressed is the SDC detector planned for deployment at the Superconducting Supercollider. The specific components for which the Wisconsin group is responsible are: the first level trigger, a sophisticated pipelined electronic event selection which passes on the data for one in a million of the collisions; the intermediate muon system, a portion of the overall muon detector which fills in the rapidity range from about 1.2 to 2; and the 35,000 ton iron solenoidal magnet and energizing coils used to measure the momentum of the muon.

4 Operational and Maintenance Expenses

The maintenance expenses for the 4 HP workstations are presently \$ 523 per month and will rise to \$ 1005 per month when the initial warranty coverage expires in December. The maintenance for the laser printer is \$ 144 per month.

.5 Faculty and Student Involvement

Faculty and students have been involved in the electronics CAD design effort. An example is that part of the equipment represents an upgrade of existing software and hardware which has been used by one of our students, to produce an ASIC that adds 4 12-bit numbers and can operate in the clocked 16-ns trigger structure. The device is a pipelined domino logic two-stage adder fabricated in 1.2μm CMOS technology[1]. This student is now using the newly acquired software and hardware to produce a greatly enhanced version of the ASIC that can add 8 11-bit numbers in a single 8 nsec cycle. The device is designed in GaAs technology from Vitesse corporation. It will enable the summation of calorimeter energies in an adder tree with circuitry half the size that would be employed with a 16 nsec throughput.

The Physics faculty and post-doctoral staff are: D. Carlsmith, S. Dasu, A. Erwin, R. Loveless, S. Lusin, D.D. Reeder, W. Smith, M. Thompson

The engineering staff are: Jeff Cherwinka, Lee Greenler, Farshid Feyzi, Tom Gorski, Joseph Lackey, Alan Pitas

The technical staff are: Grant Emmel, Glen Gregerson, M. Frankowski

Students involved to date: P. Galecki, D. Panescu, W. Temple, J. Frandy, D. Anderson, LeeAnn Daniels, J. Olsen

6 Results

6.1 Calorimeter Level 1 Trigger

The challenge is to design a pipelined trigger capable of dead-timeless operation and sensitive enough to reduce the rate from tens of MHz to a few kHz. The imposition of both fast operation and economy together with the large number of channels leads naturally to the design of custom circuits and chips. With a large and complex system the interplay of elements can often be unpredictable, so that the operation is checked at every stage by detailed simulation.

6.1.1 Electron Trigger Studies

Using the HP work stations we have simulated[5] electron triggers in SDC with high statistics and found the single tower trigger efficiency for single electrons (as a function of p_t) has a soft turn on. Upon examination of a two tower trigger we found that the threshold became quite sharp, albeit with a somewhat larger rate. We have also compared the efficiencies of several isolation algorithms using cuts on individual tower energies and the neighborhood sums. Almost all of these algorithms were found to yield good results, of about a factor of 3-4 reduction in the rate. Moreover, we learned that the requirement that the HAC energy in neighboring towers be less than 1.6 GeV, in addition to the usual $H/E < 0.05$ cut, provides a additional reduction in the background rate.

6.1.2 System Design

Based on the simulation work cited above, we have prepared and revised a level-1 calorimeter trigger specification document[6] together with our University of Chicago collaborators. The design is evolutionary for, as the calculations proceed, insights are obtained concerning improvements. For example, we have determined that the interboard communication in the calorimeter Summation Crates is quite manageable for the isolation algorithms suggested above. Although the original design implemented the isolation criteria by collecting data from each Memory Lookup (MLU) card, the design facility permits the examination of a solution in which the isolation logic is distributed across the MLU's – with the potential savings of two boards in the Calorimeter Summation Crate. Based on information obtained using the facility, we have prepared and revised a first draft of level-1 global trigger specification document[7].

We have developed a method for synchronizing the transmission of trigger data from front end electronics via fiber optics[4].

As the design solidifies, we use the facility to examine the individual card power budget. We are studying methods of power distribution within the crates.

Several of the specific modules and ASIC's (Application Specific Integrated Circuits) that have been done in part or wholly using the facility are:

6.1.3 Trigger Emulation Module

We have devised a module (Trigger Emulation Module)[2] that emulates the 60 MHz clock and control functions that are expected during SDC operation. This module is designed to stop and start clocks, delay signals by anticipated transit times, and imitate basic sequences of trigger signals. The module operates in a standard VME crate and is controlled by a standard VME processor. Its purpose is to aid in the test bench debugging of subsystem DAQ and trigger circuits, and to serve the basic functions of a trigger module for test beam experiments. The TEM is designed to operate as part of a bench test of front end electronics, where it provides patterns of level 1 and 2 trigger and clock signals that can be fed in from either pulsers, an external pattern generation module or a DAQ processor. The TEM is also designed to operate in a test beam, where the clock is externally provided by the accelerator RF signal and the triggers are produced by beam hodoscopes.

We have finished and tested 15 final production model working TEM's and shipped modules to Collaborating institutions. We have tested these modules with software both under OS9 and Vxworks operating systems. We are working with Fermilab physicists to incorporate these modules into general test bench and test beam operating systems.

6.1.4 Pattern Generation Module

We have built a module (Pattern Generation Module)[3] that produces the same detailed patterns of clock and control signals expected during SDC operation. The device and allows the user to interact with it to change the sequences of triggers and control signals. The module operates in a standard VME crate and is controlled by a standard VME processor. It produces a pattern output stream that contains sequences of trigger accepts and other control bits. This module features a user-programmable state machine which permits it to serve as a source of a wide variety of complex patterns for the TEM. The board switches patterns or engages sequences of patterns under control of external signals from the front panel or VME backplane. Sequences in excess of 1 second's worth of 60 MHz data can be put together with combinations of smaller sequences selected by descriptor words.

We have built 15 final production PGM modules which are now under test at Wisconsin. The detailed testing involves a combination of diagnostic test programs and primitive utility programs, using a MVME167 processor board running the OS/9 Operating system. The cards are brought into complete compliance with the PGM Specification document, with only minor post-assembly modifications required. In terms of maximum execution speed, each PGM will be able to run at least as fast as the TEM with which it will eventually be paired, providing for operation with a clock rate at least 10% above the nominal 60 MHz operating frequency. We have developed and used a suite of software designed to test the PGM in an environment similar to that expected in the field as well as to provide a full checkout in a controlled test environment.

6.1.5 Adder Tree ASIC

We have developed a design for an integrated circuit that can add 8 11-bit numbers in a single 8 nsec cycle. The device is designed in GaAs technology from the Vitesse corporation. It will enable the summation of calorimeter energies in an adder tree with circuitry half the size that would be employed with a 16 nsec throughput. The design also includes full diagnostics implemented on the chip itself.

6.2 Magnet Iron

The innovative and elegant design of the toroidal magnet iron has been done at the University of Wisconsin, in part using the new mechanical design facility. The University of Wsiconsin still remains the lead institution in the design effort, but the activity has been supplemented by staff of the SSC laboratory. The success of this hand-off of responsibiliy is possible only if the computer systems are compatible and adaquate networking capacity is in place. These are provided in the mechanical CAD facility.

One of the first major design reviews completed for detectors at the SSCL was the review of the magnet Iron for SDC. The Conceptual Design Report (CDR) was accepted and approved by the laboratory with alacrity in part because of the utility of the general CAD system.[9, 10, 11, 12]

A prototype of both a long and short block have been constructed at the AtomMash plant in Russia. Various quality assurance tests and bolting tests were sucessfully made shortly thereafter, validating the finite element analyses done in part using the mechanical CAD. There remains considerable revision and re-approval of the drawings before release of the production contract. Again the smoothness of the transfer of information between SSCL and the U of Wisconsin is very evident when compared to the difficulties doing similar operations between the U.S. and Russia.

6.3 Barrel Coils

The magnet is energized via eight coils which conduct 5000A of d.c. electricity. Considerable heat is generated and must be removed. The design of the coils and of the tooling used to construct them are being done using the CAD system. One of the first studies made was to examine the cost/benefit obtained by use of either Aluminum or Copper as the base material. Among the specific features of the design investigated were: implications for low conductivity water (LCW) used to remove the heat; transportation of the raw material; taping to insulate the turns; cost of the material meeting the specifications; and the welding (and verification of the weld) of the end connections.

Although not specifically made responsible for the design of the power supply and the bus bars, the UW group continues to on defining the parameters and requirements for the system. One aspect of this work is understanding the safety requirements for voltage and the resulting implications. Other technical issues involving the use of the CAD facility were: lifting fixtures, curing oven design, thermal analysis, fixture design, and cost and schedule updates. Design work has begun on the taping fixtures.

6.4 Intermediate Muon Chambers

The intermediate muon detection system is comprised of a number of drift chambers to be attached to the ends of the toroidal iron cylinder. The scale of the project is such that each of the eight chambers at each end weighs about 10 tons. Thus the attachment and installation has important safety considerations. In addition the chambers are to be located to a precision of about 0.25mm. Yet another consideration is that the barrel drift chambers of the central region extend well over the ends of the iron, requiring the intermediate chambers to be inserted blindly should these be in place. A complex scheme was devised using an expensive counterwighted installation fixture, which was proved to be a valid solution using mechanical CAD techniques.[13]

It soon became apparent, however, that if the installation of the barrel and intermediate were coordinated it would be possible always to use the crane, while lifting over the center of gravity, thus eliminating the expensive installation fixture. This "bottoms-up" approach to installation imposes constraints on the schedule of construction of the various modules, but the cost savings in time and money were deemed worthy. Again the mechanical CAD was used to explore the tolerances and the motion during installation. The various attachments to the iron were designed to mount multi-tower modules (whose wieght ranges from 10 to 35 tons) using the CAD facility and drawings were prepared for the design report. Shop drawings for actual construction of the parts will proceed as soon as the actual construction is initiated.

Since its arrival the laser measurement system has been invaluable in adjusting and levelling the tables used in the prototype construction and to measure reliably and reproducibly the straightness of the 9m long tubes delivered from the extruder. The straightness measurement is only possible using this equipment. The tubes must be located with an accuracy of about 1/4 to 1/2 mm with respect to the wires. The location of the tubes is to be monitored using the laser system. Finite element calculations using the Mechanical CAD system were used to check the gravitational sag and to separate gravitational effects from extrusion errors. A prototype composed of sixteen cells was assembled without epoxy. This was done to check the assembly scheme. Variations on the theme of holding the tubes during the setting of the expoxy will be explored and their success measured using the laser measurement system.

Using the mechanical CAD we modified the layout of the tubes such that in one dimension only six layers were needed instead of eight, a more economical arrangement. Drawings were made to reflect this change.

The new laser alignment tooling was received and tested. The equipment worked well. Accuracies to 25 microns over 10 meters appear to be possible given the proper environment and operator care.

A detailed fabrication schedule and resource allocation for the construction and assembly of the intermediate muon system was initiated using the MacProjectPro commercial software. This is the method of choice used by the experiment management. Various scenarios were examined to see, for example, the effects of epoxy setting times on crew size and time to completion.

Measurement of the tension of the anodes wire in the drift tubes is essential for monitoring the quality control of the tube assembly and to check the long term stability of the feed-through and crimping of the wire. Although there are several possible approaches to the problem, we elected to pursue those which permit the measurment after the tubes are installed. S. Lusin has proved an innovative approach to the problem.[14]

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