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SCYLLA IV-P COMPUTER BASED CONTROL AND DATA ACQUISTION SYSTEM

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INTRODUCTION

The Scylla IV-P computer-based control system replaces the hardwired special purpose relay logic control system that was used on previous CTR experiments at Los Alamos. This work was initially described in November 1975.[1]

Since 1975 the computer system has grown and matured. The experiment began operation in January of 1976 and since that time there have been approximately 3600 main bank discharges, over two thirds of them plasma discharges.

CONTROL HARDWARE

The main computer is a Prime 300 with 64K words of main storage, two Tektronix 4010 terminals, a Versatec line printer, a card reader, and two 3M word disks. The interface to the experiment is through a CAMAC branch driver with two crates. All signals from and to the bank, which comprise both digital and analog inputs and outputs, the control panel functions, and all the data acquisition devices as well as the teletype driver module which is the link to the CTR Network PDP-10, are interfaced to the computer via the CAMAC branch highway (Fig. 1).

The control panel contains various switches, lights, and buttons for running the experiment. A key lock controls the AC power. A large scram button turns off the power to the buffer relay chassis, allowing the operator to bring the machine to a safe state in an emergency. There are buttons to start a charging sequence and to initiate the preliminary and final charge cycles. An LED display containing five alphanumeric characters is used to indicate cycle or timing information. Sixteen switches allow the operator to select the type of machine cycle to be run. A set of thumbwheel switches can be used to graphically display signals of interest in addition to those normally displayed during the machine cycle.

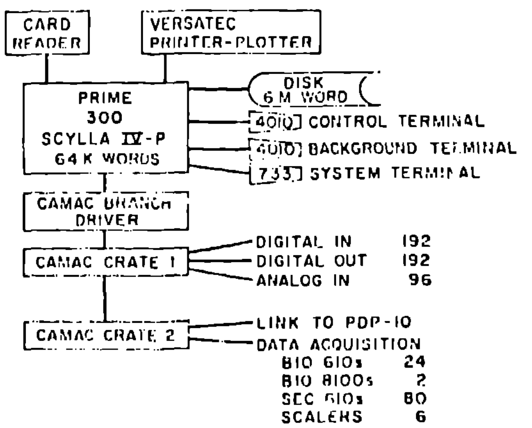

Figure 1
Hardware for Scylla IV-P Computer System.

The safety interlock system is hardwired for protection of the operating personnel. If a door is opened or a scram button is pushed the machine is immediately brought to a safe state. The control program monitors all interlocks and prints a message on the CRT screen stating which interlock was broken.

A CAMAC "keep alive" or "fail safe" module protects against computer failure. This module controls the power to the buffer relay chassis through which all signals to the experiment run. If this circuit is not pulsed every 50 milliseconds by the computer, it turns off the power, and all systems revert to a safe state.

Great care has been taken to avoid electromagnetic and radio frequency interference. Buffer relays, isolation transformers, and a double-shielded screen room protect the computer from the theta pinch environment. All cabling was done carefully to minimize ground loops.

CONTROL SOFTWARE

The control program is driven from lists contained in disk files, allowing a high degree of flexibility in operation.

Instructions defining the sequence of operations for a machine cycle or shot are compiled with a control language consisting of macro calls to the assembler. Twenty seven commands have been implemented, and new ones are easy to add. The operators compile a list of instructions such as the following.

```
TURN ON DUMPJ
WAIT UNTIL VOLTAGE GT 50
DISPLAY PRBKM01V LEFT
```

The Prime assembler takes these instructions, which are actually a set of macros calls, and converts them to 12 word blocks. Each block consists of a command number, sequence number, a switch word, a signal number, an eight character label, and four parameter words. The command number identifies the type of command. The sequence number allows branching within the control program. The switch word determines on which type of machine cycle an instruction will be executed: different instructions are executed for a trigger test than for a main bank discharge. The signal number identifies the signal in this operation. The label contains any alphanumeric information needed by the command, such as the signal name for error messages or the program name for requested tasks. The parameter words can be used to store any necessary information, such as the number of clock ticks in a wait instruction or a value needed by a requested program (Fig. 2A,B).

These twelve word blocks are then used by the instruction processor in the control program. The entire list is read for each machine cycle, but only those instructions with both the correct sequence number and proper switch type are executed.

Other lists contain information on input, output, and analog signals. The input and output lists contain signal numbers and associated eight character labels.

To assemble the instruction

```
        TURN ON HLASRARM
```

which turns on the digital signal to arm the holographic interferometer laser bank, assume the following variables are predefined.

```
ON        EQU     1
OFF       EQU     0
HLASRARM  EQU     170
*
SET TYPE = 987
SET SEQN = 3
```

Using these macros

```
TURN      MAC
          IF (<1>.EQ.1)     CMD 1,<2>
          IF (<1>.EQ.0)     CMD 12,<2>
          DATA              0,0,0,0
          ENDM
*
CMD       MAC
          DEC     <1>       COMMAND NUMBER
          DATA    SEQN      SEQUENCE NUMBER
          DATA    TYPE      SHOT TYPE
          DATA    <2>       SIGNAL NUMBER
          BCI     4,<2>     SIGNAL NAME
          ENDM
```

the instruction is converted to the following twelve word block.

```
1               COMMAND NUMBER
3               SEQUENCE NUMBER
987             SHOT TYPE
170             SIGNAL NUMBER

'HL'
'AS'            SIGNAL NAME
'RA'
'RM'

0
0               PARAMETERS
0
0
```

Figure 2A
Example of instruction expansion

To assemble the instruction

```
        MESSAGE (**LASER READY**)
```

which prints a message on the operator's console, assume the following variables are predefined.

```
SET TYPE = 468
SET SEQN = 16
```

Using this macro

```
MESSAGE MAC
        DEC     7         COMMAND NUMBER
        DATA    SEQN      SEQUENCE NUMBER
        DATA    TYPE      SHOT TYPE
        DATA    0         SIGNAL NUMBER
        BCI     8,<1>     8 WORDS OF
                            ALPHANUMERICS
        ENDM
```

the instruction is converted to the following twelve word block.

```
7       COMMAND NUMBER
16      SEQUENCE NUMBER
468     SHOT TYPE
0       SIGNAL NUMBER

'**'
'LA'    LABEL FIELD
'SE'
'R '

'RE'
'AD'    PARAMETER FIELD
'Y*'
'* '
```

Figure 2B
Example of instruction expansion.

The analog list contains several entries for each signal. The uses of these are described below.

All lists are easily modified with the Prime text editor to change the cycle sequence or signal function.

The control program consists of two main tasks, a monitor and an instruction processor. The instruction processor steps through the list of instructions and takes the necessary action, turning signals on or off or requesting other tasks. The monitor scans signals and status lists and ascertains that the signals are in the required state or at the required level. Potentially dangerous operations are prohibited as a protection against human error.

Analog signals are monitored through a "window". The analog list contains for each signal an upper and lower limit for the "off" state, an upper and lower limit for the "on" state, and a time value at which the signal should reach its full scale value. While the signal is turned off it must stay within its "off" limits. When the signal is turned on, the limits change linearly to the "on" limit values over the time period specified. If the signal goes out of these bounds, the machine cycle is aborted (Fig. 3).

These two main tasks, the monitor and the instruction processor, remain in main storage

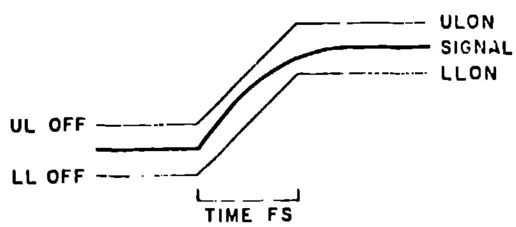

Figure 3
Analog signal monitoring with changing limits.

throughout a cycle. Other tasks are called into main storage from disk as needed.

The Background DOS feature of Prime's Real Time Operating System has been implemented. This feature allows a background user from a second terminal to use the complete DOS operating system concurrently with the operation of the experiment. Data analysis programs can thus be executed on existing data while new data is being taken.

A simple graphics library has been written to display data. This library contains routines to plot floating point or integer data, to position the cursor for labeling, and to erase the screen and make hard copies. It is a compact and efficient package and has been adequate for most needs.

The Tektronix PLOT10 graphics package has also been implemented on the Scylla IV-P computer. This package is larger and less efficient, but is in some respects more powerful and is compatible with existing PDP-10 programs.

DATA ACQUISITION

There is a variety of data acquisition devices currently in use on Scylla IV-P. Twenty four Biomation 610 and eighty SEC 610 transient recorders are used to digitize plasma luminosity, magnetic field loop-probe, and other diagnostic signals. Two Biomation 8100's record coupled cavity interferometry data. Scalers are used to count neutrons. All these devices have buffer storage and are read into the computer after they have finished digitizing. They are typically triggered and read at the beginning of a machine cycle for calibration purposes and again at the end of the cycle to collect the data.

The data from a machine cycle (shot) are saved on a disk file, one file per shot. The information from each device is saved in a record with a 20 word header and a variable number of packed data words. Data are retrieved by shot number and logical device number.

The header contains information such as shot number, date, physical and logical device numbers, calibration information, CAMAC crate, slot, and subaddress, ASCII label for the device, type of shot, etc. The use of a logical device number, in addition to a physical device number, allows a diagnostic to be moved to a different physical unit without changing the analysis program that uses it. Only the logical device number in the header needs to be changed.

The data portion of each record is packed to conserve disk space. Six bit information is packed eight six bit items into three sixteen bit computer words. Eight bit information is packed two to one.

The data files are stored on removable disk cartridges. When one disk is full a new one is started.

A system has been devised for saving constants along with the data for a shot. These can be any ASCII or floating point items, such as RC constants and other settings on diagnostics or labels telling where a diagnostic is positioned. These constants are saved in the same format as all other device records, with a 20 word header and a variable number of data items, except the data are floating point or ASCII items instead of integers. Each has a logical unit number associated with it by which it can be retrieved.

A second computer, a Prime 100, will run the two dimensional Thomson scattering diagnostic. This device records plasma light intensity versus wavelength and radius, from which electron temperature can be calculated. A three-grating polychrometer disperses the scattered spectrum and screens out unshifted laser light. The resulting image is digitized by a silicon intensified target TV camera and read into the computer for analysis. With only 32K of main storage and a floppy disk, the Prime 100 is too small to do extensive analysis. Therefore the Thomson scattering data will be shipped to the PDP-10 using a CAMAC teletype driver link similar to the one described below for the 300. The two Primes will be linked to communicate information such as shot numbers and timing signals.

Over the life of the experiment a large data base of diagnostic information has been acquired, approximately 50 million 16 bit words. This data base is easily accessible from either the Prime 300 or the PDP-10 and has allowed extensive analysis of the machine operations. Cross correllations and averages over many shots and other numerical techniques facilitate a deeper understanding than was previously possible.

PDP-10 LINK

The Prime 300 and 100 have been linked to the CTR network PDP-10 computer through teletype driver modules, SEC TCO-100's, using regular terminal lines from the PDP-10. The line speed is currently 1200 baud, with a planned increase to 9600 baud in the near future.

Software has been developed which allows the terminal on the Prime to look like a terminal to the PDP-10, and also allows the Prime to ship ASCII files and shot data. All information is currently being sent as ASCII or simulated ASCII characters. An eight bit protocol for binary data is being developed for the PDP-10 which should greatly simplify the transmission of non-ASCII information.

The bulk of the data for a shot (data from all six and eight bit transient digitizers) is compressed before shipping. The data are differenced and saved as a series of counts and differenced values. This scheme reduces the required storage space and transmission time by about two thirds.

Data are currently being sent as six bit simulated ASCII characters. For transmission the 16 bit Prime words are divided into six bit bytes. An offset is added to these to put them in the range of legal ASCII characters (no control characters, etc.). On the other end the PDP-10 receiving program subtracts off the offset and packs the six bit information into the 36 bit words of the PDP-10.

To ensure that all characters are sent to the PDP-10 correctly, a scheme has been devised for checking echoes. A string of characters is sent and the echo is checked. Non-matching echos (errors, operator messages, etc.) are printed on the screen. When all characters have been matched by their echo, a carriage return is sent. If a match is not made in a given length of time, a CTRL U (delete this line) character is sent and the line is sent again. Up to twenty attempts are made to resend the line. If all of these attempts fail, the program aborts. No problems have arisen in transmitting information from the PDP-10 to the Prime, therefore no checking is done on this data.

On the PDP-10 data are saved in files which correspond to disk packs on the Prime. There is an ASCII file which serves as a directory of data disks and shot numbers. This directory includes the names of the data files, the shots on these files, and the number of the magnetic tape on which these files are permanently archived. The shipping program updates this directory each time a shot is shipped, adding entries for new data disks when necessary.

Some selected Prime system calls have been simulated on the PDP-10 to allow program compatibility between the two computers. It is now possible to write programs which, with only minor modifications, can run on either computer. Thus programs can be developed on the PDP-10 in a timesharing environment for use on the Prime, where computer time is at a premium, and Prime programs can be run on the PDP-10 for extensive data analysis and reduction.

CONCLUSION

The Scylla IV-P Theta Pinch was the first CTR experiment at Los Alamos to be completely computer controlled. There have been problems, but on the whole it has performed very satisfactorily. It has proven to be simple, flexible, and reliable. The ZT-40 experiment will utilize a computer based control system which builds on the experience gained on Scylla IV-P.

ACKNOWLEDGEMENTS

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REFERENCE

1. J. W. Lillberg, G. I. Chandler, and F. T. Seibel, Scylla IV-P Computer Based Control and Data Acquisition System," These Proceedings, 1975.

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