THE DATA ACQUISITION SYSTEM (DAS) FOR THE IMPROVED CERN SC

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Abstract

A digital data acquisition system (DAS) based on a minicomputer is described which registers the failure sequences in various equipment areas of the CERN synchrocyclotron (henceforward referred to as the SC). The avalanches of failure signals which occur from time to time are tapped from the alarm/security systems, time-resolved to 10 msec and recorded on a printer in order to aid SC failure diagnosis. The mechanisms of the DAS and its relation to the SC equipment are explained in some detail. All programs were constructed at assembler language level for speed and for ease of on-line program maintenance. The alarm sequences recorded have been of considerable help during the running in of the new radiofrequency system. Now that the new SC is operational, the DAS furnishes useful data from several equipment areas to the operators and engineers.

Introduction

It was felt that a better understanding of the series of events occurring upon SC failures than could be obtained with visual failure indicators was necessary in order to decrease the time taken in machine fault-tracing. Some failures happened mysteriously and the sequences of alarms occurring needed to be analysed so as to find the likely source of trouble and get the SC running again as soon as possible.

Experience had shown that the most sensitive equipment area was the radiofrequency system, and so it was the first system chosen to have its alarms monitored by a fast alarm-scanning system known as the DAS[1]. A minicomputer system was developed in the period 1971 - 1973 to scan at 100 Hz up to 576 alarm signals and to produce a printout of the alarm events resolved to 10 msec[2][3].

The scanning speed proved to be just high enough to resolve the failure signal sequences from the SC alarm/security equipment as shown in the attached sample of printout in section 2. To achieve this speed, the programs had to be constructed at assembler level.

The necessity of including interlock signals with the alarm signals sent to the DAS is discussed in section 1.2. The evaluation of alarm-events to obtain a printout containing only equipment failure sequences is described in section 2.2., where the role of the interlock signal in alarm-event selection is clearly shown.

The utility of the DAS depends upon the skill of interpretation of the printed alarm sequences. It is necessary to have a sound knowledge of the systems to which it is connected to get the best out of it as the DAS cannot make either interpretation or diagnosis.

1. System Hardware and Input Signals

1.1 Hardware description

The central processor is a Siemens 301 computer. It is a 16 k word, 24 bit, single accumulator, 1.6 μsec cycle-time machine with multiprogramming at assembler language level. Its input/output passes via an accumulator interface. There are two interrupt levels, conditional (for input/output handling requests, etc.) which waits for specifically marked interrupt-points in programs, and immediate (for simulating non-hardwired instructions). Peripherals are restricted to paper-tape reader and punch, operator's teleprinter, hardware clock and the signal input/output units.

A closed loop TV system serves to transmit the data typed by the teleprinter to the SC control room and various equipment areas. The hardware clock was built to provide the time and day for the scanning. It is quartz controlled and it provides at the computer inputs a time indication down to msec. It also serves to trigger the scanning at 100 Hz and to trigger a printout reaction every 10 minutes.

The signals to be led to the DAS from each SC locality are first concentrated in a locally placed junction box and then run to the computer by standard multi-wire telephone cables. The appropriate separation and organisation of the alarm and interlock signals for input to the computer is made in a rack in the computer room such that interlock signals are fanned out to cover the alarm signals one for one.

The alarms with their interlock signals are passively input via two Siemens GRODE crates which contain up to 30 cards of 24 inputs each at 12 V. The cards provide galvanic isolation of signals with ferrite core transformers and noise immunity with 1 msec lag-filters.

Additionally, we obtained further noise immunity by desensitizing the input signals (nominal 24 V) by zener diode buffering in front of the 12 V inputs.

A small number of trigger signals are input via a Siemens ALDE crate. These include the 100 Hz clock signal for the scanning, the 10 minutes pulse and a manual scan-restart signal. These signals generate a conditional interrupt which gets serviced by a special program which determines the action to take depending upon the situation and which trigger caused the interrupt.

1.2 Derivation of input signals

Each SC equipment area (radiofrequency, vacuum pumps, water cooling, slow extraction system, ion source, etc.) has an alarm/security system incorporated with it. It is from these security systems that the DAS input signals are taken because of the concentration of alarm signals available there. In most areas so far connected, the alarms are picked

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off for the DAS at the point where they enter the security system which is immune to DAS short-circuits.

1.2.1 Precautions in picking off signals
Considerable care is taken to ensure that the working of the security systems is not adversely affected by connecting their signals to the DAS. The signals from each equipment area are arranged at the computer inputs to float together independently of the signals from other areas. This avoids DC earth-loops between different equipment areas being caused by the DAS. Most connections of signals to the DAS are made directly from the alarm signals concerned, so each separate equipment chassis which has signals picked off for the DAS can be unplugged from it by a connector near the chassis in order to facilitate equipment maintenance and earth-fault tracing.

1.2.2 The importance of interlock signals
The signals led to the DAS consist of alarm signals with corresponding interlock signals to cover them. The importance of the interlock lies in the facts that it indicates to the DAS whether a particular equipment sub-system is running or not, and, that the DAS has been built to record only the alarms emanating from running systems.

Consider a single SC equipment sub-system which is protected by a number of alarms emanating from it and which has an interlock signal indicating the state of the sub-system (on/off). While an alarm exists, the running of the sub-system is normally inhibited and the interlock stays "out". In this state, alarm-events which occur are not recorded by the DAS. It is only when the sub-system is running (interlock"in") that the DAS is to record alarm-events. In practice, there is normally a short delay before a sub-system gets switched off by one or more of its alarms entering the alarm-state, so there is often a convenient recordable time-lag between the "alarm" and the corresponding "interlock out" as can be observed in the alarm-sequence print-outs a sample of which is shown in section 2.

It follows that to enable the DAS to record only alarm-events from running systems, the alarms from each sub-system must be accompanied by the covering interlock signal.

1.2.3 Signal input to the computer The DAS is laid out for a maximum of 576 alarms, each alarm being covered by an interlock signal in parallel. Each incoming interlock signal is fanned out to cover all its alarm signals by means of a fast reed-relay such that interlocks cover alarms one for one. A cross-connection matrix between the incoming signals and the computer inputs is hardwired to organize and separate the alarm and interlock signals. This arrangement, apparently wasting computer input capacity by duplicating interlock signals, helps to reduce the execution time of the scan program to within acceptable limits. The scan program, each time it is started, does not have to waste time to work out which signals are alarms and which interlocks correspond to which alarms. Alarm signals are led to even-numbered input cards and interlock signals to odd-numbered cards such that, for example, alarm bit 4 of card 20 is covered by interlock bit 4 of card 21. Normal DAS input polarity is where zero volts represents a state of "alarm" or of "interlock out".

2. System Software and Data Handling Principles

2.1 Pre-treatment of input signals

Each time (once every 10 msec) that the alarm and interlock inputs are scanned, they need to undergo a pre-treatment before they can be used. Three 48-cell registers of 24 bits per cell contained in computer core-memory serve to correct the polarity of the scanned signals and to select them prior to their deposition in memory for evaluation. Each of the three registers corresponds bit for bit to the inputs of the 48 signal-input cards.

The register called REVBIT has a bit set high (1) for each input signal needing polarity reversal to become standard.

The register called HOLDOFF has a bit set low (0) for each separate interlock input to be inhibited i.e. held off or "out". This register is used to de-activate unconnected or unwanted DAS inputs by simulating an "equipment off" condition.

The register called HOLDON has a bit set high (1) for each separate alarm input to be suppressed, i.e. held on or "clear". Frequently, due to individual alarm suppressions in remote equipment areas, the DAS has to automatically suppress alarm inputs for itself. The alarms to be suppressed are those remaining in the alarm-state while the corresponding equipment is running. If they persist after five minutes, the scanning is stopped and an alarm-suppression program is triggered which subsequently restarts the scanning again.

Manual intervention on the computer teleprinter is required to unsuppress alarms listed in HOLDON or to alter any part of HOLDOFF or REVBIT. By means of these three registers, a typed instruction controls the suppression, inhibition, re-activation or polarity reversal of any alarm/interlock signal input.

2.2 Evaluation of input signals

Each time it is triggered, the scan program deposits the clock-time and the state of all alarm and interlock input bits (576 of each) in one of two alternately used buffers in computer core-memory, after having performed the polarity corrections and selections of the scanned inputs as indicated in registers REVBIT, HOLDON and HOLDOFF. The other buffer, filled from the previous scan 10 msec earlier, is compared against it and any detected changes of bit-state are analysed to determine which changes, if any, must be stored in an alarm-buffer for interpretation and print-out.

Careful selection of the alarm-events, to exclude the printing of any which come from equipment that is not running, is possible by means of the interlock signal which covers each alarm. A table follows which indicates which printout gets produced, if any, for the changes of state of a single alarm/interlock input-signal pair.

Table 1 : Criteria for Alarm-event Print-out

Key for alarm bit : 1 = clear, 0 = alarm
Key for interlock bit : 1 = sub-system on
0 = sub-system off

alarm	intlk	situation	print-out
1 → 0	1	alarm, system on	ALARM
0 → 1	1	clear, system on	ALM CLEAR
1 → 0	0	alarm, system off	-
0 → 1	0	clear, system off	-
1	1 → 0	system switch-off	-
1	0 → 1	system switch-on	-
0	1 → 0	system failing	INTLK OUT
0	0 → 1	to be suppressed	ALARM

Any simultaneous changes of alarm and interlock together provoke print-outs only when they change in opposite directions which is very uncommon.

2.3 Structure of programs

All programs were written in assembler language to minimize program execution time and to ease on-line intervention inside the programs. Software-simulated instructions were avoided due to their uncertain execution times and their vulnerability. As the precise behaviour of the input signals is not known, the DAS software occasionally fails when an unexpected situation occurs. On-line intervention is then necessary to get the DAS running again as soon as possible, and as experience is gained, the programs are adapted accordingly to become more reliable. The schema of the data flow through the DAS indicates that in order to minimize the possibility of old data being lost or overwritten by a fresh alarm-data sequence, some alarm-event storage capacity is included in the printout program (see Fig. 1).

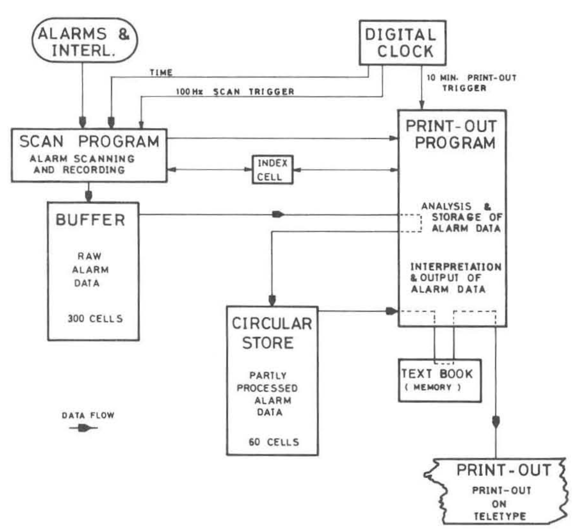

Fig. 1 Overall Schema of DAS Alarm-data Flow

2.3.1 The scan program was constructed for speed and efficiency. Its execution time is about 5 msec. It has a high program-priority level and no interrupt points set anywhere within it. The start-calls for the printout program were placed after the input scanning and evaluation routines. The use of standard macro-calls was avoided, specially shortened routines being constructed instead. Single instructions were saved, particularly inside those recursive loops which are cycled 24 times, once per pair of input cards. The arrangement of the input signals contributes to program speed as explained in section 1.2.3, and the evaluation of the signals is explained in sections 2.1 and 2.2. The structure of the data deposited by the scan program in its 300-cell alarm-buffer is given in Fig. 2.

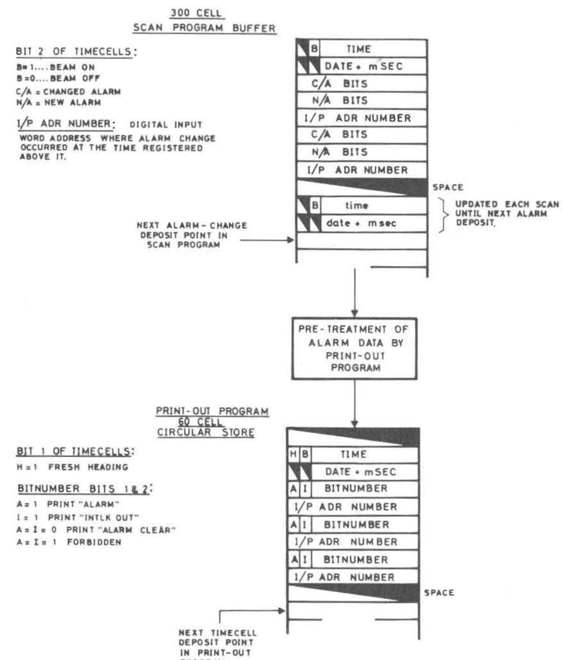

Fig. 2 Method of Alarm-data Storage in the Scan and Print-out Programs

2.3.2 An index cell is included in the scan program to indicate the condition of scanning to the print-out program which reacts accordingly. Bit 1 is set high (1) whenever the scan program resets its alarm deposition pointers back to the top of its alarm-buffer after a 5-minute alarm-sequence recording time. Bit 2 is set high (1) whenever the scan program stops itself being triggered when an alarm to be suppressed exists at the end of a 5-minute recording period. Other bits are used as supplementary indications such as buffer overload or other special conditions.

2.3.3 The printout program has a lower priority level than the scan program and has no severe time restrictions except that it must execute an instruction marked as interruptible within any period of 0.5 msec so as not to significantly delay the starting of the scan program. Simple macro-calls are used and the printout program has a modular structure.

As seen in Fig. 1, the program is split into two main parts. The first part extracts the raw alarm-data from the scan program, interprets them and stores them in a 60-cell circular store in a form suitable for conversion by a printout routine (see Fig. 2). The second part takes the "digested" data from the circular store and produces an alphanumeric alarm-event text sequence which is formed one line at a time and printed out, accompanied by appropriate headings and other indications as shown in Fig. 3.

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14H20M 00.002S   R/F- ON :


            S.C. ALARM PROTOCOL   DAY  043    1975

   TIME            STATE        SYSTEM             LOCATION     ORIGIN
14H28M 05.032S   R/F- ON :
14H28M 05.032S   ALARM      EQ2: CONVRTR,ROTCO  ER6 81AG7* WATERFLOW        2419
14H28M 05.282S   INTLK OUT  EQ2: CONVRTR,ROTCO  ER6 B1AG7* WATERFLOW        2419
14H28M 05.382S   ALARM      S-C: OIL ON ROTCO   ER6 A7AG8  ROTCO START      3617
14H28M 05.422S   ALARM      EQ2: ROTCO AT STG4  ER6 81BG7  OIL SUPPLY       26 3
14H28M 05.432S   ALARM      EQ2: SCREEN,RF-OSC  ER6 83B10  STG4 ROTCO       24 7
14H28M 05.442S   ALARM      EQ2: H.V.R. SMIT    ER6 89BG8  OSCILL READY     2014
14H28M 05.442S   ALARM      EQ2: R/F STANDBY*   ER6 B2A10  STG4 ROTCO       2211
14H28M 05.442S   INTLK OUT  S-C: OIL ON ROTCO   ER6 A7AG8  ROTCO START      3617
14H28M 05.452S   ALARM      *** S.C. R/F ****                               16 1
14H28M 05.452S   INTLK OUT  EQ2: SCREEN,RF-OSC  ER6 B3B10  STG4 ROTCO       24 7
14H28M 05.452S   INTLK OUT  EQ2: ROTCO AT STG4  ER6 81BG7  OIL SUPPLY       26 3
14H28M 05.462S   INTLK OUT  EQ2: R/F STANDBY*   ER6 82A10  STG4 ROTCO       2211
14H28M 05.542S   INTLK OUT  EQ2: H.V.R. SMIT    ER6 89BG8  OSCILL READY     2014
14H28M 29.082S   ALARM      EQ2: CONVRTR,ROTCO  ER6 81AG6  O/C CONVERTER    2418
14H28M 29.122S   INTLK OUT  EQ2: CONVRTR,ROTCO  ER6 81AG6  O/C CONVERTER    2418
14H29M 35.262S   ALARM      EQ2: CONVRTR,ROTCO  ER6 B1AG5  O/C CONVERTER    2418
14H29M 35.292S   ALM CLEAR  EQ2: CONVRTR,ROTCO  ER6 81AG6  O/C CONVERTER    2418
14H31M 59.422S   R/F- OFF:
14H33M 05.012S   R/F- OFF:

SCAN STOP:- ALARM STATE STILL ACTIVE 5 MINUTES AFTER FIRST ALARM.



SUPPRESSED ALARMS:-
       24, 6
       26, 7
       34, 6
       36, 7
       38, 2
       38, 3
       38, 4
       38,18
       40,17
14H34M 37.373S   R/F- ON :
14H40M 00.002S   R/F- ON :
14H50M 00.002S   R/F- ON :
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Fig. 3 A Sample Printout of an Alarm Sequence

The greatest possible care was taken to avoid that alarm data gets lost due to a sudden avalanche of alarm-events. The extraction of alarm data from the scan program takes priority over the generation of printout from the circular store data. Also, any data loss resulting from an avalanche of alarm-events is partial, controlled and rejects old alarm-data still to be printed in favour of a fresh alarm sequence which starts a new 5-minute recording period.

2.3.4 <u>An alarm suppression program</u> of low priorty level serves to suppress alarm inputs where necessary. It sets a bit high (1) in the scan program HOLDON register for each alarm it finds in the alarm state with its interlock still remaining "in". It then lists all the alarms so far suppressed in HOLDON and provokes a time printout , restarting the 100 Hz scan cycling if it has stopped. The program does not execute inside any 5-minute recording period. After scanning has stopped due to an alarm that needs suppressing, the program either gets triggered manually by a button or automatically by a clock-pulse. Two "master" alarms exist which do not get suppressed. These are the main on/off signals from the two interchangeable radiofrequency systems of the SC. They have their interlocks created artificially, and have the power of restarting the 100 Hz scanning when either clears, indicating "R/F-ON" as seen following the list of suppressed alarms in Fig. 3.

2.3.5 <u>Memory core-store utilisation</u>

Multiprogram monitor and control system	4 k
Service programs	2 k
Scan program and program trigger routine	1¼k
Print-out program	1½k
Alphanumeric text storage	4 k
Alarm suppression program	¼ k
Spare capacity	3 k
	16 k

Conclusion

The fact that such a system described above has been successfully used to aid SC machine development and running indicates that the principles used are sound, and hence the construction of such a system for other accelerators or in industry is within reason.

References

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3. R. Cusack, H. Schroot, A computer controlled data acquisition system using 100 Hz sampling, CERN-MSC-M-6, 9.8.1973.