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THE SERIAL DATA ACQUSITION SYSTEM AT PETRA

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Summary

Design principles, realization parameters, and results of experience are reported of SEDAC, the serial data acquisition and control system which connects all of PETRA's distributed equipment to a centralized computer pool. Currently, 800 vacuum power supplies, 64 rf cavities, and 150 beams monitors are on line.

Introduction

A storage ring of PETRA's size and complexity is manageable only through the use of computers. The only computer independent parts of the control system are safety circuits such as radiation and personnel interlocks, which have to be hard wired. All other systems are connected to the central control room via a multiplex system rather than via separate cable links for each component.
Since access to the component supplies and control equipment is mandatory even during operation of the storage ring, they were concentrated in the 10 halls around the ring. The Equipment Control Modules (ECMs) in these substations are connected to the computers in the central control room via the SErial Data Acquisition and Control system (SEDAC).

SEDAC fulfills the following requirements:
- modular concept:
  One ECM completely handles one piece of accelerator equipment (e.g. one ECM for one magnet power supply), as opposed to general interfaces for digital output, digital input, analog output, analog input. This eliminates the switchyard between equipment and control modules.
  If package density permits, one ECM can handle several identical units (e.g. one ECM for 4 ion sputter pumps).
- Modules may be changed in a powered crate without affecting the other modules in that crate.
- Changing a crate controller or a whole crate does not bother the rest of the system.
- Clean ground separation must be maintained throughout the whole system.
- To keep down complexity and price, no features not necessary for the application should be implemented.

Since no commercially available system met all of these requirements, the PETRA control group designed and built SEDAC.

Hardware Hierarchy

One SEDAC system consists of (Fig.1):
- the SEDAC driver, which is a PADAC[1] computer peripheral
- a transmission line (four RG58U coaxial cables, one for writing data to the ECMs, one for reading data, and one pair for analog signals up to ~5 MHz),
- pick up stations in the halls for ground free connection to the transmission line by transformer coupling. The write data line is not interrupted, since the transformer primary is formed by feeding the center conductor straight through the ferrite ring core. Within one substation, data is transmitted symmetrically via twisted pair lines.
  On their way back from the addressed ECM to the SEDAC driver, the read data are passed through all intermediate substations and actively repeated in each crate controller. Unpowered crates are bridged by relays.
- substations consisting of SEDAC crates with a crate controller and up to 11 ECMs each.
  The four divisions vacuum, rf, monitors, and magnets are equipped with independent SEDAC systems. This feature is extremely important for test of equipment and algorithms during setup and maintenance periods.

Data Transmission

Data is transmitted in packages called telegrams. For every telegram, the SEDAC driver transmits 46 bits to an ECM and expects 19 bits back. Data bits are biphase encoded. Using a bit time of 4 μs, a telegram is transmitted every 250 μs. Telegrams not needed for data transfer are used for request collection.

Transmitted telegrams consist of 5 bytes with a parity bit each:
byte 1 2 bits function code
 1 bit 'common pulse' for operations addressing more than one ECM simultaneously
 5 bits crate address

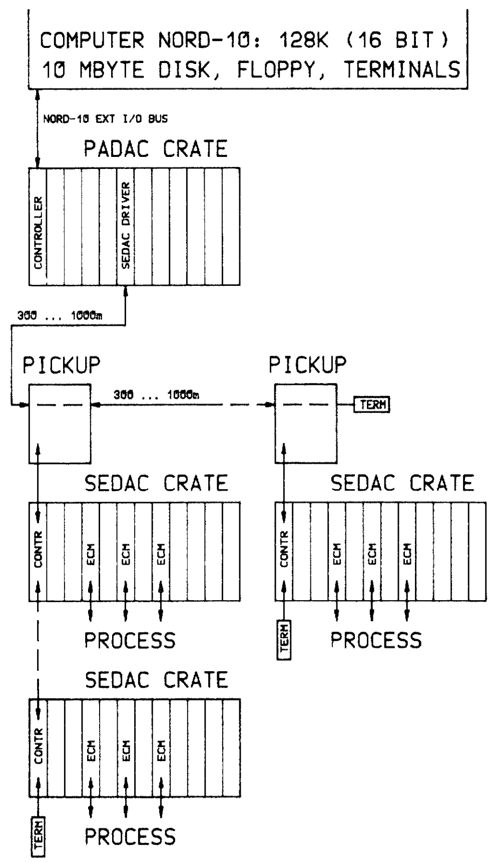

Fig. 1 SEDAC System Layout

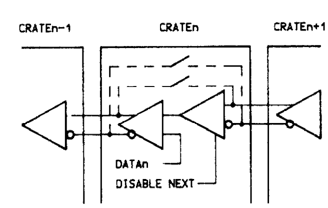

Fig. 2 Crate Controller Chaining

byte 2 8 bits subaddress
The base subaddress of an ECM is established by a code plug rather than by its position within the crate.

byte 3 vertical parity
Together with the horizontal parity bit for each byte, this enables the recognition of 2-bit errors during data transmission.

byte 4 high order write data

byte 5 low order write data

bit 46 bit time frame for response bit

The received telegrams consist of 2 bytes with parity:

byte 1 high read data

byte 2 low order read data

bit 19 response bit which indicates that the addressed ECM exists and received a formally correct telegram.

Four telegram functions are available:
- digital write
- digital read
- analog switching of one signal (current sourced) to the analog line
- request collection

Analog transmission was built into the system, but the designers of the individual ECMs preferred A/D and D/A conversion within their modules instead.
Request collection telegrams are automatically substituted for 'empty telegrams' by the SEDAC driver. ECMs issue requests by grounding their individual request lines to the crate controller, where they are arbitrated in a position dependent priority scheme. In response to the next request collection telegram, 2 bytes are returned to the SEDAC driver:

byte 1 crate address

byte 2 requestors sub address

Both bytes are generated by reading out the address plugs of the crate controller and the requesting ECM. If several request addresses are transmitted back during this telegram, the crate controller closests to the computer will win, since it transmits its data and blocks any other from further down the line. Clearly, no response times can be guaranteed. Thus, ECMs must not rely on computer action for fail safe operation.

Packaging

SEDAC is housed in standard NIM bins 5 units high with a modified back plane. Of the 12 available slots, one is used for the crate controller, leaving 11 for ECMs. The front panels are used for cable connections to the controlled equipment and indicators. The relatively low package density permits the use of sturdy connectors and convection cooling. Connection to the backplane is made through a standard 64 way indirect connector with self-guiding properties (DIN 41 612 - IEC 130/14). Of the 64 pins, 20 are used for bus bars distributing +5V, +15V, -15V, and +24V, 20 transmit the data bus between crate controller and ECMs, 4 take care of request, grant, and 50 Hz clock, while the remaining 20 are free to establish inter-module busses within the crate. Busses are made of ribbon cable with mass termination connectors, which in turn are plugged onto the backplane wire wrap pins. Every second line is grounded, which together with the conservative system speed eliminates cross talk problems.
Each SEDAC crate has its own power supply connected to 220 VAC. This was favored over the approach of distributing raw DC and providing fine regulation at either the crate or board level, which turned out to be more expensive under the aspect of changing crates while others remain on line.

User Interface

Realization of SEDAC was split between 'system' and 'user' groups. The system people provided the data links from the computer via SEDAC driver, pickup stations, powered crates, and crate controllers to the ECM backplane connector. The design, realization, and installation of ECMs was done by those who were also responsible for the accelerator components controlled by their ECMs. At the end of 1975, this system/user interface was defined and frozen.
To minimize the number of bus pins, data is transmitted between crate controller and ECMs in serial form also. The crate controller checks, decodes, and splits up the telegrms into address and data parts. It provides all data and timing signals for the ECM bus interface:

XST pulse at start of telegram - used for reset and to load subaddress into shift register for request collection

WDT write data line

SSA shift subaddress clock line

RSP response wired or bus - used to indicate that ECM exists at current subaddress

SDT shift data clock line

WT static signal during write telegram

RD static signal during read telegram

PRD prepare read, pulse preceding input data transfer - used for parallel loading of read shift registers

RDT read data wired or bus

XWT execute write pulse after correctly received write telegrams - used to execute transmitted function

CP common pulse generated after correctly received telegram that included CP bit - used for multimodule operations, mainly energy ramping and multi-magnet beams steering by incrementing/decrementing power supply DACs after slope information has been setup with write telegrams.

RQ request line

RQG request grant - used to gate subaddress information onto RDT bus

For luminosity measurements, a completely different type of crate controller is used. It plugs into a CAMAC crate and provides standard 24 bit CAMAC transfers with a different telegram format on the same serial line.

Conclusions

With only minor changes, the PETRA control system was implemented along the guidelines laid out in 1975-76[2]. Four SEDAC systems with 95 crates containing ~ 850 ECMs are in operation now (Feb. '79).
The majority of the ECMs are
240 correction coil controllers
200 quad ion sputter pump controllers
80 cavity controllers
80 digital i/o rf controllers
80 digital input rf modules
The rest are of ~20 different types for tasks such as video line switching, DVM multiplexing, beam monitoring, etc.

Experience has proven SEDAC to be both powerful enough to handle the complete process I/O for this application and simple enough to be connected in a straightforward way without a complicated adaption interface. This made it possible for the equipment designers to build themselves the ECMs needed for their tasks, thus helping to get PETRA on the air ahead of schedule.

References

1) G. Hochweller, H. Frese; Tools for Man Machine Communication in the PETRA Control System, these proceedings.
2) H. Frese et al., PETRA Control System, IEEE Trans. Nucl. Sci. 1977, p. 792.