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ABSTRACT

In the Central Research Institute for Physics a Basic Principle Simulator for WWER-440 Nuclear Power Plants is under development. This report describes the input/output subsystem of the simulator. This subsystem is a special peripheral forming a control desk and displaying every main parameter of the model. During development special attention was paid to the hardware support of the controllers by the control desk, because this part of the model is regarded as very time consuming.

This paper gives a short summary on the hardware configuration of the simulator computer as well.

АННОТАЦИЯ

В Центральном институте физических исследований разрабатывается Симулятор основных принципов (Basic Principle Simulator) для АЭС типа ВВЭР-440. В отчете описывается подсистема ввода/вывода симулятора. Эта подсистема является функционально ориентированной периферией в форме пульта управления, которая отображает все главные параметры модели. В ходе разработки особое внимание уделялось поддержке симуляции контроллеров аппаратными средствами, так как она считается одной из функций модели, требующей наибольших затрат машинного времени.

В отчете дается также краткое обобщение конфигурации аппаратного обеспечения ЭВМ симулятора.

KIVONAT

A Központi Fizikai Kutató Intézetben Alapelvi Szimulátort fejlesztünk a WWER-440 atomerőművek részére. Ez a riport a szimulátor input/output alrendszerét irja le. Ez az alrendszer egy vezérlőpult alaku célperiféria, amely megjeleniti a modell összes fő paraméterét. A fejlesztés alatt különös hangsulyt kapott a vezérlők szimulációjának hardware támogatása, mivel a vezérlők szimulációját a modell egyik legidőigényesebb feladatának tekintjük.

A riport rövid összefoglalást ad a szimulátor számitógép hardware konfigurációjáról is.

1. Introduction

This report describes the input/output subsystem of the WWER-440 Basic Principle Simulator. At present this simulator is under development in our Institute for training purposes of the dynamic behaviour of a WWER-440 Nuclear Power Plant. The goal of the development is to provide a teaching and demonstration tool for initial training of nuclear power plant operators and for courses of university students. The main goal of the Basic Principle Simulator is to give an apprehension of the basic principles for the process functions and of the operational features to meet the basic problems and difficulties encountered at various plant states.

In comparison with a full-scope simulator the Basic Principle Simulator provides the dynamics of the main power plant processes and basic controllers but it does not simulate the instrumentation and control of any existing nuclear power plant. Because the scope of the instrumentation and control simulation is limited in this system its hardware is considerably smaller than that of a full-scope simulator.

The hardware of the Basic Principle Simulator includes

- the computer system,
- the control desk, and
- the instructor's display station.

This report concentrates on the control desk of the simulator which is a special input/output peripheral supporting the simulation in the computer system.

2. Computer configuration

The simulation is done with a TPA-1148 computer /program compatible with the PDP-11 series of computers/ with 1 Mbyte operating memory and furnished by a floating point coprocessor. The configuration has two 29-Mbyte /EC-5o61/ disc units and three 5-Mbyte cartridge disc units /CM-54oo/ as backing memory, two magnetic tape units /CM-53o3/, one line printer /B-3oo/ and one serial line multiplexor. Eleven display terminals and one colour semigraphic display are connected to the data multiplexcr. These display terminals are used for program development, but during simulation only one display and the colour display are used as an instructor station.

All of the input/output operations of the simulator is provided by the control desk. The control desk is connected to the computer by two different ways; in the input direction through a serial asynchronous line of the data multiplexor, while in the output direction the connection is provided by a DMA /Direct Memory Acces/ interface.

The computer configuration is presented in Fig. 1.

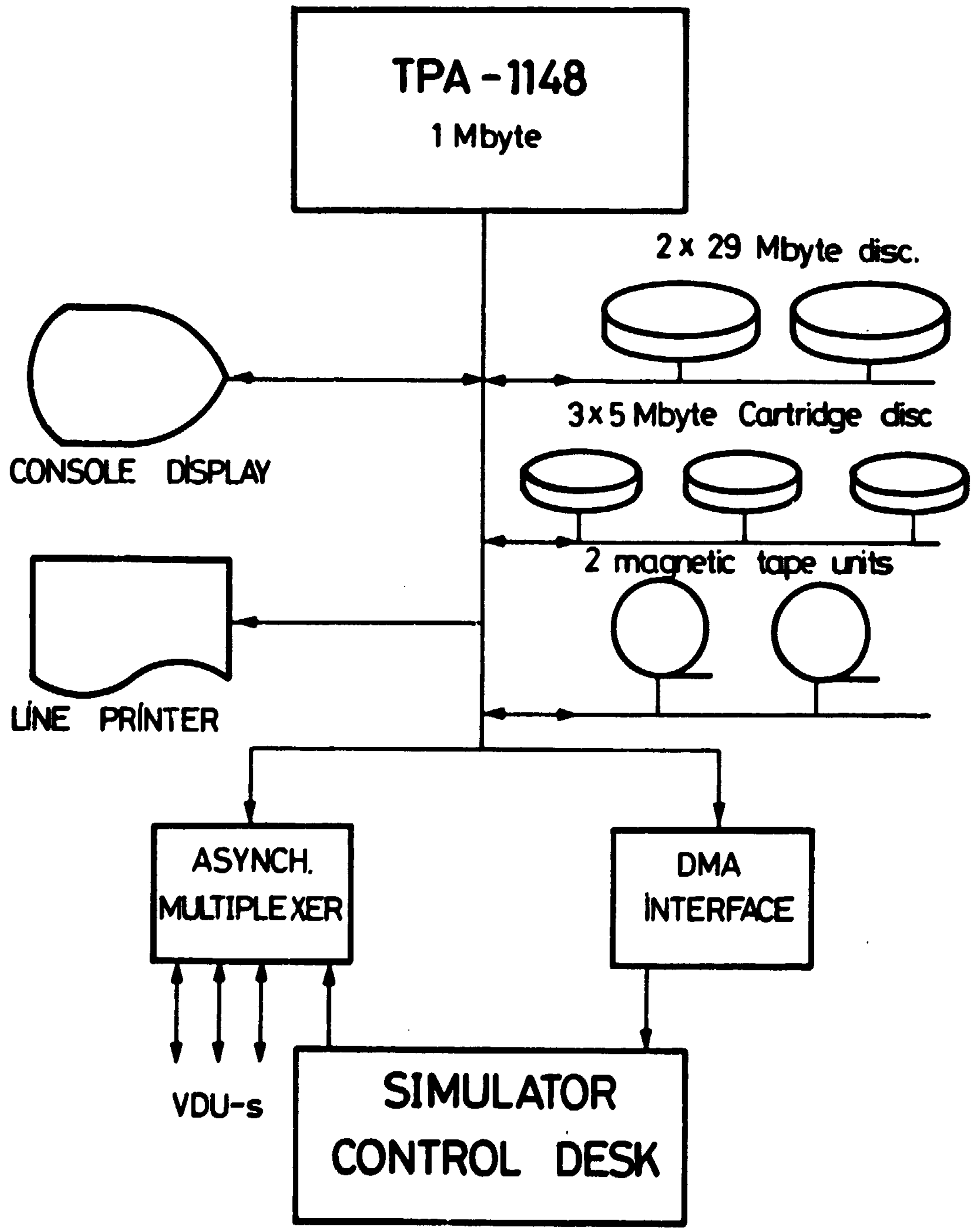


Fig. 1.

Hardware configuration of the simulator computer

3. The structure of the control desk

The control desk of the Basic Principle Simulator is a sophisticated, microprocessor based peripheral containing three basic parts:

- input subsystem,
- output subsystem, and
- controller subsystem.

The control desk contains all of the instrumentations needed for the data presentation of the fundamental relationships of a WWER-440 nuclear power plant. The main technical characteristics of the desk can be seen in Appendix 1.

The input subsystem scans input devices in the desk and transmits this information once in a second through a serial asynchronous line to the simulation computer. The data transmission is initiated through the data line.

The output subsystem is connected to a DMA interface of the simulation computer. The received information is displayed in the desk according to its address. The output of the subsystem consists of

- analogue indicators,
- digital displays,
- alarm windows.

The controller subsystem is connected both to the input and output subsystems. The input subsystem scans the state of the controllers once a second as the other inputs of the desk, while these devices can be controlled through the output subsystem as well. Moreover the content of the controller devices can be modified through the data line e.g. in case of backtracking.

The control desk is designed in a modular way which allows changes to be made in a flexible manner. On the desk there are three main areas as

- mimic diagram,
- analogue indicators,
- control station.

A schematic picture of the control desk with main mechanical measures can be seen in Fig.2.

In the mimic diagram the state of the valves, pumps and controllers is indicated by LED diodes and alarm windows, mounted near to the affected technological unit, display the alarm status of the relevant component. The mimic diagram forms the upper vertical panel of the control desk, and it was built from mosaic tiles in order to allow easy modifications.

Under the mimic diagram there is another vertical panel containing all of the analogue indicators of the simulator. Here every main analogue parameter of the model is displayed.

On the horizontal part of the desk is the control station of the simulator. The control station contains pushbuttons and switches for the control of the relevant model components.

3.1. Input subsystem

A Z-8o microprocessor controls the operation of the input and the controller subsystems. The block diagram of this subsystem is presented in Fig.3. The microprocessor scans every input module with about 100 msec. cycle time and measures the states of the input lines. One input module contains 64 input lines. In the desk there are 8 modules, i.e. altogether there are 512 input lines. From these 128 lines are used in the controller subsystem /see Point 3.3./, the remaining lines are measured as digital information . A part of the digital information is regarded as being coded in BCD code, the other part represents binary information.

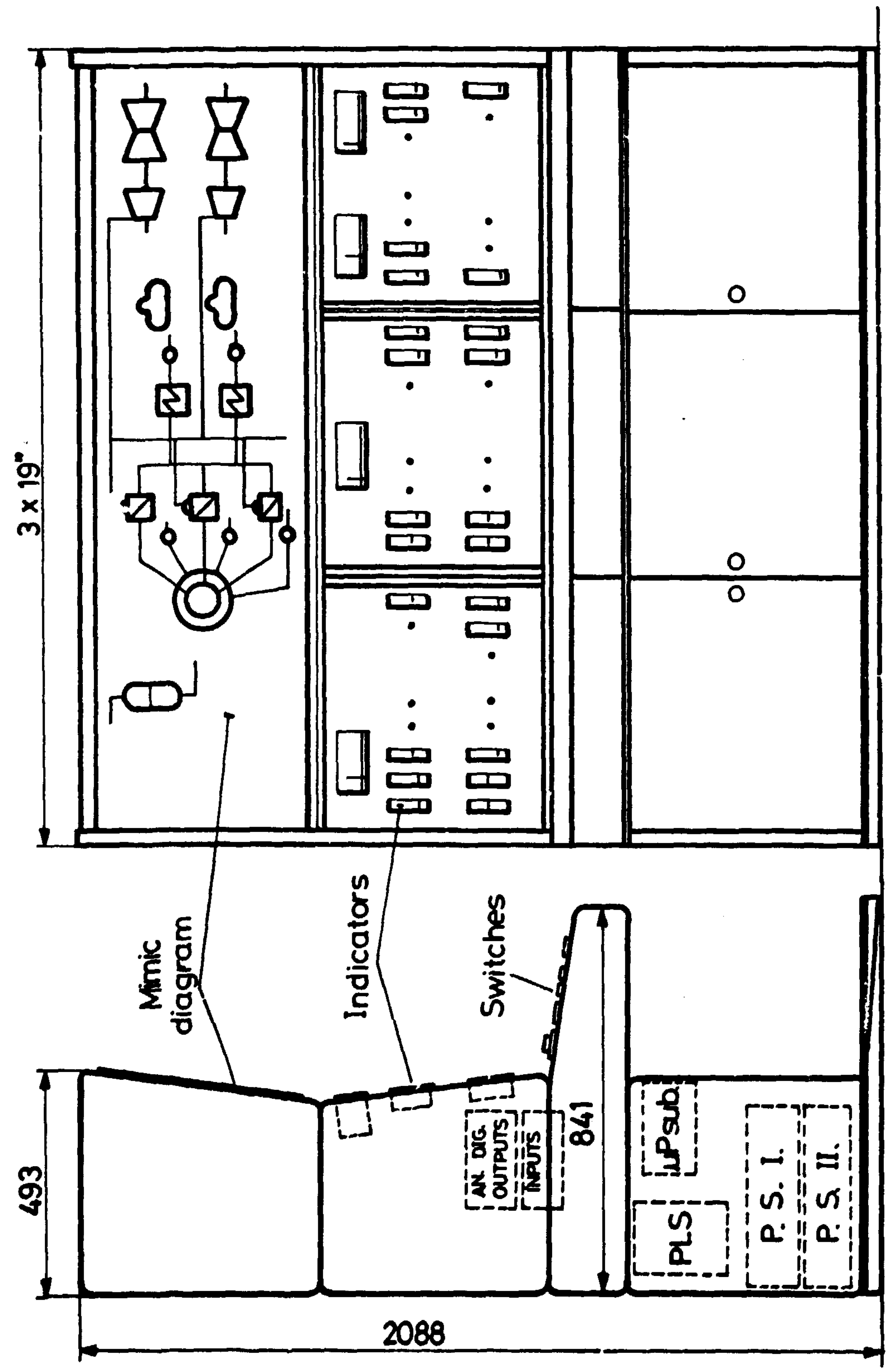
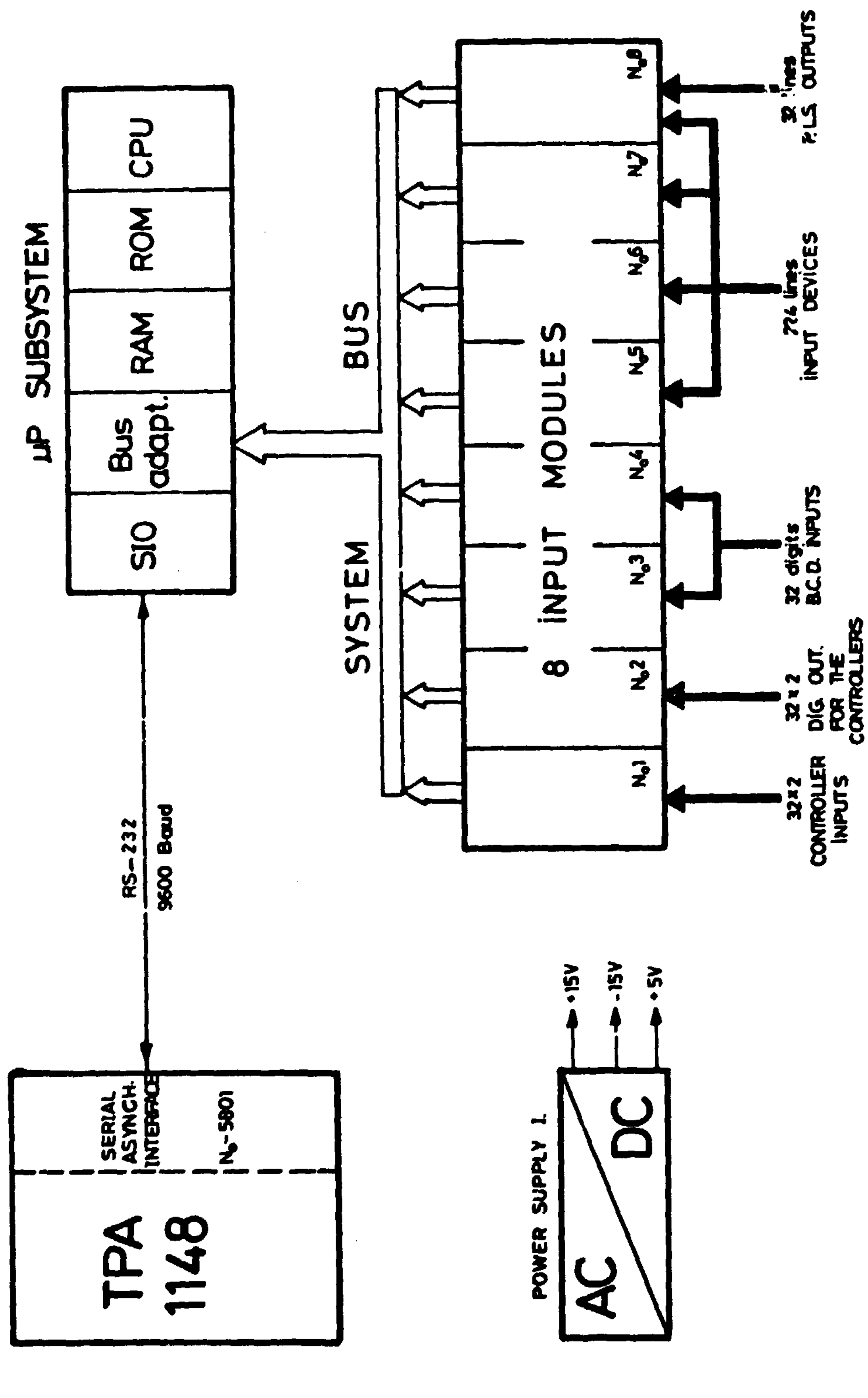

3 x 19"
Mimic diagram
Indicators
Switches
Control desk
493
841
2088
AN. DIG. OUTPUTS
INPUTS
PLS
µPsub
P. S. I.
P. S. II.

Fig. 2.



Block diagram of the input subsystem

Fig. 3.

The input subsystem stores the BCD and binary information into 48 bytes during each scanning period. Moreover there are additional 32 bytes in the controller subsystem, thus in every second there are 8o bytes to be transmitted into the simulation computer. The input subsystem begins the transmission of these 8o bytes in a single data package when it receives a polling sequence through the asynchronous data line. The transmission speed is 96oo Baud thus the input information is transferred into the simulation computer in 0,1 sec.

3.2. Output subsystem

The output information can be classified into two basically different groups as

- analogue-, and
- digital

data. For this reason the output subsystem contains two different kind of modules: analogue and digital units. Each module receives bytes through a DMA interface but this information is processed in the different kind of modules in a different way.

In the analogue modules a received byte is regarded as an 8-bite long binary fraction in the range of 0÷255/256. The analogue module produces an analogue voltage from the received byte, moreover it produces exponentional filtering for each line. An analogue module produces 32 output lines; in the output subsystem there are 4 analogue output units, thus in the control desk 128 analogue outputs are available. The analogue outputs are listed in Appendix 2.

In the digital modules 2 bits are used for each output line. This information is represented in the following way:

X 0	off
0 1	on
1 1	blinking

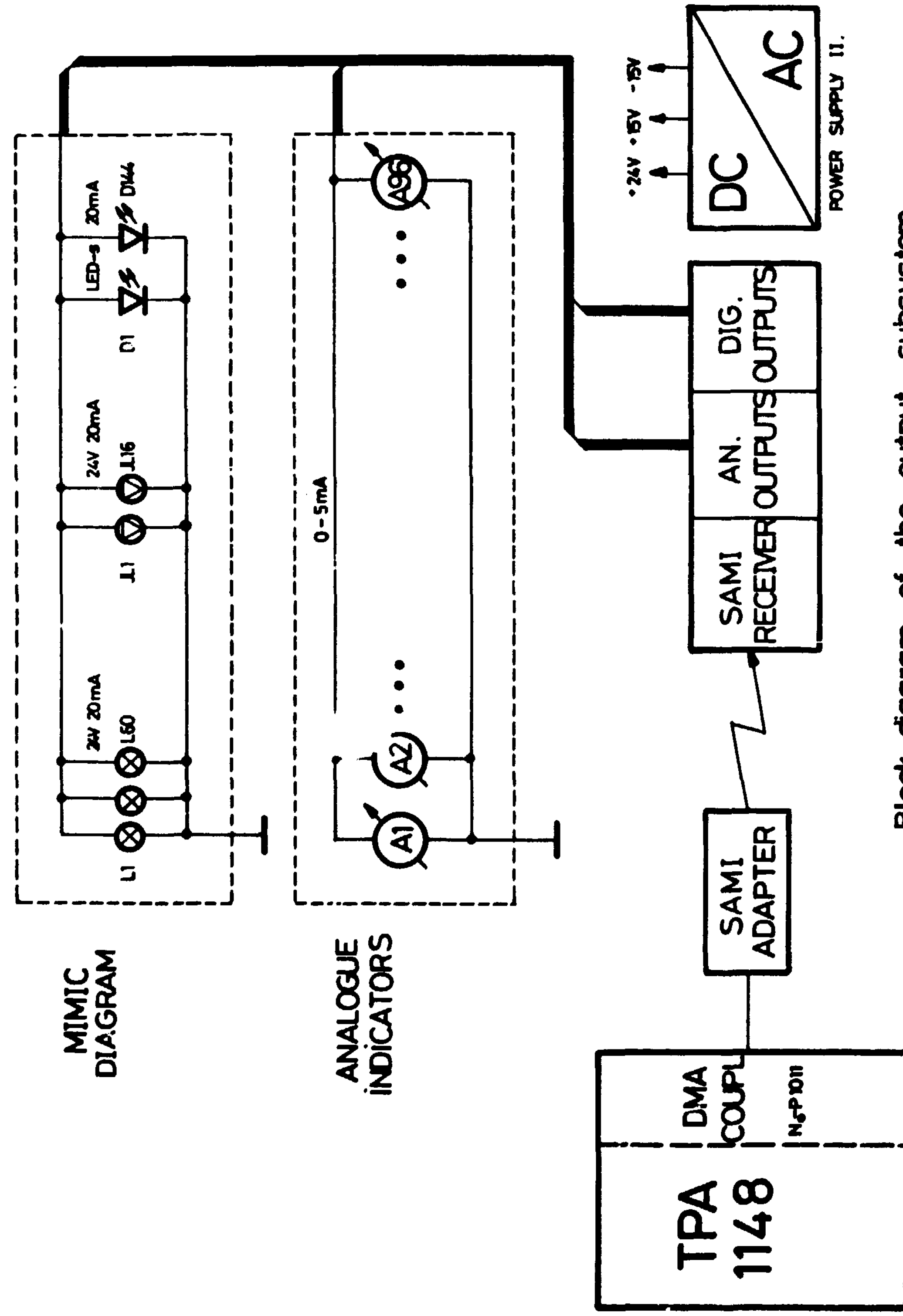
It can be seen, that digital outputs represent three states, because e.g. the alarm windows need blinking lamps till the alarm is not acknowledged. After acknowledgement an alarm window lights till the alarm exists then it is dark. In one digital output card there are 64 tristate output lines. A special customer-designed integrated circuit was designed and manufactured for this card in order to reach this information density. In the desk there are 7 digital output cards, one of them produces BCD outputs while the others provide individual output lines. The output subsystem is presented in Fig.4.

3.3. Controller subsystem

The simulation of the controller devices /pumps, valves, control rod, etc./ is a rather difficult task in a simulator, because

- very fast response time is needed,
- the controllers have to be controlled both from the computer /automatic operation, safety actions/ and from the control desk /manual operation/,
- a hierarchical order is needed among the different actuating sources /e.g. a safety action overrides the automatics/.

For these reasons the simulation of the controllers and automatics yields a quite heavy burden in the simulation computer. In this respect the control desk provides a considerably large support to the simulator computer, thus saves computation time. Each controller is represented by an up/down counter. The content of the counter represents the position of the actuating device /valve position, rod position, etc./ and it is sent every second by the input subsystem into the computer. Every counter has four inputs, two of them come from the relevant switch of the desk, and the other two inputs are connected to digital output lines. The later two inputs represent the following four states:



Block diagram of the output subsystem

Fig. 4.

0 0 - manual operation permitted
0 1 - increase the counter
1 0 - decrease the counter
1 1 - every operation is inhibited

In this way the automatic operation coming from the computer can override the manual operation. Moreover the counter can be preset with the data received from the serial line, thus a fast safety action can be simulated as well.

Physically every counter is only a byte in the memory of the Z-8o microprocessor system. 32 controllers are available in the control desk but only 26 of them are used. The list of the controllers is presented in Appendix 3.

Another problem of the controller simulation is that some automatic actions are very fast. The control desk gets new information from the computer only once in a second which is not sufficient in some cases. For this reason the controller subsystem has its own microcomputer. Since the automatics can be described by Boolean algebraic relationships, this computer is a programed logical system /PLS/ which contains a very primitive microprocessor executing only logical operations. The programs of the PLS are executed in every lo millisecond, thus it can simulate fast safety actions without causing any burden in the simulation computer. The PLS is controlled partly from the output subsystem and partly from the switches of the desk. The outputsof the PLS control lamps in the desk and it is also sent into the simulation computer via the input subsystem.

4. Memory organization

In the data base of the simulator two arrays belong to the control desk. The input array is 4o words /16-bit/ long while the output array contains 12o words. The input/output arrays store the information in the form as it exists in the control desk. At the beginning of a simulation cycle the input program requests the desk to send its information then it sorts the received data into real-type variables. At the end of the simulation cycle a data scanner program collects the variables to be transmitted in the data base, transforms them into the form previously described then stores them in the output array. After having finished one output array a DMA transfer is initiated and a new information cycle is started.

The input/output arrays are presented in Fig. 5.

INPUT ARRAY	
256 digital inputs	32 bytes
32 controller inputs	32 bytes
32 BCD inputs	16 bytes
	80 bytes

OUTPUT ARRAY	
16 BCD outputs	16 bytes
352 digital outputs	88 bytes
32 PLS outputs	8 bytes
128 analogue outputs	128 bytes
	240 bytes

Fig. 5.

Structure of the input / output data buffers

Appendix 1.

Main technical characteristics of the control desk

Max. number of analogue outputs	128
Max. number of digital outputs	256
Max. number of BCD outputs /digit/	16
Max. number of digital inputs	256
Max. number of BCD inputs /digit/	32
Max. number of controllers	32
Input scanning cycle time /msec./	1oo
Input connection type:	serial line
Input transmission speed /Baud/	96oo
Output refreshing cycle time /sec./	1
Output connection type:	DMA

Appendix 2.

Displayed analogue parameters of the WWER-44o model

Reactor:

- Reactor power
- Reactivity
- Reactor period
- Rodposition
- Boron concentration
- Xe concentration
- Average fuel temperature

Primary circuit

- Inlet temperature of the core
- Outlet temperature of the core
- Δ T of the core
- Coolant flow of the core
- Pressure drop on the core
- Pressure in the pressurizer
- Temperature in the pressurizer
- Water level in the pressurizer
- Coolant flow for each cooling loop
- Δ T for each cooling loop
- Δ P for each main circulating pump
- Flow in the primary water purification system
- Control valve position on the primary water purification system
- Valve position of the low pressure boron supply
- Valve position of the high pressure boron supply
- Water flow into the bubbling condenser

Steam system

- Power of the secondary circuit
- Water level in each steam generator
- Feedwater control valve position for each steam generator
- Feedwater temperature
- Feedwater flow for each steam generator
- Pressure of the steam generators
- Steam flow from the steam generators
- Safety valve position
- Flow through the safety valve
- Turbine bypass valve position
- Flow through the bypass valve
- Steam line flow for both steam lines

Turbines and condenders /2 pieces/

- Turbine control valve position
- Steam flow in the high pressure turbine
- Inlet pressure in the high pressure turbine
- Inlet pressure in the low pressure turbine
- Outlet temperature of the low pressure turbine
- Condensate flow
- Δp of the condensate pump
- Pressure in the feedwater tank
- Water level in the feedwater tank
- Coolant flow of the condenser
- Vacuum in the condenser
- Feedwater flow
- Feedwater temperature

Generators /2 pieces/

- Generator power
- Excitation of the generators

Appendix 3.

Controlled parameters of the WWER-440 model

Controllers

- Reactor power controller
- Water level controller of the pressurizer
- Feedwater level control for each steam generator
- Feedwater isolating valve control for each steam generator
- Steam isolating valve control for each steam generator
- Isolating valve control in the cold leg of each cooling loop
- Isolating valve control in the hot leg of each cooling loop
- Turbine bypass valve control
- Turbine controller
- Main steam isolating valve control

Inputs, without controllers

- Reactor scram
- Turbine trip
- Water injection into the pressurizer
- Pressurizer heating
- On/off control of the low pressure boron pump
- On/off control of the high pressure boron pump
- Boron supply operating mode
- On/off control for each main circulating pump
- Intercept butterfly valve control
- Condenser coolant control
- On/off control of the condensate pumps
- On/off control of the generators

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