# CONTROL SYSTEM FOR THE WARSAW CYCLOTRON

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*Abstract*

The control system for the Warsaw Cyclotron is described. PC compatible computers and PLC controllers are used as the hardware platform. Methods of combining commercial ( QNX real time operating system ) and open source software are discussed in detail.

## INTRODUCTION

The control system for the Warsaw cyclotron is relatively simple, with measurement/set-point counts in the low hundreds. It is a direct descendant of a system built about 12 years ago. The old system, like many control systems of that era, was built around PC hardware and used the MS-DOS operating system [2]. Computers were not networked, instead a remote console approach was used to access them from the control room. Control software was written in C.

When Microsoft discontinued support for MS-DOS and the next generation of Microsoft operating systems was clearly not suitable for control purposes, it was time for a change. To preserve the investment in PC hardware QNX was chosen as the next OS platform.

## OVERVIEW OF THE QNX OS

QNX is a real time, very robust and reliable, commercial version of UNIX for PC compatible computers aimed at control applications. It does not use AT&T UNIX code.

The OS version used at the Heavy Ion Laboratory is 4.25. A newer version ( 5.0 ) has been available for some time now, but the changes mainly offer more support for open standards rather then OS improvements.

A detailed description of the QNX OS can be found on the manufacturer's website [1], but some of it's features are worth mentioning here. QNX uses a micro-kernel architecture, what in practice translates into low memory and mass storage footprint, and low requirements for CPU processing power. A Pentium 100-200MHz machine with 32 MB of RAM will comfortably run most common control algorithms in real time. For use as graphic console those numbers should be doubled. A hard disk drive ( or solid state media like Compact Flash ) with storage capacity of 60MB is required for a fully functional text mode base system. Development packages ( window managers, graphic libraries, etc. ) require an additional 120MB. One can now easily buy PC systems with multi-gigabyte disk storage and gigahertz processor clocks, so QNX low system requirements seem irrelevant, but this brute force approach comes at the price of excessive power consumption, bulky heat sinks, and forced air cooling. Besides support for TCP/IP there is the QNX proprietary networking protocol ( Qnet ). The networked computers have their resources transparently available to one another by simply prefixing directory path names with the 'node number'. Another proprietary addition to UNIX standard suite of programs and utilities is the Photon window manager. It is fast and efficient and is used instead of the X window manager.

Out of the box QNX is just the OS with core libraries and utilities, C and C++ compilers, window managers, and simple GUI application builder. Third party sophisticated application builders exist, but their high prices nullify the advantage of low cost of PC hardware.

## HARDWARE

The control system at the Heavy Ion Laboratory uses a mixture of PC computers in different form factors, PLCs ( Programmable Logic Controllers ), and embedded processors.

The latter were developed and built in-house, in cases when no adequate commercial hardware existed for devices which initially lacked support for computerized remote control, like some high current power supplies. Moreover, we were concerned about ground loop currents flowing in and out of high precision circuits ( 14 to 16 bit accuracy ). Since it is easier to opto-isolate a few RS-232 lines then D/A and A/D converters, we chose to process the signals locally. The controllers also offload PC computers and significantly reduce the amount of cabling.

PLCs are used in 'mission critical' systems like the radiological safety interlock system. PLCs are also used for very simple automation tasks that require no precision analog set-points/measurements like vacuum power up sequencing. Siemens S7 series PLC were chosen because of good local support, but other manufacturers ( Omron ,GE ) offer almost the same products feature for feature.

In the early '90s a desktop PC was not recognized as an automation platform, so very few add-on I/O cards for that purpose existed on the market. The only exception were multi-port RS-232 cards intended for connecting dumb serial terminals to a PC running a multi-user OS like ( long forgotten ) Xenix. So RS-232 was and is used at the Warsaw cyclotron instead of the more robust and faster RS-485.

Since enough hardware expertise was on hand, several I/O ISA boards were developed and built in-house, ranging from simple non-isolated binary input and output boards, to A/D and D/A converters, to sophisticated, one of a kind PWM/modulator circuits for RF control. It was a good choice, as the ISA bus architecture turned out to be a very stable subsystem in the ever changing PC environment. Only 2-3 years ago it was dropped completely off new computer motherboards in favor of all PCI designs. There are many PCI I/O cards on the market now, but most manufacturers of those cards seem slow to adopt the newest (rev. 3.0 ) PCI standard of 3.3 volts only bus signaling, or keyed 3.3V and 5V cards ( rev. 2.3 ). One has to write QNX drivers for I/O cards, since QNX drivers are usually not included. So we try to keep the number of types of I/O boards low.

The architecture of the control system for the Warsaw cyclotron differs from the typical system [3]. There is no field bus, instead PC computers equipped with I/O cards are located next to controlled devices . The PCs are connected via Ethernet.

The Ethernet network can be the field bus - it has all the properties of an industrial strength interconnection. Even in the most common twisted pair form ( copper ) it sports 250V dielectric isolation, has speeds an order of magnitude higher than other technologies ( LON, CAN, Profibus [3] ), and has well standardized higher level protocols. With the advent of microprocessors or microprocessor modules with Ethernet hardware on-board, and prepackaged WWW servers or software TCP/IP stacks [4], it is easy to connect any device to the Ethernet without the use of a PC type computer.

## SOFTWARE

As it was mentioned earlier QNX out of the box lacks a database engine, scripting languages, etc. Since QNX is 'UNIX compatible' it is not all that difficult to port GPL ( General Public License ) software to QNX. Some GPL packages are even available for download pre-complied for QNX, while others can be installed using the standard 'make' utility. Some software, like graphics utilities and libraries, can not be ported due to differences in windowing environments. When ported, however, several individual software packages have to be maintained ( patches, version upgrades ) on computers running 24/7 most of the time. To avoid this troublesome and time consuming scenario a decision was made to mantain control computers with as little add-on software installed as possible. All cyclotron data is available to cyclotron users, accelerator physicists, etc. via a dedicated gateway.

The control system software for the Warsaw cyclotron falls into 3 main categories :

- local/low level control
- main ( operator ) console
- gateway to laboratory LAN

*Low level control*

Low level software uses multiple programs for ease of maintenance and code reuse. There are four processes running on each computer: startup, network, control, and application that exchange data via shared memory. The startup process registers the application process name with the main console, and assures proper start and termination of other processes. The network process is responsible for reliable exchange of application data with the main console. The repetition rate for this process is 20Hz. The control process interfaces with the hardware using device drivers, checking for alarms, updating set-points, measuring read-back values etc.. The repetition rate for this process is 100Hz. The application process is responsible for displaying data on the local console ( text mode only ), and for passing data between network and control processes. Set-points are either sent over the network from the main console, or are entered locally via the keyboard. Control can be switched from remote to local ( and vice versa ) by just one keystroke. Software is designed in such a way that remote settings take precedence over local ones – when some set-points are altered locally, and then control is switched back to the main console, set-points from the main console are automatically put into effect. The repetition rate for the application process is 10Hz.

*Main console*

The main console queries all registered low level processes in a loop and displays cyclotron data in a simple graphical manner. The Photon windowing environment makes displaying all the required information easy thanks to nine virtual desktops on one display monitor. Set-points can be entered manually or retrieved from a crude database.

All control data is also copied every 2 seconds to a small RAM disk .

*Gateway*

One QNC based PC was set aside to act as a gateway between the control network and the laboratory LAN. It has two network interface cards – one for each network. There is no routing of protocols between the nets, instead an Apache WWW server with the aid of Perl scrips reads values from the RAM disk at the main console . Only WWW protocol is enabled on the public NIC interface. It is felt that such a setup provides additional level of security to the control network. Applications and services that use cyclotron data are decoupled form the control network, and can be platform and OS independent.

## REFERENCES


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