The GNU Control System at CAMD

B. Craft and P. Jines
Center for Advanced Microstructures and Devices
Louisiana State University
3990 W. Lakeshore Drive, Baton Rouge, LA 70803, USA

Abstract

The Center for Advanced Microstructures and Devices (CAMD) at Louisiana State University operates a 1.5 GeV, synchrotron radiation dedicated, electron storage ring. The injector is a 180 MeV linear accelerator. The procurement of the entire accelerator system, including the control systems, utilized a single, fixed-price contract. The control system for the storage ring was based upon a commercial control system software package running on a DEC MicroVax and a DEC VaxStation. The interface hardware included CAMAC, GPIB, RS-232 and Allen-Bradley PLC. The control system for the injector used third-party software running on top of OS9 in a VME crate controller. The interface hardware was home-brew TTL on a VME bus-adapter card. The system has been in operation since the fall of 1992.

Efforts to interface the two control systems to each other were unsuccessful. Though OS9 provided basic TCP/IP capabilities, the third-party control software consumed essentially 100% of the available CPU. Pinging the linac control system resulted in the time-out of watch-dogs which in turn lead to a shutdown of the linac.

An upgrade of the control system is underway. The DEC and VME computers will be replaced by Pentium based PC's. The software of the upgraded control system will be based on totally free software including the Linux kernel and the GNU compiler and libraries.

1 Background

The contract, between Louisiana State University and Maxwell Laboratories, for the design, fabrication, installation, and commissioning of the "turn-key" synchrotron light source was signed in December, 1989. The decision to base the control system for the storage ring on MicroVax hardware running Vista software was made in late 1990. This was a natural choice at the time. CAMD already had one MicroVax which had been purchased to support design calculations at LSU. It and its components could serve as on-hand spares for the control-system MicroVax being supplied by Maxwell. The Vista software had grown out of Los Alamos National Laboratory. The package provided a significant infrastructure and its developers contributed their expertise to the development of the CAMD control system.

Early in the design of the accelerator systems, Maxwell Laboratories decided to subcontract the injector linac to CGR-MeV. This was also a natural decision at the time. An essentially identical linac had already been accepted by Oxford Instruments for the Helios project with IBM. The IBM/Oxford linac from CGR-MeV was in routine operation in Fishkill, NY at the time that Maxwell and CAMD agreed to the subcontract. The most significant difference between the IBM/Oxford and CAMD/Maxwell linacs was the specification of the external interface into the control system of the linac. IBM and Oxford tapped in to the control system at the analog signal level. Maxwell and CAMD specified TCP/IP access to the control system computer.

During subsystem acceptance tests in the third quarter of 1992, the inability of the linac control system to accept TCP/IP access was identified. This deficiency was considered negligible within the scope of the overall project. The accelerator systems were formally accepted by CAMD in August, 1992 and have been in routine operation since.

In the mean time, CGR-MeV delivered injector linacs to ESRF in Grenoble, France and Elettra in Treiste, Italy. Since then, they have gotten out of the injector linac business. This has left CAMD with a totally unsupported control system for the linac. Efforts to reverse-engineer the hardware of the linac control system have been frustrated by our inability to identify several rather large silicon components.

2 Design Objectives

The design objectives for the control system upgrade are straightforward:

- Replace linac control system with something supportable and maintainable
- Integrate storage ring and linac control systems
- Minimize required capital investment
- Minimize ongoing hardware and software maintenance expenses
- Develop GUI based operator interface.
- Provide documented, simplified, and unified API
- Automate as much of "Operations" as possible.

3 The GNU Design

The computer hardware platform selected for the upgrade is the generic "personal computer" based on the Intel Pentium processor. We presently have one 200MHz computer and one 166MHz computer dedicated to this project. These two computers cost less than we have been spending annually for maintenance of the MicroVax. Obviously, no spares are necessary for the basic computers because of their instant availability.

The operating system being used is Linux. The complete source to the kernel and all of the utility programs, including

compilers, editors, and libraries, is freely and readily available. The Linux kernel and the GNU compiler (gcc) are covered by the "GNU General Public License" (GPL). The necessary libraries, including libc and libm, are covered by the "GNU General Library Public License." Additionally, working within the Linux community, application specific software is freely available in source form.

The GUI will be based on Tcl/Tk which is copyrighted by the Regents of the University of California, Sun Microsystems, Inc., and other parties. The terms of its use are similar to those of the GPL. Tcl/Tk runs on Microsoft's Windows, Apple's Macintosh, and most derivatives of Unix. When running on Linux, Tk utilizes the X-windows system provided by the XFree86 package.

The API will be developed in two parallel forms: a C library and a Tcl loadable shared object library. The number of API entry points will be kept to a minimum. The first API modules developed will be string based. All conversions and formatting will be handled by the libraries.

All of the software we develop during the course of this project will be made freely available under the GPL.

3.1 Storage ring

Most of the control functions of the control system that relate to the storage ring are implemented using CAMAC. The HYTEC ethernet crate controllers and all of the CAMAC modules of the original control system will be utilized in the upgraded system. The timing system of the storage ring kickers and septum has been and will continue to be implemented in Stanford Research Systems (SRS) Timing/Delay Generators which interface to the computer through GPIB. The system of Allen-Bradley PLC's which has been used for functions such as vacuum interlock and kicker amplitude control will be maintained in the upgraded system.

3.2 Linac

Most of the control functions of the linac control system interface to the VME computer via a VME bus adapter. The external interface to this bus adapter is a 50 conductor ribbon cable. The signal levels are simple TTL. At the other end of this cable is a cage of simple cards which implement digital and analog input and output. In the upgraded control system, a PC equipped with an ISA "kludge card" will replace the VME bus adapter and associated VME computer. Use of the cage of simple interface cards will be continued. The other control signals connected to the VME crate are timing signals. These functions will be implemented using additional SRS Timing/Delay Generators.

4 Implementation

The signing of a contract for the acquisition of a superconducting wiggler in June, 1996 significantly impacted plans for the control system upgrade. The wiggler is scheduled to be installed in December of this year. Its operation will require additional control channels. Due to the large tune shift and orbit dilation caused by operation of the wiggler, its turn-on procedure will be as difficult as ramping the storage ring energy and will therefore require the use of list processors. Rather that waste effort implementing this with the old control system, the decision was made to implement it in the upgraded system. This made the CAMAC system of the storage ring the highest priority. For reasons both political and technical, the project was not begun until February this year.

The ethernet crate controllers of the CAMAC system initially presented somewhat of a problem. Though the vendor-supplied manuals state that the details of the protocol are available upon request, this is not the case. TCPDUMP, from the Network Research Group of Lawrence Berkeley National Laboratory, was used to reverse engineer the interaction between the MicroVax and the crate controllers. TCPDUMP, which is freely available, allows one to eavesdrop on an ethernet. The protocol, which is alleged to be associated with LLC2, was implement in user-space using the BSD Sockets provided by the Linux kernel. Because the protocol involves a packet sequence number that is associated, in the crate controller, with the hardware ethernet address of the host computer, a daemon was written to allow multiple applications using CAMAC to run on a single host cpu.

A minimal set of the ESONE routines was implemented. Two libraries are provided at this point: one for stand-alone testing and the other that utilizes the daemon. The entry points of these two libraries are identical. The API can be placed on top of either of these libraries. The API presently has the following entry points:

- init
- read
- write
- get_units
- set_units
- get_range
- fini

This set of entry points is not complete. Versions of read and write that manipulate arrays rather that just single words will be necessary.

The CAMAC list processors, which are used to condition magnets, ramp the storage ring, and run the BPM (beam position monitoring) system were initially feared to present a serious programming challenge. This fear was based on the fact that list processors are essentially embedded processors. Surprisingly, this fear turned out to be unfounded. The C-code developed by Maxwell Laboratories for controlling the list processors ported easily to Linux.

Two National Instruments GPIB PCI cards are used to interface to SRS Timing/Delay Generators. One is in the PC in the linac tunnel. The other, in the PC in the control room, provides for kicker timing and also interfaces to the network analyzer, spectrum analyzer, and digital scopes. The kernel-based device driver for these GPIB cards was obtained from the Linux Lab Project. A complete remote GUI has been developed that renders the "Face" of the SRS boxes on an X

display. One can configure an SRS box in the linac tunnel from the control room. The only difference is that one uses a mouse instead of a finger to push the buttons.

The Allen-Bradley PLC's in our system are 5 or 6 years old. The controllers speak only a proprietary protocol. Rather than bare the expense of upgrading three controllers to the new versions that operate with an open protocol, we purchased an over-priced interface card and its associated driver development software from Allen-Bradley. The coding for this driver has not yet begun.

There are several hundred "channels" in the control system at CAMD. This makes the control system "medium" in size. PostgreSQL, copyrighted by the Regents of the University of California and freely available, is being used for database management. Besides the information to associate mnemonics with, for example, CAMAC crate number, CAMAC slot number, and module subaddress, the database contains the information to convert numbers from binary to engineering or scientific units such as amps or beam energy. The database also contains information about ranges and limits. Eventually, most of the Tcl/Tk application code will also be stored in the database.

Work has not yet begun on the control system of the linac. As mentioned previously, the planned arrival of a superconducting wiggler has focussed control system development efforts on the CAMAC system of the storage ring. The task to displace the VME computer of the linac control system is expected to be somewhat tricky. Because the interface is basically a single ribbon cable carrying TTL signals, migration is abrupt. The old and new computers cannot simultaneously contribute to the control of the linac. This is the exact opposite of the situation with the ethernet crate controllers of the CAMAC system for the storage ring. The effort to replace the VME computer will be further hampered by the lack of comprehensive documentation.

5 Summary

The CAMAC portion of the storage ring control system, including the list processors, is fully functional in the new, Linux based control system. The magnets have been conditioned, the ring energy ramped, and the BPM's read all under the control of a PC. This system is prepared for the arrival of the superconducting wiggler.

The GPIB interfaces are fully functional and the GUI for the Timing/Delay Generators is complete. The RS-232 interface to the water systems has not been addressed but is expected to be trivial. The driver for the Allen-Bradley interface card has not yet been written and is expected to take a fair amount of work.

Due to present priorities, work has not yet begun to displace the VME computer of the linac control system. This task will be addressed in January of next year.

Acknowledgements

The authors would like to express their appreciation of Linus Torvalds and the entire Linux community for the kernel we are using. We would like to thank the Free Software Foundation for the GNU compiler and libraries. We would like thank The Regents of the University of California, Sun Microsystems, and John Ousterhout for Tcl/Tk. We would like to thank C. Schroeter for the Linux GPIB Package. This author (BC) would like to thank Alan Cox for numerous e-mails elucidating the organization of the ethernet software within the Linux kernel. We would also like to thank the developers of PostgreSQL and XFree86.