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EPICS SIMULATION TOOLS FOR CONTROL SYSTEM DEVELOPMENT

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EPICS SIMULATION TOOLS FOR CONTROL SYSTEM DEVELOPMENT*

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Abstract

When developing control system software there are many times when the ability to simulate the response of the instrumentation can be very useful. Examples are: (i) when the operator interface is being designed and the users want an idea of what the finished system might look like; (ii) when the interface hardware is not yet available; (iii) when the reaction of the control system to an error condition must be tested, but the actual occurrence of such an error would cause undesirable side effects; (iv) when operators are being trained to use the system; (v) when an improvement or bug fix needs to be tested, but the running system cannot be shut down for long. The Experimental Physics and Industrial Control System (EPICS) provides tools for building simple simulations and interfacing to more complex simulations of accelerator hardware. At the lowest level an individual data channel can be switched (at run-time as well as configuration time) to take its input from either a simulated data location or from the actual hardware. At a slightly higher level, sequences can be run on the real-time interface processor so that output to the hardware is intercepted and an appropriate substitute value is provided for the corresponding read-back records. At a still higher level a program can use the Channel Access software bus facility of EPICS to control some global aspect of an accelerator or can interface to an external accelerator simulation instead of the actual accelerator. The goal of testing control system software using simulated hardware is to minimize the changes required in shifting between the simulated system and the real system. The degree of success of the EPICS tools in meeting the minimum change goal will be addressed with suggestions for improvements. The implementation of simulated responses using EPICS tools will be discussed and examples of experience using the EPICS tools to create and interface to simulations will be given.

Introduction

The software "toolkit" provided by EPICS has been used in the development of control systems for a wide variety of applications[1]. As seen by an operator, a running EPICS application is the display, data archiving and alarm handling software running on one or several Operator Interface work stations (OPIs). Unseen are the run-time databases, sequences and other application software running on the Input/Output Controller(IOCs) and other control and data-acquisition programs that may be communicating with the IOCs from other computers attached to the network [Figure 1]. Each IOC consists of a single board VME or VXI computer using I/O boards of various kinds to communicate with the hardware in the controlled system.

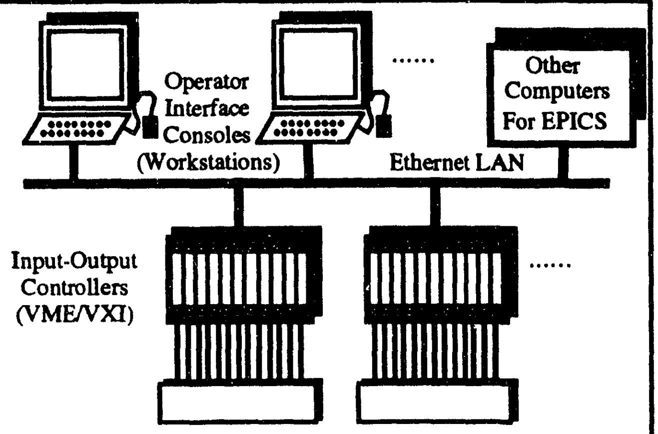

Figure 1. Physical subsystem layout of EPICS

In this paper we will discuss the implementation of various types of simulation using EPICS tools and the experience using them.

Hardware, Soft Records and Low Level Simulation

The run-time database[2] consists of a collection of uniquely named records some of which may be used to communicate directly with the I/O boards and some of which are used to control and synchronize the processing of other records. Each record consists of a set of fields whose contents reflect the status, display, processing and control properties of the record. The DTYP (device type) field is of particular interest. The device type of a hardware record indicates what type of I/O card is to be associated with it. If it is an input record then the INP field of the record will contain a hardware address that will tell the driver how to get input from a particular card on the VME bus and similarly if it is an output record the OUT field of the record will contain a hardware address that will tell the driver how to write output to a particular card. If the DTYP field has the value "Soft Channel" then the record will not be used with I/O cards at all. If it is an input record INP may contain the name of another record or a constant put into the database at configuration time, or it may be set from the operator interface or some other application. Many records must be soft records. For example calculation or subroutine records that filter data from other records, or fanout records that distribute processing to a number of other records. EPICS applications vary in the ratio of hard to soft records.

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There are usually two to three times as many soft records as hardware records in an application.

In all of the large applications for which EPICS has been used, there has been a major time lag between the time that work has started on the application and the time that the instrumentation and controlled hardware are in place. Because all access to records and fields in them is by name only, changing a record from a hardware to a soft record and vice versa will not require changes in the rest of the application. Using soft records is a very common way to test operator screens.

However, changes in the DTYP field can only be made at configuration time. Using soft record simulation a change from simulation to non-simulation requires reconfiguration of the database and rebooting the IOC. Furthermore, the details of the hardware address field are device dependent and changing them is error prone. Once they are correct, going back to soft records for simulation is not straightforward.

To address this issue almost all record types which can access hardware have fields which allow them to be switched to and from simulation mode at run time (see Table 1).

TABLE 1. Simulation Fields

SIMM	Simulation Mode: NO, YES, (or RAW)
SIML	Location of Simulation Mode
SIOL	Location of Simulation Value
SVAL	Simulation Value
SIMS	Alarm Severity if Record is in Simulation Mode

If all records which are to be put in simulation mode have the name of the same record in their SIML field then an operator can turn simulation off or on by changing only one record as is shown in the example in Figure 2.

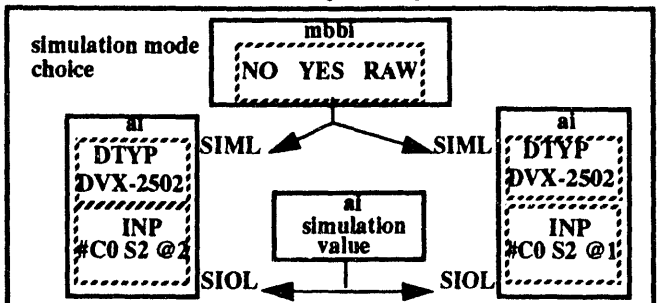

Figure 2. Switching simulation mode

In this example both analog input records which would normally get their input from a DVX-2502 I/O card may instead get their input from a simulation value record. The operator chooses by setting the multi-bit binary choice record to one of the three simulation mode choices. Using this method for switching records into simulation mode, the DTYP and hardware address fields do not need to be changed.

The possibility of a RAW simulation mode is useful for records that normally convert the raw value received from the hardware to engineering units on input or convert the value they are given in engineering units to raw output bits for the hardware. When the record is in RAW Simulation mode, the value in SIOL is assumed to be a bit mask and conversion is allowed to take place. This option is not currently available in EPICS as distributed. However, the current version of EPICS allows users to add customized record, device and driver support to their applications without rebuilding EPICS itself. For a new application at Los Alamos the RAW simulation mode was easily added for analog input and output records.

Recent Experience Using Epics to Simulate Hardware

The EPICS simulation capability is being used in the development of a control system for the Proton Storage Ring Extraction Line Beam Position Monitors (PSR BPMs) at the Los Alamos Meson Facility (LAMPF). There are 13 BPMs in the system. Each BPM generates 3 signals, for a total of 39 signals. Due to the desired data processing and conversions required, the database consists of over 600 records. The signals are to be obtained through a CAMAC crate. The VME to CAMAC interface did not exist at the time the system was started. It was being developed as part of the overall effort. The CAMAC interface was a multi-month effort, and time constraints required that the database and operator screens had to be developed in parallel with it. This meant that actual hardware signals would not be available to the control system developers. In order to develop the database, algorithms, sequences, and operator screens, the BPM signals were simulated. Data flow, record linking, sequence operation, alarm conditions, and display ergonomics were all implemented without the benefit of the BPM hardware. The simulated operator screens were used as a tool to obtain requirements from the future users of the system. This also allowed testing and debugging of the developed database. The simulation capability will be left in the control system as part of the final product. This way, the customer can run the simulator for off-line testing and maintenance of the control system software. The simulator is activated by a simple button on one of the operator screens. Simulation capability is thus useful not only for development, but life cycle maintenance as well.

Another example of the use of the SIMM/SIOL capability of EPICS was communicated to us by Carl Lionberger at Lawrence Berkeley Laboratory. There he simulated control/monitor pairs for power supplies, using the simulated database to develop displays before the actual power supplies were available.

Using the EPICS Sequencer for Simulation

The EPICS Run-Time Sequencer executes EPICS State Notation Language (SNL) programs (also called sequences) on the IOC[3]. Most current EPICS applications use the sequencer for more complicated logic than is possible with the data base alone. For example, Low Level RF applications used sequences to do complex arithmetic when calculating reflection coefficients for measuring the quality of the RF. It is easy to modify sequences so that they will run in simulation mode. In particular one of the Low Level RF sequences was modified to produce simulated values for the real and imaginary components of the reflection coefficients to test the Smith Chart Displays while developing the RF control system.

In the EPICS system, sequences can monitor a simulation choice record and modify their execution accordingly. Their flexibility allows them to make quite complicated changes in the values fed into SIOL fields. Sequences, also, can be designed so that a switch into simulation mode can be made without rebooting the IOC.

More Complex Simulations

Programs using Channel Access to communicate with the IOCS may run on any computer that possesses a channel access server[4]. Currently there is a wide choice of such computers. Channel Access has been used to communicate with commercial products such as Mathematica, pvWave, IDL, and WingZ. Calculation for simulated values can be processed using any of these tools and then applied to the EPICS database values using Channel Access.

One very sophisticated use of Channel Access was developed by Kenneth Evans at Argonne National Laboratories[5]. His program Xorbit is an accelerator physics code that tracks particle orbits. He uses Channel Access to allow Xorbit to communicate with control system parameters. He also developed an emulation of Channel Access on Unix to allow his program to communicate with Mathematica and other applications in the same way that these programs communicate with the control system.

Another example of a sophisticated simulation was a particle tracking code developed at the SSC[6]. A Hypercube parallel processing computer was used as a simulator engine. Specialized network code and hardware were used to transport information between this simulation and the memory of the IOC. EPICS subroutine records were used to access this simulated data.

Communication with EPICS is possible but not always as straight forward as simply using Channel Access for these more sophisticated simulations. Often there is a need for large quantities of data to be processed at high rep-rates. One company which deals with large simulations would need 1000 channels recorded at 100 Hertz. Rates like this are not possible with Channel Access using ethernet to communicate with the current version of the database running on a 68040 CPU. To achieve this rate today a modification at the IOC level or faster hardware would be required. The current rates for channel access using a 10 Mbit ethernet is about 5-10 Hertz for closed loop control. The current database can process ~100 signals at 60Hertz on a 68040[7].

Summary

EPICS provides very good tools for developing low level simulations which can be used to test and develop operator screens, databases and sequences before the hardware is in place. It is less helpful in developing sophisticated simulations of complex behavior, but does provide facilities for connecting with more complex programs running in other environments. When complexity and high rep rates are both needed, some modifications to the existing EPICS system will need to be made.

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