INTEGRATING COTS EQUIPMENT IN THE CERN ACCELERATOR DOMAIN

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ABSTRACT

Successful integration of industrial equipment in the CERN accelerator complex relies mainly on 3 key components. The first part is the Controls Middleware (CMW). That provides a common communication infrastructure for the accelerator controls at CERN. The second part is timing. To orchestrate and align electronic and electrical equipment across the 27 km Large Hadron Collider (LHC) at sub nanosecond precision, an elaborate timing scheme is needed. Every component has to be configured and aligned within nanoseconds and then trigger in perfect harmony with each other.

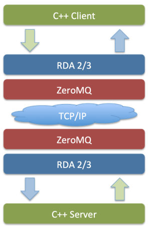
The third and last bit is configuration management. The COTS devices have to be kept up to date, remotely managed and compatible with each other at all times. This is done through a combination of networked Preboot eXecution Environment (PXE) mounting network accessible storages on the front ends, where operating systems and packages can be maintained across systems. In this article we demonstrate how COTS based National Instruments (NI) PCI eXtensions for Instrumentation (PXI) and cRIO systems have been integrated in the CERN accelerator domain for measurement and monitoring systems.

CERN MIDDLEWARE

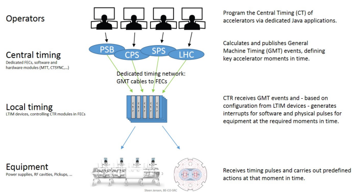
Accelerator Environment

The Controls MiddleWare (CMW) project was launched twenty years ago, to unify middleware solutions used to operate the CERN accelerator complex. Initially the equipment access library "Remote Device Access" (RDA), was based on CORBA, however the ever growing demands from the run-time environment revealed shortcomings of the system and during the previous long shutdown of the LHC (2013-2014) CORBA was replaced with ZeroMQ.

The model is based on named devices with properties and data fields within the property. Each device belongs to a Device Class and it is the Device Class that defines the properties, which can be used to access the device. By invoking get, set or subscribe on the device with the property name, the value of this property can be read or changed.

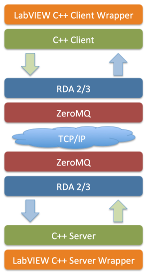


CERN's General Machine Timing (GMT) system guarantees that all accelerators in the complex act as a networked particle production facility by coordinating and synchronizing their activities. The system is based on multi-drop RS-485 networks piloted by CTG cards. On the receiving side, different modules react to messages on the network by arming counters, producing pulses on their front panel connectors or interrupts to synchronize the different front-end computers to events happening in the accelerators.



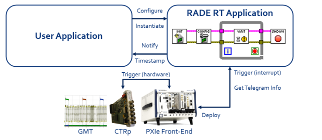
RADE Environment

The CMW stack is integrated into RADE by using the built in "Call Library Function Node" in LabVIEW^{TM}. A wrapper library around the RDA stack creates an instance that is kept in a factory pattern singleton, acting as a reference between subsequent calls in LabVIEW.

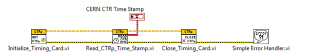


The RADE CMW interface has been designed with ease of use and performance in mind, leveraging the standard "Open, Use Close" paradigm encouraged by the programming language. The architecture is the same as for the CMW stack with an added C++ client wrapper for both the Server and Client libraries. The library has been ported to both CentOS, OpenEmbedded, Pharlap and Windows.

Due to the extensive documentation and memory-based hardware design of the CERN timing library and NI-VISA drivers, the integration of the GMT timing receiver in the RADE framework was straight forward. By knowing the hardware addresses and interrupts, we could map the CTRp card and make use of it on PCI or PXI based systems.



As for the RADE LabVIEW^{TM} interface, we modeled it after the CMW server interface with the same typical "Open, Use, Close" approach used in most LabVIEW^{TM} hardware interfaces.

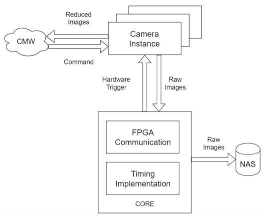


COTS INTEGRATION EXAMPLES

AWAKE Experiment

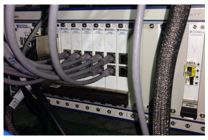
The Advanced Proton Driven Plasma Wakefield Acceleration Experiment (AWAKE) is an accelerator R&D project. It is a proof-of-concept experiment investigating the use of plasma wakefields driven by a proton bunch to accelerate charged particles, to achieve this a powerful pulsed laser is used.

The AWAKE acquisition system uses multiple cameras to monitor the specific laser. The system is composed of a PXI crate, up to 12 cameras and a Network Attached Storage (NAS). When an external trigger arrives, the PXI acquires raw images from the cameras which, store them on the NAS and publish the data to the CERN infrastructure via the RADE based CMW server.



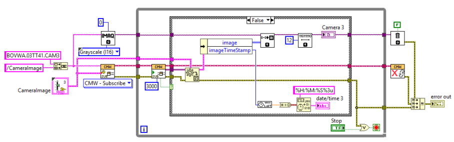
AWAKE Cameras communication overview

X 12

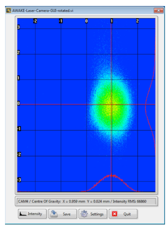


AWAKE PXI Chassis with 6 PXI-8234 cards (Dual GigE Port)

CMW is used to both control the server and publish data from the cameras. Each camera feed has its own dedicated CMW server. Any user on the CERN network can subscribe to the CMW server with many different interfaces such as C++, MATLAB (via JAPC), Python and Java.



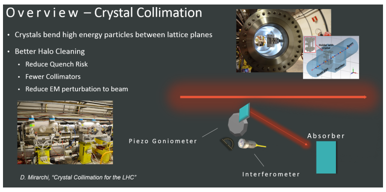
The AWAKE CMW subscription based on LabVIEW RADE VIs



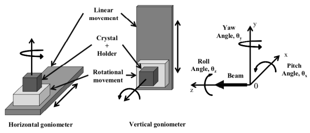
An example of picture acquired

Crystal Piezo Goniometer

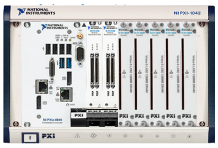
The Crystal Piezo Goniometer (CPG) project consists of a new type of collimator using bent crystals. As the beam halo envelope particles enter the crystal at a certain channeling angle, they are trapped inside the crystals latices and their trajectory is effectively shifted. This method of collimation comes with intrinsic advantages, such as a reduced quench risk, reduced equipment damage and an overall more efficient and less intrusive collimation process.



The goal of the software application developed in LabVIEW^{TM} is to follow on the previous collimator success and implement the process control based out of an RT PXI implementing the Stepper motor and PiezoGoniometer control. As the control of the piezo-goniometer is a critical parameter regulating the critical channeling angle, it is regulated by a closed control loop running at 2kHz.



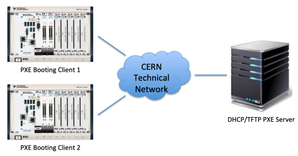
CPG movements overview



PXI COTS system used for the CPG control system

At CERN, most of the critical front-end computers are booted from memory using the PXE. This avoids relying on the file system integrity on physical storage and makes it easier to distribute and update the control software.

The PXE boot capabilities have been brought to PXI systems thanks to a special bios feature specified by the EN-SMM group at CERN and provided by NI.

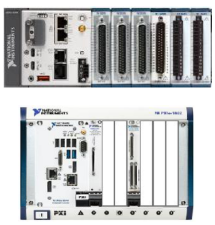


PXE Boot outline

Twin EBIS Experiment

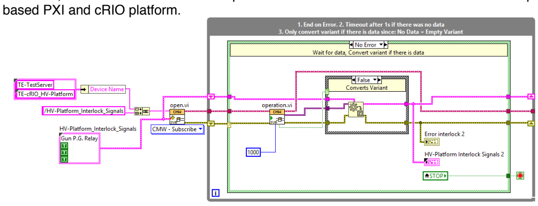
The goal of TwinEBIS (Second version, Electron Beam Ion Source) is to research a more affordable and technologically advanced carbon cancer treatment accelerator, reducing the physical size and cost of the accelerator. Ultimately the accelerator should fit in existing hospital x-ray rooms, making groundbreaking cancer therapy available for all. The control system is based on COTS National Instruments (NI) PXI and cRIO platform with the aim of reusing the lab prototype commercially in the future. This means that all the hardware and software used has to function both inside and outside the CERN environment without too many dependencies on the existing infrastructure, and by using the new RDA3 based middleware, this would be possible.

The TwinEBIS test bench



PXI & cRIO COTS systems used for the TwinEBIS control system

The control system operates on three different platforms with a large potential difference. The voltage is 40kV for the High Voltage Platform, 30kV for the Gun platform and 0V for the ground platform. Each controller, located on the different platforms, intercommunicate via CMW, and an effort was made to port the RADE CMW libraries to both the Pharlap based PXI and cRIO platform.



TwinEBIS subscription based on LabVIEW RADE VIs

CONCLUSIONS

The proof of concept implementation of the CMW server and CERN GMT timing has been successfully implemented on both the PXI and cRIO platforms for all the test systems. The implementation has proven to be robust, scalable and performant, and has significantly reduced the development time for NI based systems requiring full system integration in the CERN accelerator domain. The use of the RADE framework has made it possible to implement and integrate all the code without the need of any development outside the LabVIEW^{TM} environment.

In addition, the BIOS successfully in operation for the LHC collimators since 2007 has been modified to allow the download of bigger software images.

In the future we are planning on adding support for automatic deployment and registration of the CMW based devices in the new CERN Control System Database(CCDB) interface and adapt the CMW server to the new FESA DevServer environment. In addition, we are also considering to LabVIEW RT support for the new CERN White Rabbit (WR) timing system. A proof of concept has been implemented for the NI-cRIO platform and a 1588 HA WR compatible receiver is being tested in the lab.

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