DEVELOPMENT OF FESA-BASED DATA ACQUISITION AND CONTROL FOR FAIR

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Abstract

GSI has selected the CERN Front-End Software Architecture (FESA) to operate future beam diagnostic devices for the upcoming FAIR facility. The FESA framework is installed and operational at the GSI site, giving equipment specialists the possibility to develop FESA classes for device control and data acquisition. This contribution outlines first developments of FESA-based systems for various applications. Prototype DAQ systems based on FESA are the BPM system of the synchrotron SIS18 with data rates up to 7 GBit/s and a large scaler setup for particle counters called LASSIE. FESA classes that address Gigabit Ethernet cameras are used for video imaging tasks like scintillator screen observation. Control oriented FESA classes access industrial Programmable Logic Controllers (PLCs) for the slow control of beam diagnostic devices. To monitor temperatures and set fan speeds of VME crates, a class communicating via the CAN bus has been developed.

FESA CONNECTIVITY

The Front-End Software Architecture (FESA) framework from CERN [1] provides a complete development and testing environment for programmers. The new FESA version 3.0 is developed in a collaboration between CERN and GSI to make it lab-independent and therefore easily deployable at any other facility. FESA is able to access various types of front-end devices: Any VME module with a known register mapping or a Linux driver can be easily read out and configured. Front-ends with Ethernet connectivity can be controlled via standard C++-sockets or via libraries from the device manufacturer. The access to devices with a CAN bus interface or to Programmable Logic Controllers (PLCs) has also been realized with FESA at GSI.

DATA ACQUISITION SYSTEMS

FESA is well suited for data acquisition tasks in beam diagnostics. Several FESA classes have been developed at GSI, replacing old measurement systems or implementing new functionalities.

BPM System (TOPOS)

One of the first FESA installations which has been deployed at GSI is the Tune, Orbit and Position Measurement System (TOPOS) [2]. In the GSI heavy ion synchrotron SIS18, twelve BPMs are connected to Libera Hadron devices, delivering beam position data for each individual bunch over a whole acceleration cycle. Position data is sent over Ethernet to two powerful Linux computers (Dual Intel Xeon QuadCore 2 GHz CPU, 32 GB RAM, 64 bit Scientific Linux). For every BPM/Libera combination, there is one BPM FESA class that receives and handles the data stream. During acceleration, the bunch frequency increases from 800 kHz at the injection to a maximum of ~ 6 MHz at the flattop, depending on the desired ion energy. The resulting data rate is between 70 MBit/s and 580 MBit/s per BPM. The FESA classes handle this huge amount of data, process it and send this reduced stream of data to the graphical user interface (GUI) for presentation. The tune of the machine is calculated throughout the complete acceleration cycle, allowing an online tune observation [3]. Tasks like data storage, system calibration, bunch tracking and the excitation of the beam with stripline exciter plates can be performed upon request. Figure 1 shows the TOPOS GUI in raw data mode with longitudinal bunch profiles.

Figure 1: TOPOS in raw data mode, showing longitudinal bunch profiles of four bunches in the GSI synchrotron over several turns.

Scaler System (LASSIE)

The Large Analog Signal and Scaling Information Environment (LASSIE) is a FESA-based system to monitor, analyse and distribute a large number of analogue and digital signals. It is used to correlate different machine parameters and measurement values of the accelerator like depicted in Fig. 2. During a slow sequential beam extraction out of the synchrotron, the signals from a beam transformer, a magnet and three beam loss monitors can be presented. The user can interactively select the desired data channels to be visualized on the screen. Counter signals from the hardware are plugged into several VME SIS3820 [4] scaler boards. The GSI setup is prepared to handle up to 192 channels with a sampling rate of up to 1 MHz. During operation, the typical scaler latching frequency is between 100 and 1000 Hz. At this frequency, the data of all 192 channels can easily be transferred through the VME bus and processed by the FESA class. When higher frequencies are demanded, the VME backplane becomes a bottleneck, since its maximal transfer rate is about 50 MByte/s depending on the transfer mode [5]. Filtering mechanisms inside FESA ensure, that only relevant data which is seen in the GUI is transferred over the network. LASSIE is available in the GSI main control room and will replace the previous ABLASS system [6].

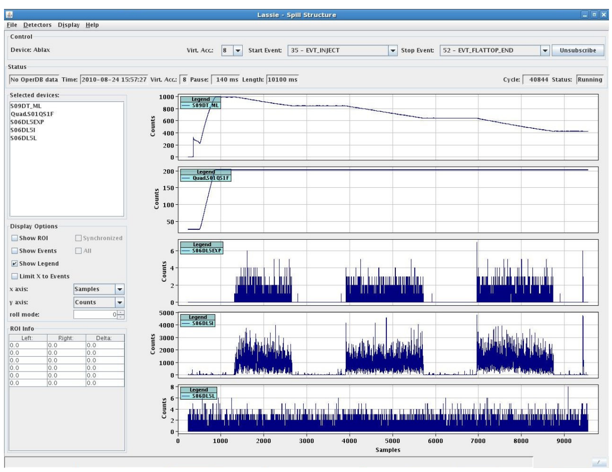

Figure 2: LASSIE screenshot of a sequential slow extraction out of the GSI synchrotron, showing the following machine parameters (top to bottom): beam current in the ring, magnet ramp and signals of three beam loss monitors.

Gigabit Ethernet Cameras

Many beam diagnostic systems rely on two dimensional image data from cameras, e.g. the readout of scintillator screens or Beam Induced Fluorescence monitors. Currently, FireWire cameras are used to obtain the images and their readout is done via Windows and LabView drivers. To overcome limitations regarding cable length and Windows/LabView, Gigabit Ethernet (GigE) cameras have been tested at GSI. The cameras come with Linux drivers and software development kits from the vendors, making it possible to address them directly out of FESA. For a first test, two different GigE cameras have been integrated: The Prosilica GC 650 and the IDS uEye UI-5240SE-M. Both models provide Linux libraries for camera access which have been linked to the FESA class.

To avoid network overload, the computer processing the camera images can be equipped with two network cards: one for the standard accelerator network, the other as point-to-point connection to the GigE camera. The camera class acquires the images and sends them to any GUI which has subscribed to receive the data. If the original image data is not needed, network bandwidth can be saved by distributing solely the projections and the histogram of the images.

The performance of the system in a prototype GUI reached 10 frames per second (see Fig. 3). Future machine vision systems for FAIR will be implemented using GigE cameras and FESA.

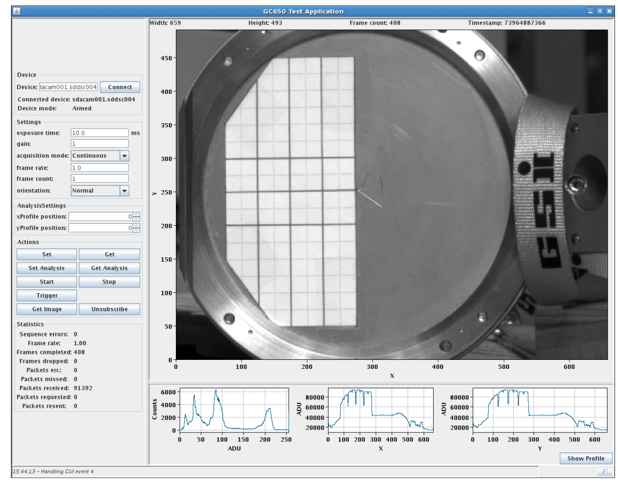

Figure 3: GigE camera readout with FESA. The screenshots shows the prototype GUI with an image of a scintillator screen test installation.

CONTROL TASKS

PLC/Slow Control

At the GSI accelerators, Siemens Simatic PLCs are used as a reliable slow control solution. The IEPLC tool by CERN [7] offers a convenient way to bring PLCs into the control system. The IEPLC configuration data defines the PLC hardware setup and the communication parameters between the PLC and a client like FESA. The tool produces source code which is uploaded into the PLC and a C++ library which can be linked to FESA or any other client. The communication with the PLC is realised via standard Ethernet.

The PLC installation at the GSI beam diagnostic devices controls several voltages and relays of the Beam Induced Fluorescence (BIF) monitors: 12 bit DACs provide adjustable voltages to camera irises, for the amplification control stages of image intensified cameras and for the calibration LEDs inside the beam pipe. Relay modules provide a remote reset capability of system components like cameras or a gas pressure controller. The PLC access via FESA has been integrated into the existing software for the control of Beam Induced Fluorescence monitors which is already in operation at GSI [8]. For device experts and maintenance, a standalone application to control all PLC parameters is available.

Network Devices

Lots of commercial hardware comes with integrated Ethernet connectivity. Since FESA classes are standard C++ code, connections to devices via TCP/IP or UDP are easily implementable. Remote controllable power plugs (Anel NET-PwrCtrl PRO) have been integrated to enable a convenient remote reset ability within FESA. A UDP packet is sent to the device to trigger the remote power sockets. In the FESA class, a UDP listener waits for a response packet to see, if the command was correctly executed and if the device is still up and running. For rapidly changing hardware installations in the experimental areas, this setup provides a simple reset solution.

Using the TCP/IP protocol, a FESA class for a Pfeiffer gas control device (RVC 300) has been developed. The gas control itself features only an RS232 port, so an RS232 to Ethernet converter (Lantronix UDS2100) is used to bring the device into the network. The FESA class connects to the converter and sends the commands via TCP/IP. The converter forwards the command to the gas control and sends back the answer over the network. The values for the actual and the demanded pressure are queried every second from the hardware. A small GUI enables the user to monitor the pressures and to set a new pressure value.

Network devices with libraries from the manufacturer are also addressable in FESA, e.g. the high voltage power supply from CAEN.

High Voltage Power Supply

Several beam diagnostic devices need high voltages for proper operation. The CAEN x527 series is a modular high voltage power supply system which can be equipped with up to 192 individual channels. It is controllable over Ethernet and comes with Linux libraries, making it easy to set, get and monitor the voltages and the current of each channel. The existing FESA class is currently extended to provide advanced functionality: Special image intensifiers need two voltages which have to be ramped up simultaneously within a small offset. This ramping procedure is carried out by the class and is synchronously monitored, to detect malfunctions and to shut down the voltage in case of an error.

CAN

Some old devices at GSI do not offer Ethernet connectivity, but have a CAN interface. To make these devices remotely accessible, a CAN FESA class has been developed. The class uses a PCI CAN card in a Linux PC to communicate with these devices. The current use-case of the class is the control of old VME crates (Wiener 6021 series) without Ethernet port. The single board computer inside the fan tray of the crate controls the power to the VME backplane. It also monitors system parameters like fan speeds, temperatures and the power levels of the different voltage lines. If the CPU module in the crate does not respond anymore, a system reset becomes necessary. To shut down the voltage of the whole VME bus, a CAN command is sent and the power is cut. The CAN connection can also be used to monitor the device parameters. CAN devices can be daisy-chained, so up to 127 devices can be controlled within one CAN bus segment.

SUMMARY AND OUTLOOK

As expected, FESA is an excellent tool to control and acquire data from front-ends in various form factors. The installations at GSI run very stable and are already in operation in the main control room. FESA can be used to provide a universal layer between the control system and other protocols like the CAN bus or PLCs. Future FESA projects include a Fast Current Transformer which is read out by a 500 MHz 12 bit ADC (SIS3350 [4]). The aim of this setup is to perform bunch tomography.

To overcome limitations of the VME architecture, a new form factor called 'xTCA for physics' is currently tested at GSI. xTCA provides a serial backplane which can handle various high speed protocols like Gigabit Ethernet, 10 Gigabit Ethernet, serial Rapid IO (sRIO) and PCI Express with a bandwidth of up to 20 GBit/s. It is possible to create fast point-to-point connections between the different modules inside the crate. Further promising advantages are the ability to exchange modules during operation (hot-swap) and to detect and isolate errors without the necessity to interrupt the operation. A first performance test of the system will be carried out using GigE cameras, a 4x GigE adapter by Kontron (AM4301) and an Adlink AMC-1000 processor module.

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