Detector control system for CBM-TOF

S. Dong\textsuperscript{a}, G.M. Huang\textsuperscript{a,1}, J. Fräijenhauf\textsuperscript{b}, P.-A. Loizeau\textsuperscript{b}, I. Deppner\textsuperscript{c}, N. Herrmann\textsuperscript{c}, D. Wang\textsuperscript{a}

\textsuperscript{a}Central China Normal University, No.152 Luoyu Road, 430079 Wuhan, China
\textsuperscript{b}GSI Helmholtzzentrum f"{u}r Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany
\textsuperscript{c}Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

E-mail: s.dong@mails.ccnu.edu.cn, gmhuang@mail.ccnu.edu.cn

ABSTRACT: For charged hadron identification, a high-performance Time-Of-Flight (TOF) RPC wall is being built for the CBM experiment at FAIR. The detector control system (DCS) for CBM-TOF is designed based on EPICS. Instruments, including power supplies, power supply distributors, and gas control systems, are controlled and monitored in a CBM full system test-setup called mCBM (mini-CBM). For monitoring the environment of the detector in a radiant environment and the status of front-end electronics (FEE), a slow control application is implemented based on IPbus, which is an FPGA-based slow control bus also used in TOF fast data acquisition (DAQ) system. Besides the functions of controlling and monitoring, exception handling and data archiving functions are also implemented. This control system was fully verified in beam tests in 2019 at GSI.

KEYWORDS: Control and monitor systems online; Detector control systems (detector and experiment monitoring and slow-control systems, architecture, hardware, algorithms, databases)

\textsuperscript{1}Corresponding author.
1 Introduction

Compressed Baryonic Matter (CBM) is a heavy-ion experiment located at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. This experiment will use high-energy nucleus-nucleus collisions to study the equation-of-state of nuclear matter at neutron star core densities, and the search for phase transitions, chiral symmetry restoration, and exotic forms of QCD matter.

A 120 m² large TOF wall composed of Multi-gap Resistive Plate Chambers (MRPC) is the key element in CBM. The TOF providing hadron identification at incident beam energies between 2A and 11A GeV. The system time resolution should be better than 80 ps, including all electronics jitter and the resolution of the time reference system.

Towards the realization of the CBM experiment, the mCBM test-setup is a significant project. It will allow us to test and optimize the performance of the detector subsystems, including the software chain under realistic experimental conditions, which will significantly reduce the commissioning time for CBM at SIS100. The mCBM is being installed at the SIS18 facility of GSI/FAIR.

2 DCS at mCBM

To handle this kind of large and complex system which has tens or even hundreds of computers, thousands of devices and instruments, to have a stable and scalable control system is fundamental.

The control system of CBM-TOF is designed based on the Experimental Physics and Industrial Control System[1] (EPICS), for setup and monitoring of hardware that is not time-critical and can be run at a low priority, such as low/high voltage modules, temperature sensors, pressure gauges, and front-end electronics. The instruments are used in mCBM is shown in Table 1.

EPICS is widely used to create distributed soft real-time control systems to operate devices such as particle accelerators, large experiments, and major telescopes. It is designed based on specific network protocols, Channel Access and pvAccess, which are for high bandwidth, soft real-time networking applications. Client/Server and Publish/Subscribe techniques are used to communicate between various computers.
Table 1. Instruments are being controlled and monitored in mCBM

| Instrument          | Model                  | Port  |
|---------------------|------------------------|-------|
| Low voltage         | MeanWell RCP-2000-12   |       |
|                     | MeanWell RKP-1UI-CMU1  | Http  |
| Low voltage distributor | GSI Low voltage distributor | RS232 |
| High voltage        | SY1527LC               | TCP/IP|
|                     | A1526P                 |       |
|                     | A1526N                 |       |
| Gas flow            | Bronkhorst control units | I2C   |
| FEE                 | Front-end electronics  | IPbus |
| Detector environment| Front-end electronics  | IPbus |

Three parts can describe an EPICS control application, Operator Interface (OPI), Input-Output Controller (IOC), and Local area network (LAN). OPI is a workstation that can run various EPICS tools such as Motif Editor and Display Manager (MEDM), Control System Studio[2] (CSS). IOC supports EPICS run time databases together with the other software components. LAN is the communication network that allows the IOCs and OPIs to communicate.

The physical structure of CBM-TOF DCS is shown in Figure 1. The OPIs of the mTOF DCS are designed based on CSS. IOCs communicate with instruments via kinds of interfaces, such as USB, I2C and ethernet. In consideration of convenience and cost, the Raspberry Pi is widely used in this experiment.

Figure 1. TOF DCS Physical Structure
2.1 Power Supplies and Gas Flow

The power distribution box designed by GSI can split the low voltage (12 V) from 1 channel to 16 channels. It distributes the MeanWell power supply system, which supports 112 A output maximum to front-end electrical and clock scatter network. Figure 2 shows the structure of the low voltage power supply system. An Arduino development board in the distribution box is used to control the relays to switch on/off of each channel. A Raspberry Pi 3B communicates with the Arduino board via the USB interface. StreamDevice[3] is adopted in low voltage IOC to send and receive strings to control devices. It is a generic EPICS device support for devices with a "byte stream" based communication interface, which means the devices that can be controlled by sending and receiving strings.

![Figure 2. mTOF LV Structure](http://example.com/figure2.png)

We use Caen SY1527LC Crate and HV modules (Caen A1526P/N) to power MRPC modules. Since there is not EPICS IOC support by the manufactory, and only an official C program driver is supplied. We built the IOC of high voltage based on StreamDevice module and AsynDriver[4] module. AsynDriver is a general-purpose facility for interfacing device-specific code to low-level drivers, and it drives the driver of power supply for controlling and monitoring. The official driver ethernet to control the power supply through ethernet, the HV IOC will communicate the power supply via TCP/IP.

A gas control box designed by the Laboratory of Instrumentation and Experimental Particle Physics (LIP) is adopted in mCBM. By this box, the flow speed of three kinds of gases(i-C4H10, C2H2F4, SF6) are controlled. The status of the environment of the box, such as gas pressure, atmospheric pressure, temperature, and relative humidity, are also monitored. There is a Raspberry Pi to be used to controls Bronkhorst Control Units via I2C protocol inside the box. The gas flow IOC is running on the same Raspberry Pi (mtofgas01) in the control box.
2.2 FEE and Detector Environment

The readout chain of mTOF is based on the GBTx[5] and GBT-SCA ASICs[6], the Data Pre-processing Board (AFCK), the software and firmware based on the IPbus protocol. The fast control software communicates with the hardware through an IPbus master. The GBT-SCA ASIC is part of the GBT chip-set, has the purpose of distributing control and monitoring signals to the on-detector FEE and monitor detector environmental parameters. The SCA provides several user-configurable electrical interface ports, able to perform concurrent data transfer operations. For monitoring the environment of the detector such as temperature, pressure, and humidity, the status of FEE and
controlling the FEE, the firmware, and software for slow control are developed based on the fast control system. The slow control data is transferred from GBT-SCA and then transferred with the GBT data frame, which includes detector data and FEE data. In this way, control and data share the same link, and that saves a separate potential isolator for controls. Figure 5 present the structure of slow control and fast control system.

A python EPICS IOC for GBT-SCA was designed based on the libraries of IPbus and EPICS. The EPICS IOC can control the ADC, GPIO, and I2C interfaces of GBT-SCA. Two sensors (BME280) are equipped on Feed Though PCB for monitoring detector environments, one is inside the detector, and another is outside. They are connected with the I2C ports of SCA. The ADC ports are used to monitor the voltages on FEE and the temperature of SCA ASIC. GPIO4 of SCA is used to switch between GBTx recovered CLK and external 160MHz CLK for FEE, and some LEDs are connected to indicate whether PCB works properly.

2.3 Archive and Exception Handle

We use CSS Archive Tools to build the archive system. The database is designed based on PostgreSQL. For mTOF, 2635 channels are archived, and nearly 200MB disk space spend per Day. The archive Tools will build a web server, from which we can view the status of the archive system. The status of the archive system can be checked at any time from outside of the experiment cave.

As more devices will be controlled, the DCS should act as a whole part and be very robust and stable. Each part will have some impact on some other part. For example, if some problems occur on high voltage, first all HV channels should be shut down, then the low voltage will be shut down. As Figure 6 showed that some exception handles were implemented using the EPICS Sequencer module[7].

Figure 5. ECS and DCS of mTOF


3 Conclusions

The detector control system for CBM-TOF is designed based on EPICS and has been tested in beam tests in 2019 at GSI. In addition to the instruments like power supply and flow control devices, the control path from the detector to FEE and DAQ is developed.

Acknowledgments

We would like to thank the CBM TOF team for their work.

References

[1] L. R. Dalesio, J. O. Hill, M. Kraimer, S. Lewis, D. Murray, S. Hunt et al., *The experimental physics and industrial control system architecture: past, present, and future*, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 352 (1994) 179–184.

[2] J. Hatje, M. Clausen, C. Gerke, M. Moeller and H. Rickens, *Control system studio (css)*, *ICALEPCS07*, Knoxville, TN, USA (2007) .

[3] D. Zimoch, *Epics streamdevice*, 2017.
[4] M. R. Kraimer, M. Rivers and E. Norum, *Epics: Asynchronous driver support*, in *Proc. Int. Conf. Accelerator and Large Experimental Physics Control Systems*, pp. 074–5, 2005.

[5] P. Moreira, K. Wyllie, B. Yu, A. Marchioro, C. Paillard, K. Kloukinas et al., *The gbt project*, .

[6] A. Caratelli, S. Bonacini, K. Kloukinas, A. Marchioro, P. Moreira, R. De Oliveira et al., *The gbt-sca, a radiation tolerant asic for detector control and monitoring applications in hep experiments*, *Journal of Instrumentation* **10** (2015) C03034.

[7] W. Lupton and B. Franksen, *State notation language and sequencer usersâ€™ guide*, 2000.