# DATA ACQUISITION AND CONTROL SYSTEM FOR SAMSUNG SUPERCONDUCTOR TEST FACILITY

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*Abstract*

Samsung Superconductor Test Facility (SSTF), a superconductor and superconducting magnet test facility, has been constructed at Samsung Advanced Institute of Technology. The main purpose of SSTF is to manufacture and test superconducting magnets for the Korean Superconducting Tokamak Advanced Research tokamak. The data Acquisition and Control (DAC) system for SSTF is composed of UNIX workstations, VME controllers running VxWorks real time OS, VME I/O modules and PLC. The quench detection and magnet protection system using Digital Signal Processors are being developed. EPICS is used for the acquisition and distribution of experimental data via TCP/IP. A script-based interpretive shell program and commercial Mathematica are used to manipulate the experimental raw data produced by EPICS in the Channel Access (CA) server. We present here the status of the SSTF DAC system and the recent results of commissioning and superconductor sample test.

## 1 INTRODUCTION

The Korean Superconducting Tokamak Advanced Research (KSTAR) project to build a superconducting magnet tokamak for the steady-state plasma experiments is on going and its first operation will be in the fall of 2003. The main parameters of the KSTAR tokamak are listed in Table. 1. KSTAR magnets are fully superconducting, composed of 16 toroidal field (TF) coils producing 3.5 T at the TF coil center, 14 poloidal field (PF) coils which produce 15.8 Volts-sec and 12 field error correction (FEC) coils [1].

Table 1: Main parameters of KSTAR

| | |
|---|---|
| Toroidal field, $B_T$ (T) | 3.5 |
| Plasma current, $I_P$ (MA) | 2.0 |
| Major Radius, $R_0$ (m) | 1.8 |
| Minor Radius, a (m) | 0.5 |
| Elongation, $\kappa_X$ | 2.0 |
| Triangularity, $\delta_X$ | 0.8 |
| Poloidal divertor nulls | 2 |
| Pulse length (s) | 20 |

SSTF has been constructed at Samsung Advanced Institute of Technology (SAIT) to fabricate and test superconducting strands, conductors and magnets. It consists of a vacuum cryostat, helium and liquid nitrgen cooling systems, vacuum system, background magnet system, power supply system and data acquisition and control system. The Large Vacuum Cryostat (LVC) with diameter 6 m and height 7.6 m is located in a pit 9 m x 9 m x 6 m deep. It is connected to three cold boxes (CB#1, #2 and #3) and each of them is a control and sum box, a valve box and a current lead box, respectively [2].

Recently, the operation for the commissioning the SSTF with KSTAR TF full-scale CICC (Cable In Conduit Conductor) sample has been performed. This paper presents the status of SSTF data acquisition and control (DAC) system and the brief results of the recent experiment.

## 2 SSTF DAC SYSTEM

### *2.1 System Overview*

Figure 1 shows a schematic block diagram of the SSTF DAC system. It is based on the VMEbus and Solaris-OS UNIX host workstations. Two VME crates house Motorola MVME167 boards with 68040 CPU running VxWorks 5.3 as a real time OS. Each crate contains the various I/O modules. For lower level control of vacuum, valves and power supplies, sets of PLC are also used. All of the signals from sensors are conditioned using isolation amplifiers. Voltage tap signals will be isolated by high voltage isolators to be installed near the cryostat to protect the DAC system from possible surge voltage arising from accidents.

We use the EPICS software as a data acquisition tool and also a script-based interpretive shell program named GUS for data archiving and off-line analysis.

### *2.2 VME I/O Boards*

Various VME I/O modules are used for SSTF data acquisition and control. At present, 128 channels of VMIC VMIVME3122 boards are used to monitor temperature, pressure, magnetic field and voltage from sensors.

A quench detection and magnet protection system using a Quad DSP board, Pentek4275 connected to two high speed ADCs (Pentek4270) via local MIX bus is under development.

In addition to these, a VMIVME4100 Digital to Analog Converter, a Pentek1420 clock and NIGPIB1014 VME boards are used.

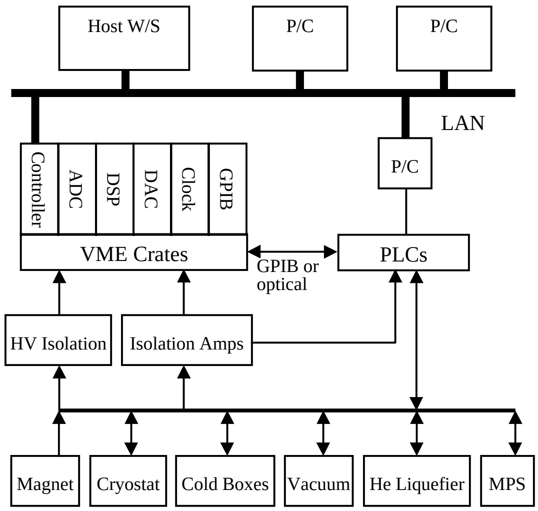



Figure 1: Schematic Block Diagram of SSTF DAC system.

## 2.3 Quench Detection and Magnet Protection

Voltage taps, optical fibers and pressure transducers are employed to detect a quench. With the large number of magnet monitoring signals and the complexity of the algorithms, it is inappropriate to use conventional analog hardware for quench signal processing. It has been proposed to use a digitized computer-based signal processing system with ADC and DSP and this is now under development at SSTF [3].

Signals from voltage taps are conditioned through isolation signal conditioners and digitized by and ADC and passed to DSP's which determine whether the signals came from a quench of the coils. The criteria to determine whether it's quench or not is as follows:

$$V \geq V_{th},\ dV/dt \geq 0,\ d^2V/dt^2 \geq 0,$$

where $V_{th}$ is the threshold voltage value that is determined by the quench analysis according to the tokamak operating status.

Internal fiberoptic sensors will detect quenches by measuring the temperature rise associated with a quench inside the superconducting cable. Fiberoptics have advantage of insensitivity to electromagnetism and are non-invasive. Copper-coated optical fibers are used because they can survive high heat treatment temperatures and extremely low temperatures. To measure the temperature change resulting in change of optical path length, Michelson interferometry is used as shown in Figure 2.

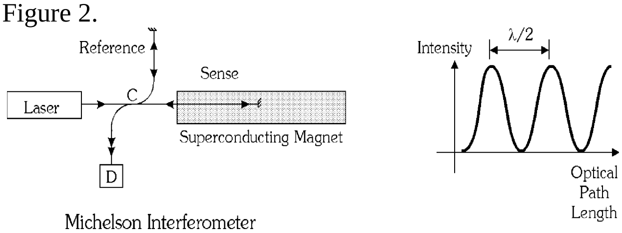



Figure 2: Layout of Michelson Interferometry

As the optical path length of the sensing arm changes, lights from the sensing and reference arms interfere producing fringes as shown in the right half of the figure. By counting the number and direction of fringes, the change in optical path length of the sensing arm can be measured very accurately and eventually the temperature change can be measured [4].

## 2.4 Signal Processing

Due to electromagnetic noise, all of the signals are conditioned by isolation amplifiers. Voltage tap signals will be isolated by high voltage isolators with a maximum isolation voltage about 20 kV. At present, 100 channels of isolation amplifier are being used at SSTF. They can isolate up to few kilovolts with either high or low pass filters and the gains are selectable by resistor change.

## 2.5 EPICS

EPICS (Experimental Physics and Industrial Control System) is being used as the central data acquisition and control software [5]. The main purpose of EPICS is to provide a fast, easy interface to supervisory control, steady-state control, and data acquisition and also to provide an operator interface to all control system parameters.

We use the latest version of EPICS (Release R.3.13) on Solaris. Currently, IOCs are the VME controllers. An EPICS run-time database on the IOC and Channel Access (CA) constitute the core of EPICS software. Records defined in databases are accessed by EPICS client software using the logical field names of the records. EPICS databases are edited using Capfast and a simple text editor and complied to be loaded into the IOC by a VxWorks startup script file.

## 2.6 GUS

A script-based interpretive shell GUS (General Purpose Data Acquisition Shell for Unix System) is being used as the data archive and off-line analysis software. The primary function of GUS is to provide a data sharing method among modularized objects called Data Access Modules (DAMs). GUS consists of a user interface, command parser, built-in command, and DAMs. GUS also incorporates the Unix shell and is able to utilize the existing Unix programs and this makes up the 5th major component of GUS. GUS also provides a standard data I/O method and any external program using the standard I/O routine can share the variables and data of GUS.

For the application to SSTF, modules for EPICS have been written as DAMs; TCP/IP GPIB, graphics, matrix manipulation, file I/O, variable manipulation, gas property and a database. The database module also includes a sensor calibration package. When GUS acquires a voltage signal via an EPICS CA module, the package finds the proper calibration data and required physical property database to provide a calibrated value.

Three GUS script programs, “cooling.scr”, “view.scr”, “hpsa.mcr” run independently. “cooling.scr” accesses the variables through EPICS CA, converts the data to calibrated values, and stores the data in a database format. “view.scr” reads the stored data and shows the data using graphics. “hpsa.mcr” is a macro script which has several subroutines for data acquisition and analysis.

## 3 SSTF COMMISSIONING AND CICC SAMPLE TEST

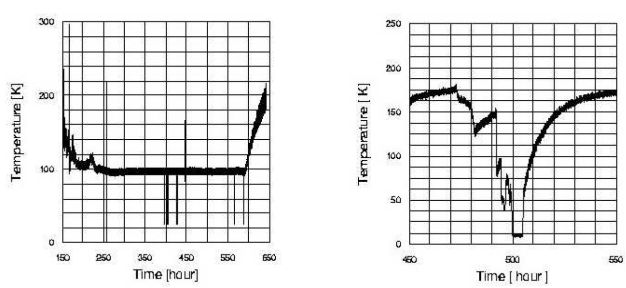
The SSTF commissioning operation has been performed from June through August using KSTAR full scale TF CICC and Joint sample. The sample under test is about 3.5 m long and has about 50 sensors, which are internal and external voltage taps, Cernox temperature sensors, Hall probe arrays and optical fibers. Table 2 lists the number of signals monitored during the experiment.

Table 2: Signal Inventory for SSTF sample test

| Location | Temperature | Pressure | Voltage | Total |
|---|---|---|---|---|
| CB#1 | 8 | 5 | 0 | 13 |
| CB#2 | 18 | 9 | 0 | 27 |
| CB#3 | 5 | 0 | 4 | 9 |
| LVC | 3 | 0 | 0 | 3 |
| Sample | 5 | 0 | 24 | 29 |
| | | | Total | 81 |

Most of data from the SSTF vacuum cryostat, cold box 1, 2, and 3 are monitored and saved every minute, while voltage tap signals from the sample under test are sampled every 0.1 second.

Figure 3 shows the LVC thermal shield cool down history and the helium cooling system operation history during the test. Thermal shields can sustain less than 100K during the test period and the Helium return temperature from the sample during the test is about 8K at a pressure of 60 psi.




(a) (b)

Figure 3: Cool down history of thermal shield (a) and the sample (b)

The frequency response characteristics of the sample conductor and joint assembly are determined by sweeping the applied voltage frequencies to the sample. Figure 4 shows the preliminary results from the test. The joint assembly shows improved DC resistance over the lap joints used for the sample terminations, but significant increase in AC loss over 100 Hz, which is similar to those of lap joints.

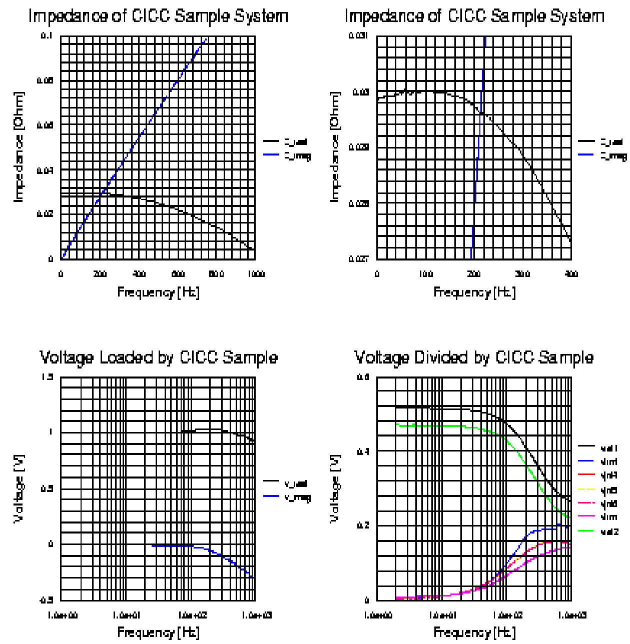



Figure 4: Preliminary Results on Frequency Sweeping Test of the Full Scale KSTAR TF Conductor Sample

## 4 CONCLUSION

The SSTF DAC system has been developed and tested during the commissioning operation using the KSTAR TF full scale CICC sample. For the full test of real superconducting magnets under various operating scenarios, the quench detection and magnet protection system using a DSP and a fast ADC is being developed. In order to protect the DAC system from the high voltage noise, high voltage isolators and more isolation amplifiers will be installed.

## REFERENCES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