Test Stand for SRF Cavity Electronics

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Various types of electronic printed circuits (PC) cards are used to measure different signals on four superconductive cavity cryomodules currently installed at the Cornell Energy Storage Ring (CESR). My project involved the design of a test stand able to check and troubleshoot these cards in a quick and effective manner in order to avoid their failure during operation periods and improve testing time efficiency.

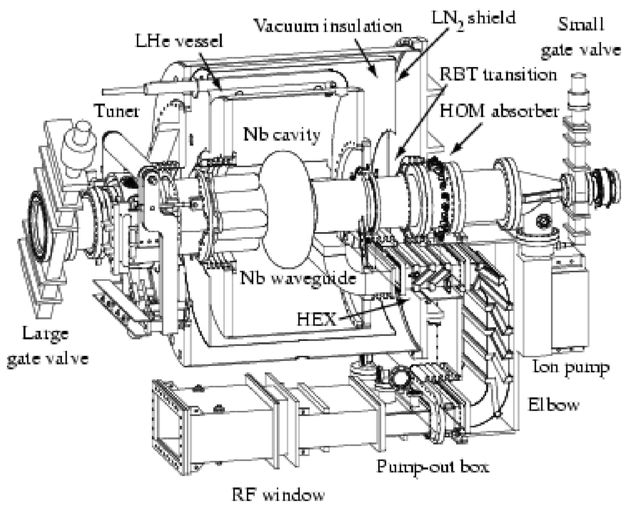

FIG. 1: SRF cryomodule and its components

I. INTRODUCTION

There are four Superconductive Radio Frequency (SRF) cryomodules (Fig.1) installed at CESR. The cryomodule is a very complex device featuring different parts operating under different conditions: from extremely low temperature (4.5K), to room temperatures, from 19 psi (absolute pressure), to high vacuum. It also has to support high average current beams (up to 0.4 A each) of electrons and positrons in the accelerator by providing high Radio Frequency (RF) voltage (up to 3 MV) and power (up to 300 kW) to the beams. To operate such a device, one has to monitor and control many parameters: liquid helium level, cooling water flow rate, vacuum in the cavity, RF power, RF voltage across the cavity gap and more. As a consequence, various sensors are used for measurements and a number of signals have to be pre-processed in the CESR tunnel. These delicate electronics are located in the so called break-out-box (BOB). The environment in the tunnel during acceleration operation is very harsh on electronics due to the high level of radiations and especially for CMOS (complementary metal-oxide semiconductor) components that may experience occasional failures and loss of performance. From here, it is necessary to have a test stand that can check as many PC boards as possible during the routine shutdowns of CESR to assure reliable operation of the accelerator. In specific, the stand would be able to scan through eight types of cards: tuner control, cryogenic linear temperature sensor (CLTS), Allen-Bradley carbon resistors (AB), interlock comparators, amplifier, thermocouple (TC), low flow and high flow cards. Early on, when SRF electronics were first designed, a simple test chassis was built for testing the boards but over time demonstrated its inadequacy and inconvenience. For this reason, my summer project was to design a new test stand that would allow quicker testing with computer-assisted control and data acquisition via LabVIEW software of all the cards utilized in CESR SRF cavities.

II. DESCRIPTION OF PC CARD TYPES

There are eight types of cards that are currently used by the SRF cryomodules. Each has a certain function, unique characteristics, and specific type of signal generation. Because of their singular nature, these cards will influence the design of both our test chassis and the interactive LabVIEW software so it is fundamental to understand them before we proceed with our project in a more concrete way. The first card in our list is the tuner control card, which is one of the more complex. Its role is directly related to the activity of the SRF cavity, as it controls the stepping motor direction and speed, the tuner limits and the interlocks while also providing an interface between remote and local controls. Because of such an important role this card sends and receives data continuously and that is why it will later utilize both input and output modes in our LabVIEW software. Next is the thermocouple card. This is used to measure the temperature of cooling water in different parts of the system and temperature of the beam pipe at various locations. Because of its monitoring nature, the TC card only sends outputs to the computer. The other two types of temperature monitoring cards are the CLTS and AB cards. Although similar in function, these two cards have very different specs: the CLTS changes linearly with temperatures from 4 K up to room temperature and it is used to monitor various parts of the cryostat in this range; the Allen-Bradley card features carbon thermometers also used to measure cryogenic temperatures, but with one difference: they are extremely sensitive to small variations at low temperatures but very inaccurate above 200 K. Next are high flow and low flow cards. They are pretty similar to each other since they share the same components and they only differ in few parameter configurations. Their function is to monitor the flow of the cooling water, which is vital to the RF window and beam pipe cooling system. The high flow card measures flow from 1 to 6 GPM (gallon per minute) and the low flow card from 0.1 to 1 GPM. These two cards are close to the tuner control card in signal processing, since they receive inputs from the SRF apparatus and sends outputs to the computer. To conclude, the amplifier card perform general purpose differential amplification of voltages using an AD620 and the interlock comparators card performs general purpose CESR interlock switching. All the cards with the exception of the tuner control one are multi-channels: the amplifier card has 4 identical channels while all others have 8.

III. SIGNAL TYPES

Now that different types of cards have been analyze it is essential to understand what kind of signals are been used during both input and output operations because of the close relationship with the creation and development of the LabVIEW software platform. We encounter two fundamental types of signal: analog and digital. The analog signal can be described as a signal with a continuous nature rather than a pulsed or discrete one, an example of it can be given by frequency and amplitude changes in physical phenomena. A digital signal, on the other hand, has only two possible discrete levels a high (on) level or low (off) level and a good example would be a TTL line. Since the outcome of these two kinds of signals is very different, we have to establish which card utilizes them in order to create our program. Consequently, we see that the tuner control card receives inputs in analog and digital form and sends outputs in analog; the TC, amplifier, AB, CLTS and flow meter cards receive and send analog signals, while the interlock comparators one has analog inputs and digital outputs.

IV. SOFTWARE PLATFORM

The reason for creating a computer-assisted control and data acquisition software is to check the cards once they are connected to our test chassis. That is why we use LabVIEW, software based on the graphic programming language G designed to create virtual instruments (vi) capable of interacting and controlling various external machinery and apparatuses. This is crucial since we want to simulate the same signals that our cards will receive when the accelerator is in operation. In order to do so, we will have to provide our new chassis with D-Sub connectors so that our computer and cards will be able to exchange information. When we start developing the software, it is important to keep in mind how these different components will be linked to each other: a computer will be connected trough a PCMCIA card to a National Instrument terminal block that will be wired either in analog differential mode or digital mode depending on the signals to be processed. From the terminal block, all the wires will be connected to three D-Sub connectors, one for inputs and two for outputs, which will be used to check different cards on the test chassis. The type of signal that we are expecting from the cards is a critically important issue because we always measure voltages coming out of the various channels to extrapolate our information and knowing if we are using digital mode or analog mode will change the software configurations. As an example, if we expect a digital line, we will have a jump in voltage usually between 0V and +5V and we will relate it to a toggle switch or Boolean indicator. If we expect an analog differential signal, we will have continuous voltage changes and we will have indicators or graphs. The software that I designed has a virtual instrument panel for each card to be tested and it is suited specifically for the tasks to be performed. As an example, the high flow vi (Fig.2) outputs a modifiable square wave that simulates the output of a rotor water flow meter while displaying different indicators for each of the 8 channels. Simultaneously, the vi is programmed to read the voltages coming out of the card and convert them with a mathematical formula to the amount of water that would be passing through the pipe during operation periods. To conclude, the software used was National Instrument LabVIEW 6.1 edition.

V. THE INTERNAL WIRING DIAGRAMS

The performance of a good test chassis also depends on the wiring of its internal components. That presents another interesting part of the project. By looking at the schematic diagram of the single cards, we were able to wire outputs and inputs to the appropriate

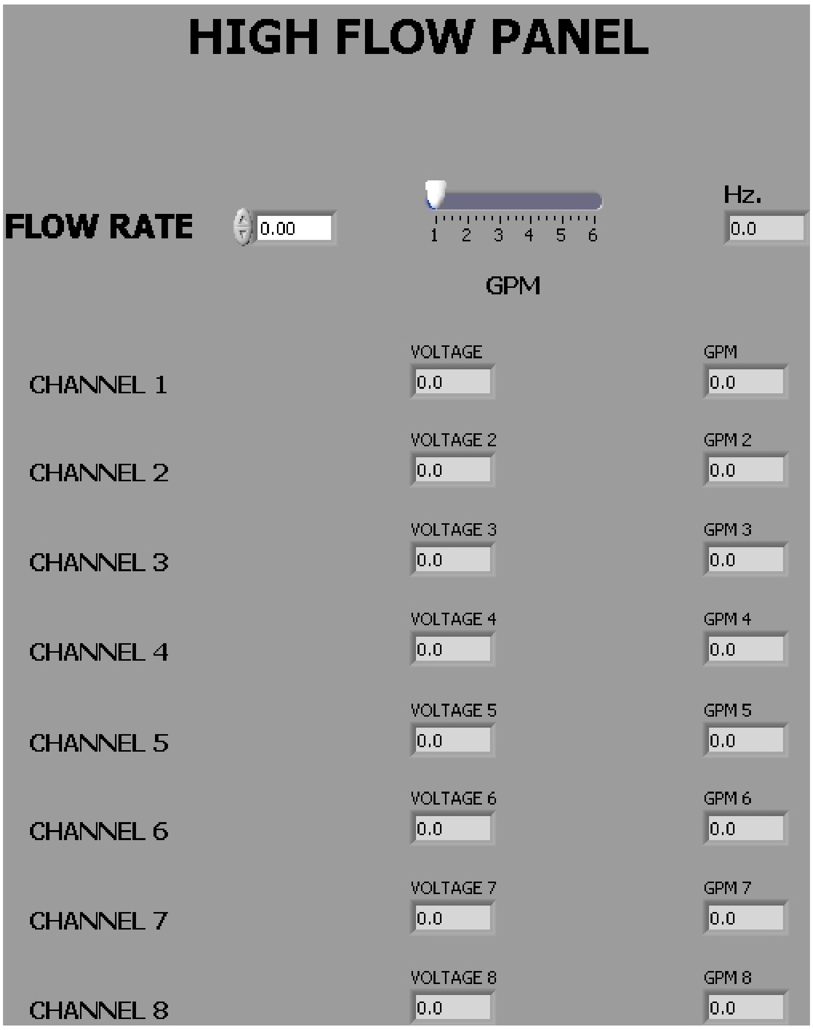

FIG. 2: Front Panel High Flow vi

D-Sub connectors pins and front panel components. The wiring diagram provided us a map of the system that was later used to develop the LabVIEW program. A power supply was also wired to the chassis in order to provide an independent source of power without using computer resources. The software used was OrCAD 9.2 edition.

VI. THE EXTERIOR DESIGN

Since the cards topic has been introduced and their characteristics, type of signals and relations with LabVIEW have been explained it is time to be more concrete and discuss the real face of this chassis. We know that our test should have enough space to host all 8 kinds of cards at once, which should have enough D-Sub connectors to enable transfer of data between cards and the computer. This should provide toggle switches and LEDs to satisfy the different requirements of the cards. That is why a good sized front panel (Fig.3) was crucial along with proper labels and connectors, depending on the type of card to be used. The process of creating an external face was very mechanical, but it also involved some reasoning and brainstorming with my mentors, as we were trying to visualize something that one will need to use but does not exist. Collecting the various parts, measuring their dimensions, and creating a full scale design was part of the challenge. The software used during the elaboration was AutoCAD 2002.

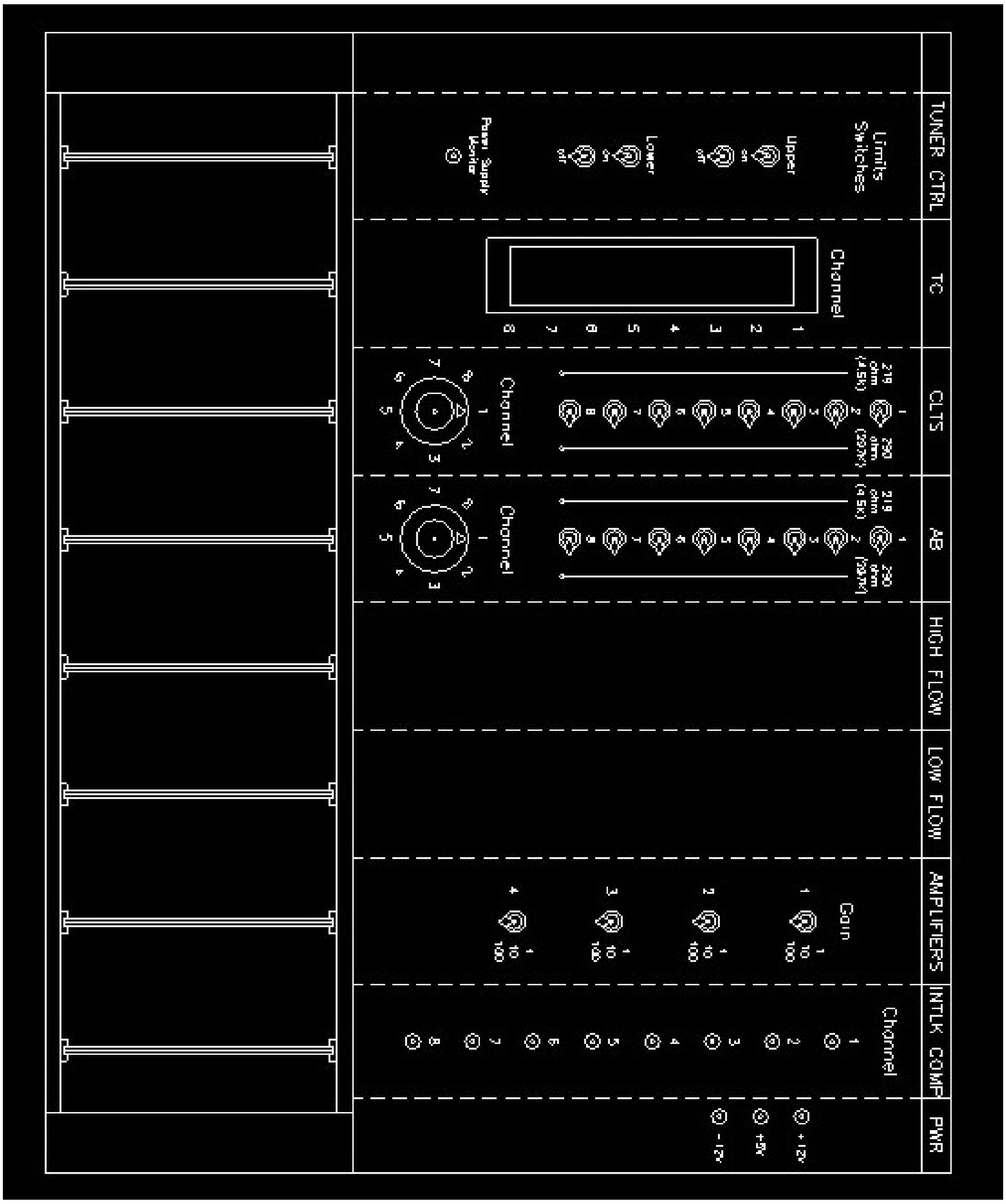

FIG. 3: Front Panel Design

VII. RESULTS

At this moment, the exterior design has been completed, the inside circuitry diagrams have been readied and the LabVIEW software has been programmed. Our software has been tested thanks to the use of various external simulation devices such as a function generator, a pulse generator, an oscilloscope, a DC power supply and a RMS multimeter. At this point, the AutoCAD drawings have been sent to the electronic shop and I can say that my summer project has been completed successfully.

VIII. CONCLUSIONS

I began this project with little knowledge of AutoCAD and no knowledge of either OrCAD or LabVIEW. Thanks to the help of my mentors and various online resources, I was able to gain a basic independence with these powerful tools and I have been more familiarized to the electrical engineering reality. I was able to understand more about particle accelerators and, overall, I had a truly great learning experience.

IX. ACKNOWLEDGEMENTS

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