

Colorado State University Accelerator Facility: Summer Internship 2013

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1.0 Introduction

1.1 Colorado State University Facility

Particle Accelerators are used today for medical, military, security, academic, industrial, and research purposes. Accelerators are growing in demand and as such there is a need for qualified employees who understand and know how to use an accelerator. More facilities are being created to train and teach students about these devices.

One such facility is the Colorado State University (CSU) Accelerator Facility. Headed by Drs. Sandra Biedron and Steven Milton, the Accelerator Facility will have four major systems: an accelerator and free electron laser (FEL) system, a laser laboratory, a microwave test stand, and a magnetic test stand. The goal of the CSU Accelerator Facility is to educate and train high-school through post-doctoral students about accelerators and beams.

1.2 My Role

During the summer of 2013, I interned at the CSU Accelerator Facility. I am currently pursuing my bachelor's degree in Electrical Engineering at the University of Illinois in Urbana-Champaign and as such had the necessary background that would help me in understanding accelerators. The United States Particle Accelerator School (USPAS) was hosted at CSU this summer. I participated in USPAS and took the Microwave Measurement course. Before USPAS, I worked on the RF Bead Pull Measurement with Josh Smith of Loveland High School. After USPAS, I worked mainly on the LLRF control system with Lucas Kang of Thomas Jefferson High School for Science and Technology. For the LLRF control system, I worked on both the software and hardware side of this system in order to get the control system up and running.

2.0 RF Cavity Bead Pull Measurement

2.1 Introduction

The RF Cavity Bead Pull Measurement is an automated bead pull design. It uses a step motor and pulleys to run the bead through a cavity. The RF Cavity Bead Pull Measurement uses LabView to automate the bead pull. Josh Smith and I improved upon both the design and the software.

2.2 Design

We improved upon the design by redesigning the pulley system, including the pulleys, the mount that the pulleys were on, and the drive pulley. The original system had plastic pulleys that were attached to L-brackets. We redesigned the pulley system to make it more durable. We ordered steel pulleys and then we fabricated the mounts and the drive pulley. We decided to make the mounts for the pulleys U-brackets to make them more stable, so they would not move. The drive pulley was designed by Josh and fits on the step motor (see Figure 1). We also acquired a stronger string and spring to make the RF bead pulley more durable.



Figure 1

2.2 Software

We also improved upon the software of the Bead Pull Measurement. The problems in the software that we fixed were how the program calculated the position of the bead as well as what data the program took. We added the ability to measure the Q value of the cavity. Once we measure the Q value, we can find the shunt impedance(R) of the cavity. The equation used to find the shunt impedance is as follows:

$$\frac{R}{Q} = \frac{1}{f} * \frac{1}{2\omega_0} * \left(\int_{gap}^{\square} \sqrt{\frac{\Delta \omega (X_{gap} * Y_{gap} * Z)}{\omega_0}} dz \right)^2$$

The integral of the square root function can be found from the measurement of the change in frequency inside the cavity as the bead passes through the cavity.

The data that the program now collects is the start and stop frequencies and velocity of the bead used for the test, the Q value, the readout of the screen as the start of the experiment, the number of steps the bead has taken, the peak frequency, the graph of the root of the deviation over the normal (which is how to verify that the Q value found is correct), and an estimated integral sum to verify the Q value.

We tested the program mainly on the Aluminum cavities using a plastic and a metal bead. The peak frequencies displayed within the range set on the control panel for the full cell Al cavity are: 2.855GHz to 2.859 GHz for the plastic bead and 2.84 GHz to 2.859 GHz for the metal one.

Josh also designed a vi for two cell cavity. The changes he made along with the new procedure to work the bead pulley are in the computer in the RF measurement laboratory.

2.3 Copper Cavity Stand

Once we had improved upon the RF bead pulley measurement system, we were ready to measure the MHz copper cavities instead of the Al cavity. The copper cavities are bigger and much heavier and therefore need a special stand that had already been designed. We assembled the pieces that we found in the RF laboratory, however not all the pieces were there. We are still missing 4 rods, the top piece, and a small side bar for the MHz stand.

3.0 LLRF Control System

3.1 Software

The LLRF and HPRF Control System uses Labview programs that are on old computers. The LLRF system software connects to VXI modules. The HPRF system connects to Beckhoff hardware. The computers that these software systems are on are outdated and need to be upgraded to a newer system. I worked on this system with Lucas Kang.

The first item that we accomplished to update the system was clone the drives of the old computers to new SATA drives. We used a program, which is on the desktop of the original drives. We now have cloned the old drives for the LLRF and HPRF control systems and have upgraded these drives to SATA drives which will run faster than the old drives.

3.1.1 Initialization

Both the LLRF and HPRF system require initializations before running the Labview programs to interface between the software and the hardware.

For the HPRF system we needed to initialize the Beckhoff system. The Beckhoff system can be initialized on the HPRF computer drive. On this drive there is a program on the desktop called TwinCat. This is the program that needs to be opened to initialize the Beckhoff system. Once you open this program it should automatically take you through the steps to initialize the Beckhoff system. However, this initialization is usable for 30 days and then it needs to be re-initialized.

During the installation of TwinCat, the program automatically generates a System-ID based on the processor and hard disk; you can then call the following number to receive a Registration Key and no longer have the 30-day free trial. The number is +49 (0) 5246 963-0. More information about the Beckhoff initialization can be found at their website [1].

The VXI initialization program is found on the LLRF system computer. It can be found on the taskbar and is a National Instruments initialization. Once you have initialized the VXI module, you then need to open up Resource Manager before opening the LabView files to insure

good communication between the hardware and the software of the control system. Resource Manager is a National Instruments program and can also be found on the task bar.

3.1.1 Labview files:

The second step in updating the system is to convert the old Labview files to the newest version of Labview, which is Labview 2012. However, there are two different versions of Labview that the control system uses. The HPRF system uses Labview 6.1, while the LLRF system uses Labview 5.0. We started to convert the control file systems to Labview 2012. The HPRF system is in Labview 6.1 which can be easily converted to Labview 2012. To convert the old Labview files to the new Labview 2012 program, we used the function mass compile, which will automatically convert the files. The mass compile function can be found under the file menu. We accomplished this with the HPRF system and were successful in converting the old files to Labview 2012. However, we encountered multiple problems with the LLRF system conversion.

The LLRF system runs on Labview 5.0 which does not convert easily to Labview 2012. In order to convert to Labview 2012, the files must first be converted into an intermediate version between Labview 5.0 and Labview 2012. We acquired Labview 8.2.1 from National Instruments. Labview 8.2.1 should be on the LLRF drive. There is also a copy on the computer in the RF Measurements lab. We still encountered problems when converting from Labview 5.0 to 8.2.1.

One of the problems that we encountered was that the Labview program, when opened needed to find and connect to certain vi's that are in libraries. These vi's are in the Labview files under vi.lib -> addons->Access, and that's where most of the vi's can be found. If they have anything to do with VXI, then they are in vi.lib->addons->instr.

Another problem that we encountered was that some of the Labview files needed access to Microsoft Access. These problems were associated with Interface Nodes in the program. When we converted the files from Labview 6.0 to Labview 2012, we also needed to reconnect Labview to Microsoft Access. To connect to Microsoft Access, the original programmer used ActiveX. To reconnect Microsoft Access we needed to replace the Interface Nodes that were having errors. Once we replaced them with Labview 2012 Interface nodes, we needed to connect a library. Right click the Interface Node and go to *class*. In *class* there are multiple programs

that you can access, we want ActiveX. In ActiveX there is a browse button, click it and a window will pop up, click browse again and a long list of libraries should appear. For Microsoft Access, the library we want has Microsoft Access Library in its title. Then we want _Application library. Another of the Labview files wants access to Excel. The process is similar to the process to access Microsoft Access, except you want the Microsoft Excel Library and then the _Application library.

Another problem that we encountered was that there was a subvi that was no longer used by Labview 2012. The subvi is the code interface nodes, which are no longer used and should be replaced with Call Library Functions. However, in order to convert these subvi's we need the original libraries for the code interface nodes. These libraries are .lsb files that we were unable to find in either LLRF or HPRF drives. The .lsb files are codes that were converted to enable use in Labview. At this time we are unable to find these files and they will probably need to be re-coded and then converted to use in the Labview system. The VXI drivers also need to be updated to the correct Labview version [2].

3.2 Hardware

The LLRF Control system hardware is a VXI module. These VXI modules can be found in a tall blue cabinet, currently located in the F-wing. This is the hardware portion of the LLRF Control system. The diagrams of the VXI connections can be found in 3.2.1 and 3.2.2.

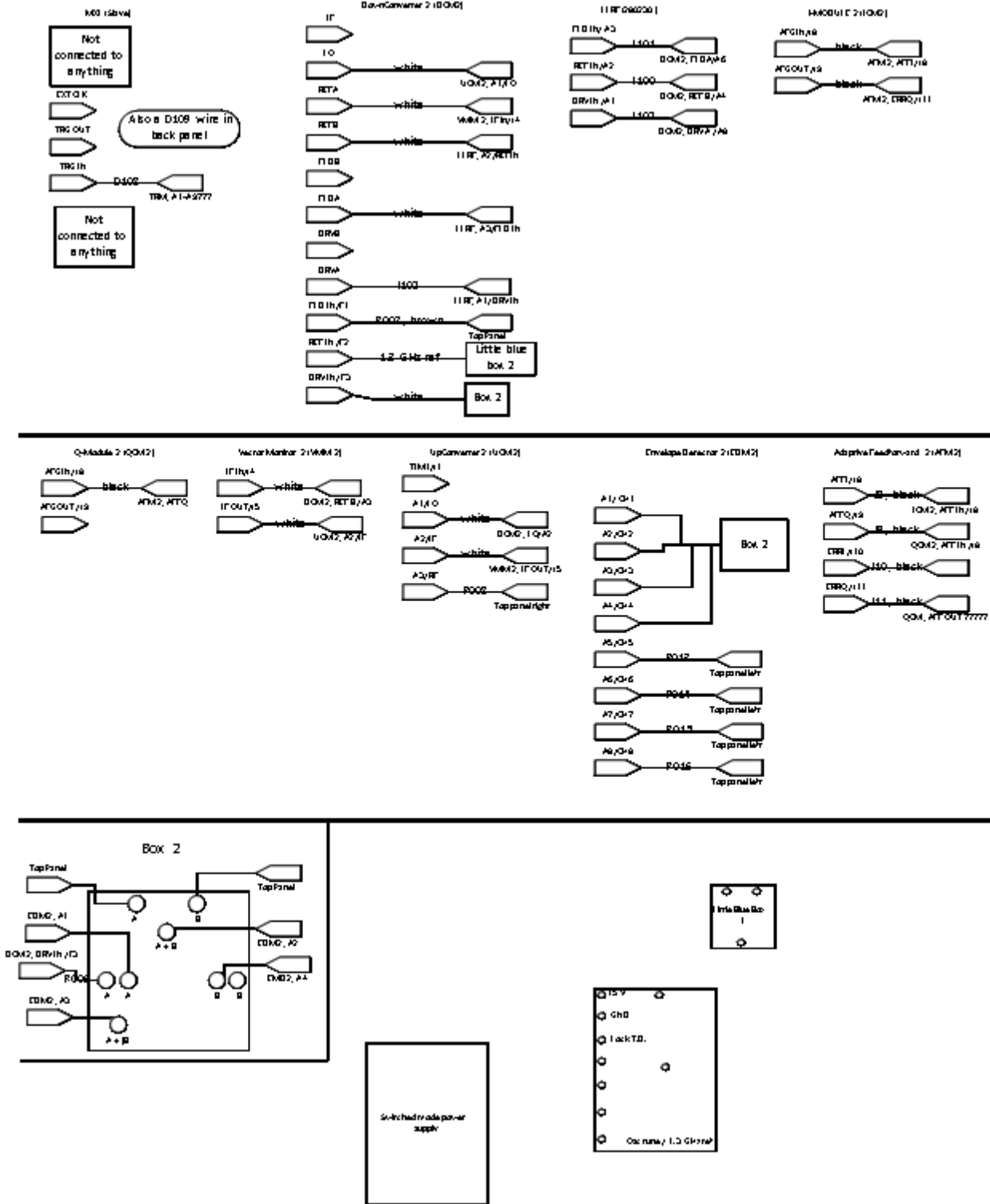
The connections within the VXI modules consist of connections between different modules and other external equipment. The top VXI module has MXI, coax Monitor, Downconverter, Vector Detector, I-Module, Q-Module, Vector Monitor, UpConverter, Envelope Detector, Adaptive Feedforward, Timing Receiver, and Timing Distribution Modules in that order from left to right. From these modules there are connections needed in order for the LLRF system to work correctly. When looking at each module individually in the diagram, you see that the left side is the connection on that module and the right side is where the wire connects. The wire number, if it had one, is on the wire. The right side of the diagram has where the connection is going (ie. UCM, which is UpConverter) and then where to connect to on that module (ie. A1/LO).

The Bottom VXI module has from left to right the following modules: MXI, Downconverter, LLRF (280230), I-Module, Q-Module, Vector Monitor, Upconverter, Envelope Detector, and Adaptive Feedforward.

There are also external devices used for the LLRF system. There are multiple external devices for the top VXI module, including a box, switched mode power supply, Osc tune, little blue boxes, and a little gray box. These connections can be found below the Bottom VXI module connections in the diagram. In the Bottom VXI module there is one external device called Box 2.

The wire connections to check that the connections are correct are in the LLRF System Overview.pdf document. As of August 20th, 2013 graduate students Taylan Sipahi and Nihan Sipahi were working on rechecking connections and some of the connections in these diagrams may be incorrect.

3.2.2 Bottom VXI Module



4.0 Conclusion

During my internship at the CSU Accelerator Facility, I learned about particle accelerators and the control system of the Accelerator facility. I gained valuable experience in a lab setting as well as working with a great group of individuals. My internship at the CSU Accelerator Facility this summer was a great experience in which I learned more about all the components of the control system of the LLRF system. Learning about the control system as well as improving the RF Bead Pull system were viable skills that will help me in later aspects of my life.

4.1 Acknowledgements

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5.0 References

[1] Beckhoff website. *TwinCat*. <http://www.beckhoffusa.com/english.asp?twincat/Lizensi.htm>

[2] VXI Module Driver Updates. *National Instruments*.
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