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Radio Frequency System for Superconducting Cavities

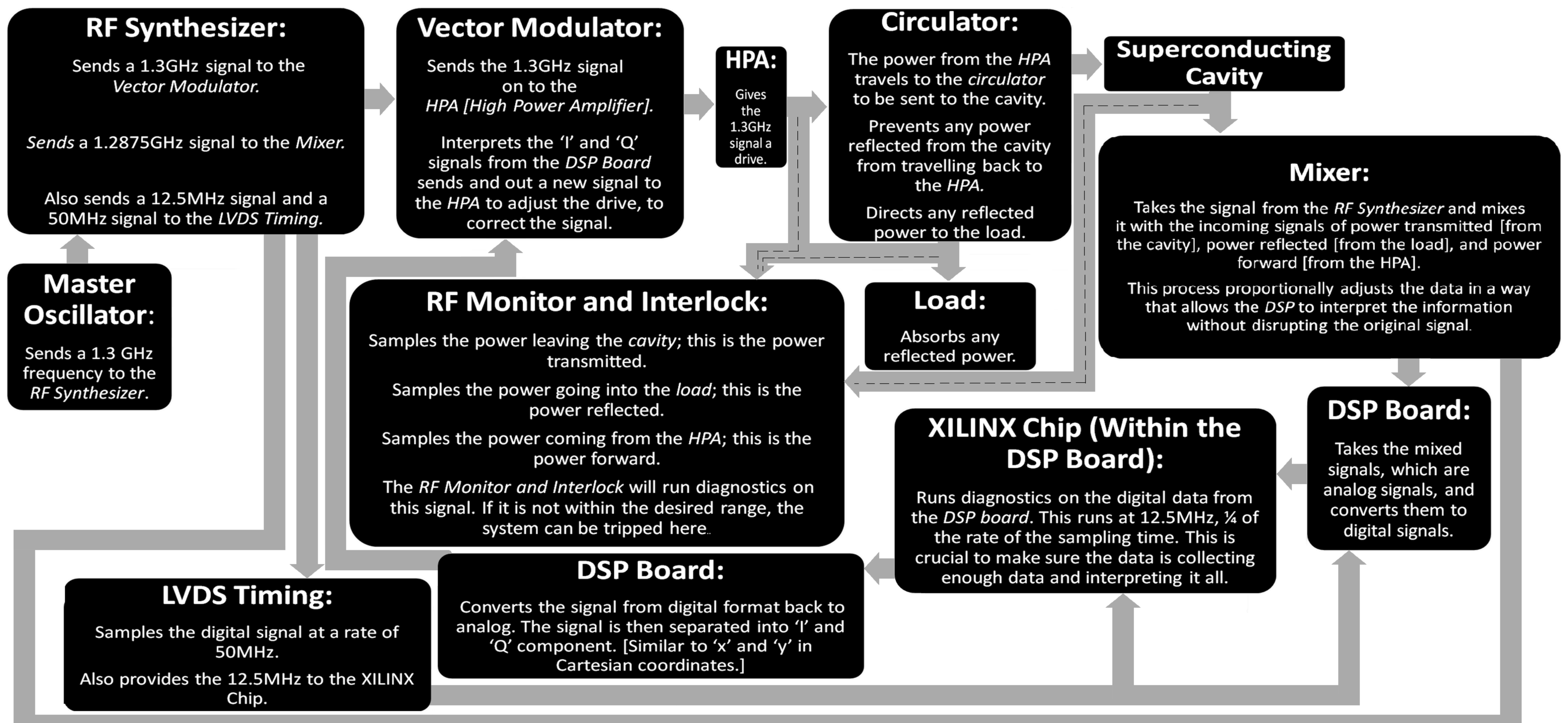
For beam energy stability, it is important to maintain very stable RF fields in the accelerating superconducting cavities. A change in the field can be caused by either Lorentz Force Detuning, the change of the cavities resonant frequency due to the force of the accelerating field on the cavity walls, or microphonics, mechanical vibrations in the environment of the cavity that transfer to the cavity and change its resonant frequency. To compensate for this, a control system can be put into place.

Introduction

The field control system is based on digital technology. The new control system developed for the Cornell ERL is based on a previous generation system, which ran 2.6 times slower than the new system. In addition to stabilizing the RF field by adjusting the RF drive power to a cavity, the new control automatically adjusts the cavity's frequency through a frequency tuner to compensate for any slow shifts in resonance frequency.

The new system works at an RF frequency of 1.3GHz and is able take measurements and execute all calculations digitally. To do this, several components and parts must be in place for the control loop to work properly.

How the New Control System Works

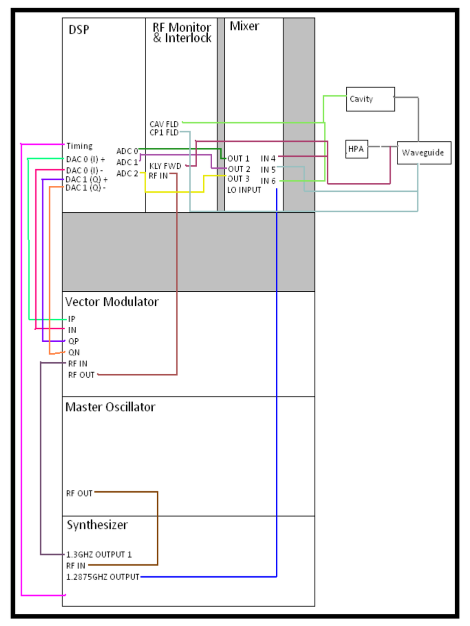


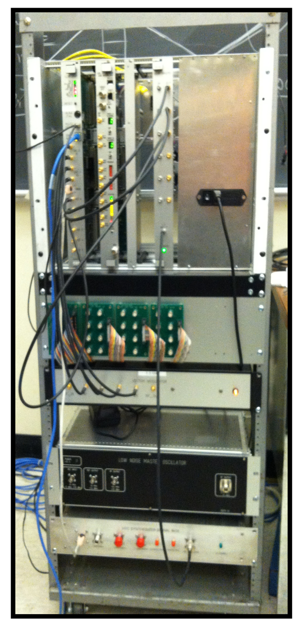
What is Inside the New Control Loop

There are several components within the control system. The control loop is shown the image on the right.

Within the control system there is a DSP board, RF monitor and interlock system, a mixer board, a vector modulator, a master oscillator, and an RF synthesizer.

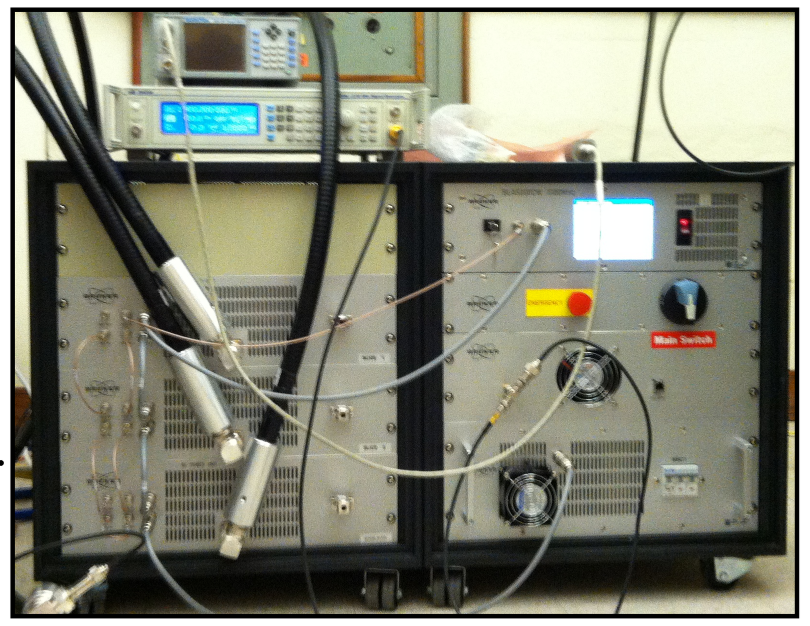
The RF synthesizer is a key component in the control loop. Because all of the RF and timing signals are created from one master oscillator, the phases between these signals are phase locked relative to each other.





The figure on the left depicts placement of these components and shows how they are connected.

What is Outside the New Control Loop



The high-power amplifier (HPA), picture to the top right, is connected to the control loop through the RF Monitor and Interlock. The HPA gives the output signal coming from the control loop the amplification needed to power the cavity.

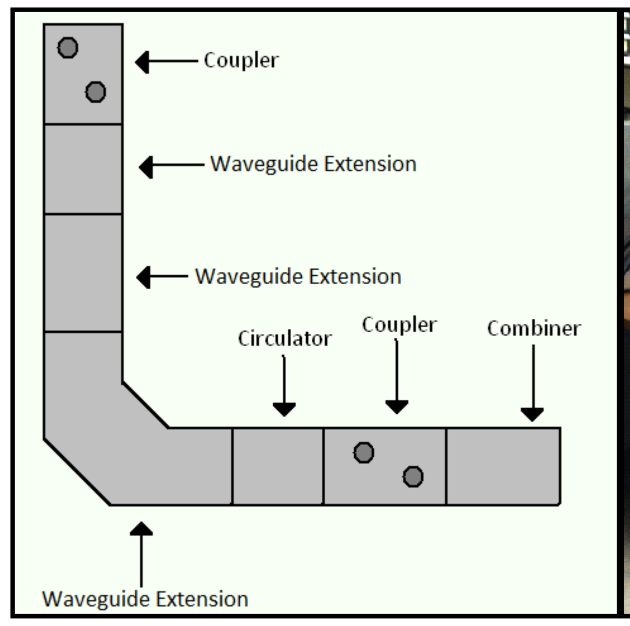
The necessary power is produced through three 'slices.' The power from each slice is then sent to the combiner.

The HPA is connected to the waveguide through the combiner. The combiner combines the power from the three 'slices.'

The first coupler allows for two probes to be in place to measure the forward power, power leaving the HPA, and the reflected power, the power reflected by the cavity.

The circulator directs the power from the HPA to the cavity and keeps any reflected power from returning to the HPA.

The waveguides simply redirect the travelling signal and the second coupler allows for a probe to be inserted to measure the power going to the cavity.



An image of the coupler-combiner-circulator system can be seen in the bottom left and an image of the actual system can be see in the bottom right.

Conclusion

The new control system allows for regulation of the phase and amplitude of the field within a superconducting cavity at a faster speed than previous systems. This is primarily due to the use of the XILINX chip and the DSP board. With the enhanced speed, researchers are able to better compensate the field perturbations caused by large levels of microphonics and Lorentz force detuning.

With its performance, the new control system meets specification for Cornell University's Energy Recovery Linac (ERL). If placed into the ERL, the control system will be responsible for 384 cavities.

References

Ho, Vivian. 2012
Liepe, Matthias. 2012
Schiller, Thomas. *Vector Sum Control of Pulsed Acellerated Fields in Lorentz Force Detuned Superconducting Cavities*. Diss. 1998.

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