Frequency Response Measurements of LEDA RF Control System

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Abstract

A VXI based control system is currently used to maintain constant field amplitude and phase in the Low Energy Demonstration Accelerator (LEDA) RFQ under various beam loading conditions. The control system uses both digital feedback for low frequency disturbances and analog feedback for higher frequency disturbances. This paper discusses the measured frequency response of the control system.

1 INTRODUCTION

The RF control system for LEDA was designed to maintain constant field amplitude and phase in the accelerating cavity (RFQ) counteracting the effects of beam noise, beam turn on, and klystron nonlinearities. Figure 1 shows a simplified block diagram of the Field Control Module (FCM) which detects the cavity field (FLD IF), controls it, and supplies baseband I and Q control signals (I_{out}, Q_{out}) to an upconvertor and amplifier. A fast analog loop and a slower digital loop work in parallel to supply the control signal outputs. The analog loop uses a standard analog IQ detector and PI filter to generate it's portion of the control output. The digital loop uses a digital IQ detector [1], digital filter, and a digital PI loop (within the DSP) to create its control signals which are added to the analog control signals to produce the final output. The FCM has the capability to use beam information from previous cavities as a feedforward control. Also shown in the diagram is the FCM capability to modulate the output I and Q values with cos(ωt) and sin(ωt) so as to track the cavity resonance. The modulation is replaced with a fixed I_ϕ and Q_ϕ for phase calibration when the cavity is on resonance.

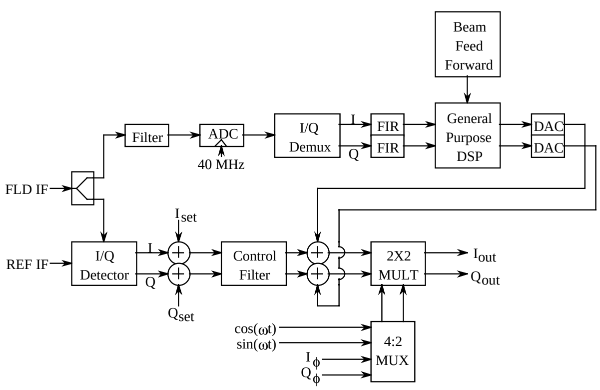

Figure 1: Simplified block diagram of RF Frequency Control Module (FCM) used at LEDA

The analog and digital loops in the FCM have overlapping bandwidths. The digital control loop is a high gain loop that has a frequency response from DC to approximately 5 kHz. The analog controls from DC to 150 kHz. This method utilises the inherent advantages of digital control (low noise, no drift) along with the high bandwidth capabilities of analog control.

The purpose of this paper is to describe the method used to measure the closed loop frequency response of the FCM as well as present the results.

2 EXPERIMENTAL SETUP

Figure 2 shows a block diagram of the experimental setup used to measure the frequency response of the FCM. The analog and digital loop gains as well as closed loop setpoints are loaded into the FCM via a VXI backplane connection using the EPICS interface. The I and Q control outputs from the FCM are upconverted to 350 MHz, amplified and coupled into a mock cavity with the same center frequency and Q as the LEDA RFQ. The cavity signal is then sampled, down converted to 50 MHz and fed back to the FCM. A network analyzer drives a voltage controlled phase shifter placed between the upconvertor and the cavity which introduces a small phase perturbation on the cavity signal. The drive signal is swept in frequency from 50 Hz to 1 MHz. The I and Q control signals are then monitored by the network analyzer which displays the frequency response of the loop.

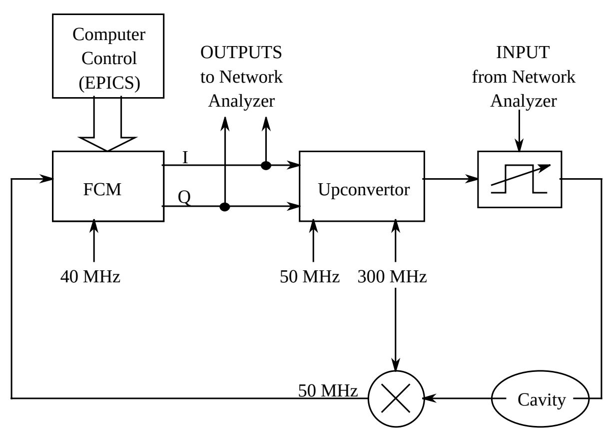

Figure 2: Experimental setup used to measure frequency response of FCM.

If the control signal from the FCM has a large I component and a small Q component, then the small phase perturbation will primarily be seen as a disturbance in the Q signal. Likewise if the control signal has a large Q component then the perturbation will show up in the I signal. Figure 3 illustrates this effect.

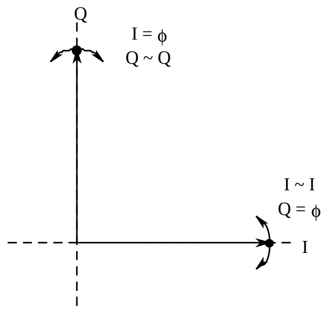

Figure 3: Phase perturbation effects on I and Q control signals.

3 RESULTS

Figure 4 shows the measured frequency response of the FCM module using just digital integrator feedback. Figure 5 shows the frequency response using both digital and analog proportional feedback. In both cases the measured DC gain of the closed loop is uncalibrated since the gains of the upconvertor, cavity, and phase shifter were not calibrated. The measurements serve to show the frequency response characteristics of the loop with the DC gain of the closed loop assumed to be 0 dB. The 3 dB point with just digital control is on the order of 4.7 kHz. If the integrator gain is increased the 3 dB point can be pushed as high as 8.6 kHz but with a corresponding loss of phase margin. The 3 dB point of the combined analog and digital control loop is around 190 kHz.

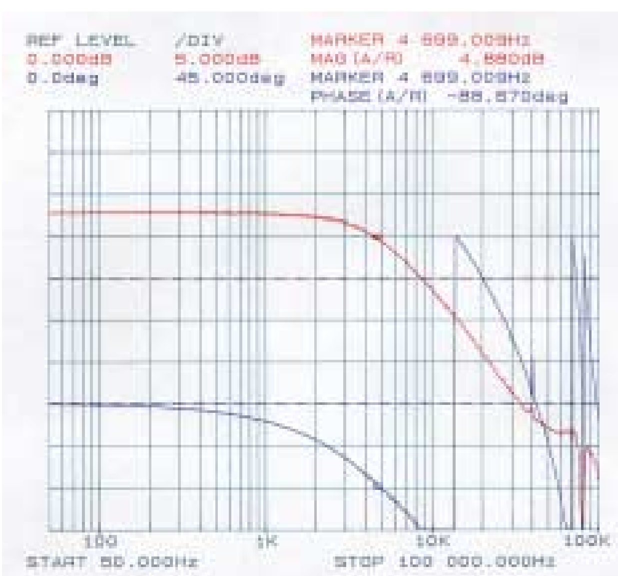

Figure 4: Measured frequency response of FCM with just digital (integrator) control.

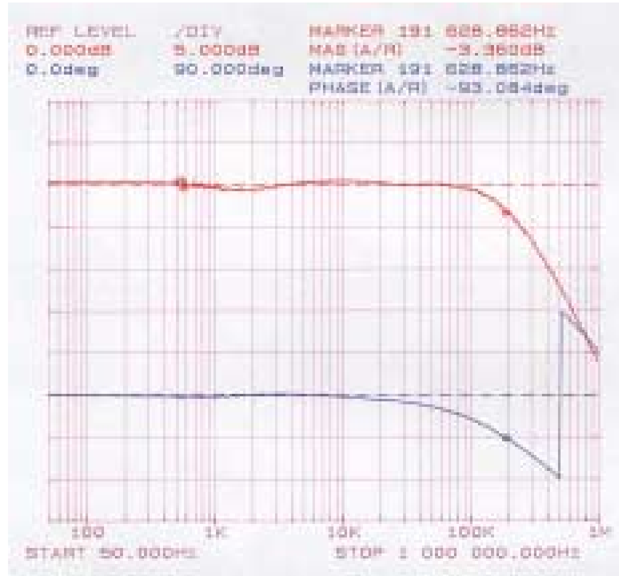

Figure 5: Measured frequency response of FCM with both digital and analog control.

4 CONCLUSION

The FCM module is capable of feedback control on the cavity field signal with a bandwidth on the order of 150 to 200 kHz. This should be sufficient to attenuate most beam noise disturbances. The higher harmonics of the beam turn-on transients will not be attenuated effectively with just feedback control, but can be attenuated through the use of feedforward control, which remains to be tested. Lastly, an effective method is shown to measure baseband frequency response characteristics of RF control systems.

REFERENCES

[1] C. Ziomek, P. Corredoura, "Digital I/Q Demodulator", PAC'95, SLAC, May 1995.