Figure 7 shows oscilloscope waveforms of the baseband correction signal (top) and the resulting AM-QPSK output of the Back-end module (bottom). This photo is of six consecutive bunches with 2ns spacing as is used in the every-bucket ALS configuration. It is important to note that the 9/4*RF phase inverts for negative correction values.

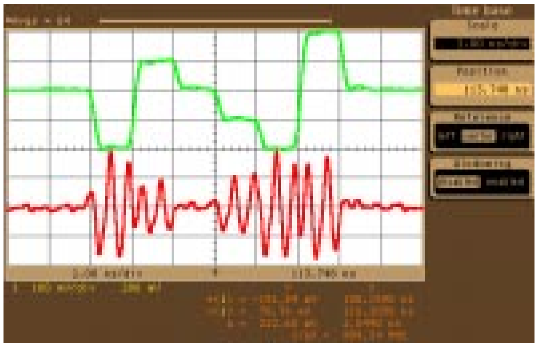

Fig. 7. Baseband correction signal and resulting amplitude and AM-QPSK modulated signal (Time Scale= 2ns/div).

4. SOFTWARE IMPLEMENTATION

The longitudinal feedback system is operated via a graphical computer interface on the users' host that communicates with real time software tasks in the remote processors over a network. The graphical interface was constructed using the EPICS software package that communicate via a register based protocol with the real time operating system VXWorks running in remote hosts located in the VXI/VME crates. The majority of the analysis codes used for machine diagnostics are written in MATLAB.[8]

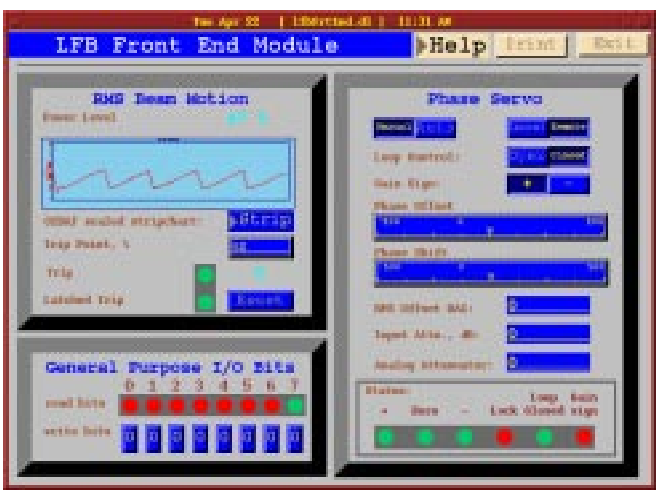

Fig. 8. The EPICs Panel

Figure 8 is an example of the EPICS control panel for the-Front-end module (the Back-End and System Oscillator have similar panels). The left sub-panel in Figure 8 is the beam motion detector showing a mode-zero signal growing in magnitude in a manner similar to figure 5. A threshold trip value can be programmed and the overthreshold trip is read and latched. The right sub-panel in Figure 8 controls the DC reference phase servo of the bunch motion detector. An automated task that can be run by pressing the auto button, locates an optimum phase and closes the servo-loop.

5. SUMMARY

The performance characteristics and features of the Front-end and Back-end include:

- SLAC designed generic VXI interface in both front and Back-end modules,
- automated DC phase servo,
- 118-MHz bandwidth , 20 dB dynamic range beam motion detector operating in both front and Back-end modules,
- 400 MHz Bandwidth phase detector,
- 42 dB of dynamic range in the Back-end.

The VXI packaging has allowed us to design a modular feedback control sytem and has simplified communication to and from these modules. The front and back end module designs have incorporated numerous features based on the operational experience from 20 months of running at the ALS. Two longitudinal feedback systems have been installed in PEP-II for the high and low energy rings. Five other systems have been produced for the ALS and DAΦNE machines.

6. ACKNOWLEDGMENTS

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module allows remote operation and calibration of all module functions. For example, the phase servo circuit can be operated and set up remotely using an auto calibration code that allows an operator to just push a button and the servo will be initialised to the best operating point.

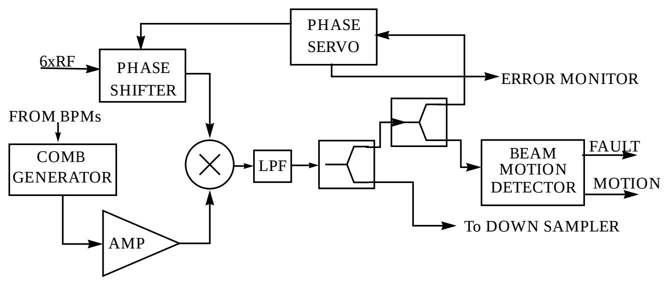

Fig. 3. Block Diagram of Front-end Module

The Back-end module transforms the baseband correction signal computed by the DSP farm into a signal within the frequency band of the power amplifiers and kicker (see figure 4). The center frequency of the kicker structures are designed to fall at 9/4, 11/4 or 13/4 of the machine RF frequency to minimize the coupling impedance the kicker presents to the beam[5,6]. The module transforms a CW carrier at the kicker center frequency into an AM-QPSK (**q**uad **p**hase **s**hift **k**eyed) modulated signal. The pure QPSK signal provides a DC kick on every bunch. The QPSK signal is amplitude modulated by the baseband correction signal that contains the feedback correction for every bunch.The output of this module is a signal spanning the entire coupled-bunch mode spectrum. For test purposes the QPSK modulator can be put into a single state (0, 90, 180, 270) by programing the gray counter using the VXI interface. The signal is then amplified using a solid state amplifier (produced by Milmega, LTD.). The VXI interface is used to control all module functions, such as adjusting the output signal's amplitude and manipulating the QPSK modulator diagnostic states for testing and calibration purposes. A broadband 120 MHz rms detector provides a check on the amount of kicker motion that is delivered to the amplifier. A separate low-frequency "WOOFER" channel sends a 10 MS/s bandwidth limited digital correction signal to the RF system via a fiber optic data link [7].

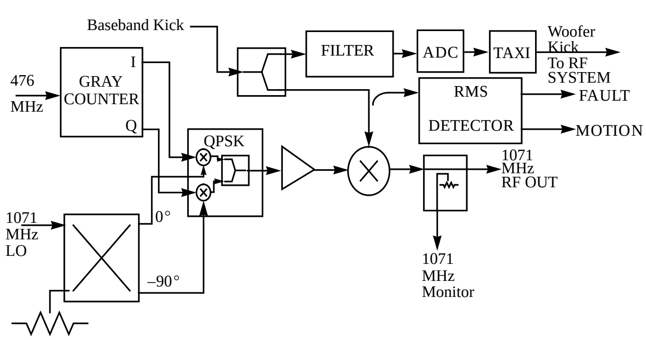

Fig. 4. Block Diagram of the Back-end Module

The woofer system has many operating modes, including diagnostic measurements of open-loop and closed-loop transfer functions between the longitudinal feedback system and the RF. To perform these tasks, the Woofer channel has six modes of operation. In typical operation the baseband kick signal is sent to the RF system using a serial fiber-optic link. In diagnostic modes the Back-end woofer channel can record the kick signal in a circular buffer or inject a test excitation in the signal path signal to the RF system. The woofer channel also has an input port where an external woofer signal can be summed with the kick signal and then transmitted to the RF system. The VXI interface allows operators to run and configure the woofer channel and synchronise the woofer path with the digital RF system.

3. RESULTS

Figure 5 shows a set of oscilloscope waveforms from the Front-end module in which simulated beam motion is growing at mode zero. The upper trace is the detected synchrotron motion of each bunch at baseband, showing a mode-zero signal growing as a linear ramp. The middle trace shows the output of the rms motion detector, which reveals the growing motion of the beam. The lower trace shows a comparator output of the beam motion detector. The Front-end module contains a comparator whose threshold can be set remotely to any degree of beam motion. This motion-over-threshold signal can be used to send an alarm or trigger the DSP farm to record a growing or runaway beam instability.

Fig. 5. Hardware simulated beam instabilities at mode 0

The kicker structures are designed to have impedance minima at multiples of the machine RF/2, and impedance maxima at odd multiples of RF/4. The four state QPSK modulation scheme sequences an input CW carrier at 9/4 RF (1071 MHz) through the phase states of 0, 90, 180, 270 at the machine RF rate (476 MHz). This produces a form of modulation with a large sideband at the RF*2 frequency, with an upper sideband at 2.5*RF. The spectrum in figure 6 shows the two sidebands, plus the suppressed carrier at 9/4 RF.

Fig. 6. Back-end kick QPSK spectrum (10dB/div).

VXI Based Multibunch Detector and QPSK Modulator for the PEP-II/ALS/DAΦNE Longitudinal Feedback System*

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Abstract

The PEP-II/ALS/DAΦNE feedback systems are complex systems implemented using analog, digital and microwave circuits. The VXI hardware implementation for the Front-end and Back-end analog processing modules is presented. The Front-end module produces a baseband beam phase signal from pickups using a microwave tone burst generator. The Back-end VXI module generates an AM/QPSK modulated signal from a baseband correction signal computed in a digital signal processor. These components are implemented in VXI packages that allow a wide spectrum of system functions including a 120 MHz bandwidth rms detector, reference phase servo, woofer link to the RF control system, standard VXI status/control, and user defined registers. The details of the design and implementation of the VXI modules including performance characteristics are presented.

1. INTRODUCTION AND OVERVIEW

The multi-bunch feedback system was designed as part of a multi-lab collaboaration for use at the PEP-II, ALS and DAΦNE machines. It is a programmable system implemented in a family of VXI and VME modules and operates at sampling rates up to 500 MHz. The beam motion is phase detected at a 6*RF frequency and processed in the Front-end VXI module. The output of the Front-end module is a baseband signal (DC-500 MHz) representing all the coupled-bunch modes of beam motion. The baseband signal is digitized and downsampled in the Downsampler VXI module. A distributed DSP function is implemented in an array processor constructed of VME based DSP modules. The recombination of the parallel computation results, and the output D/A converter are contained in a Hold Buffer VXI module. The baseband D/A output is then up-converted to 9/4 RF frequency and AM-QPSK modulated in a Back-end VXI module. The VXI packaging allows construction of mixed analog, digital and microwave functions, with a general purpose computer interface for configuration, control and monitoring functions. An extensive EPICS-based control software system is used to operate the feedback system. The system can also be used to measure bunch-by-bunch currents in the machine [1]

2. IMPLEMENTATION

Figure 1 shows a simplified block diagram of the feedback system. Most of the digital functions (DSP, Downsampler, Holdbuffer) has been discussed in previous papers[2,3]. The master oscillator shown generates the phase-locked 6*RF and 9/4*RF oscillators (PEP-II configuration) using a divided RF/4 signal from the master timing VXI module [4]. The RF/4 signal is multiplied via a step-recovery diode and the resulting spectral comb is filtered to provide both 6*RF and 9/4*RF signals in phase syncronisism to the beam.The system oscillator contains a small daughter board that controls switches, and other diagnostic functions. The control for these functions is through an interface data bus from the Front-end module. The system oscillator also has the capability of generating a simulated beam impulse so the system can be tested and calibrated off line.

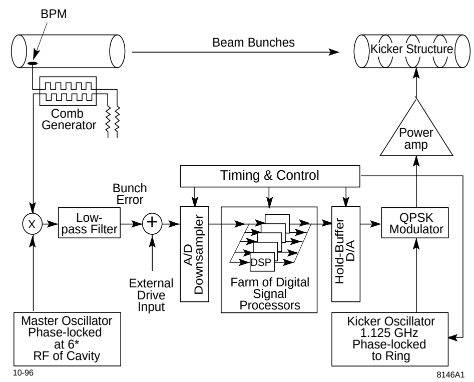

Fig. 1. Block Diagram of the Longitudinal Feedback System.

The heart of the Front-end beam signal processing is a stripline comb generator that is a passive band pass structure contained in the master oscillator chassis. The impulse response of this device is a finite length 4 cycle tone burst at the 6th harmonic of the ring RF (2856 MHZ for PEP-II). Figure 2 illustrates a four tap, -30dB, comb generator tuned for the PEP-II system. A four tap comb generator generates a unique beam phase signal for every bucket in the PEP-II system. This device is made from a copper-clad teflon material and then gold plated to lower the losses.

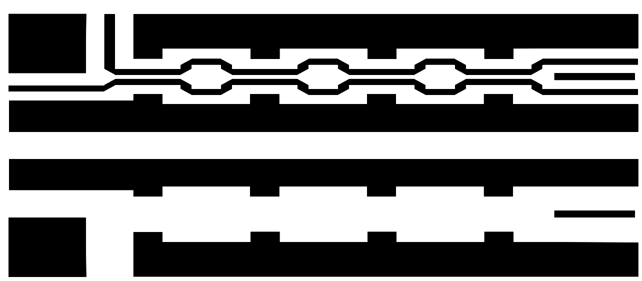

Fig. 2. Stripline Comb Generator.

The Front-end module shown in figure 3 contains a phase detector (operating at 6*RF) to detect synchrotron motion of each bunch. This circuit is implemented with 400 MHz bandwidth to provide bunch to bunch isolation. The module has a low frequency DC coupled phase servo to adjust the reference phase of the system to the average synchronous phase of the bunches. The final major component is a beam motion detector circuit that provides a bandwidth limited (120 MHz) measurement of the excitation of the beam. The VXI interface in this

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