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THE LOW-LEVEL RF BEAM CONTROL SYSTEM FOR THE BOOSTER OF THE BEIJING PROTON SYNCHROTRON (BPS)

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Summary

A prototype of a low level RF beam control system for the BPS Booster was designed and built at Fermilab during the past year. Machine parameters are:

RF Frequency range 2.76-6.31 MHz,
Harmonic number h=3,
Repetition rate 12.5 Hz,
Maximum synchrotron frequency 12 KHz

No phase transition occurs during acceleration. We have adopted computer controlled digital curve generators for the frequency program and other programs such as the radial position offset, radial position loop gain, etc. for the operational flexibility available with such programs. The frequency mixing method was chosen for the analog beam control loops, including the phase loop and radial position loop, for improving the signal to noise ratio within the wide frequency band and for convenience in signal processing. The system is composed of a series of modules which are to be operated in several modified NIM crates. This will allow maximum flexibility during the development phase of accelerator operation. Here we give a brief description of the LLRF system and some preliminary design and test results. Study and improvement of the system will be continued. A simplified block diagram of the system is shown in Figure 1.[1,2]

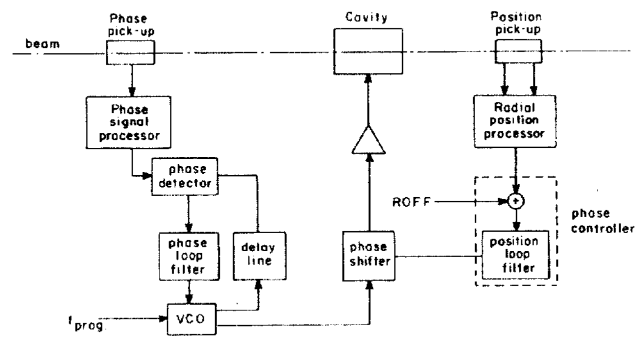

Figure 1. Over-all block diagram of the BPS Booster RF Beam Control System.

Frequency and Phase Control

Our phase loop is a dc coupled phase lock loop. The output is a constant amplitude sine wave which tracks the signal from the beam pick-up over the operational frequency range. A block diagram of the phase loop is shown in Figure 2. The loop is composed of four modules: VCO, phase detector, loop filter and crystal oscillator. The loop filter cut-off frequency, gain, and analog switch can be controlled by computer generated program signals so the open or closed loop response, static gain, and gating can be changed according to our requirements.

The measured loop characteristics are: Closed loop cut-off frequency (∿ 3 db) > 20 KHz, static gain $> 1 \times 10^7$ (sec^{-1}), phase shift due to amplitude variation of the beam signal $< \pm 3^0$ (20 db), $< \pm 5^0$ (40 db).

Radial Position Loop

The radial position signal, obtained by amplitude to phase conversion of beam displacement signals, is used to control the phase of the VCO output signal.

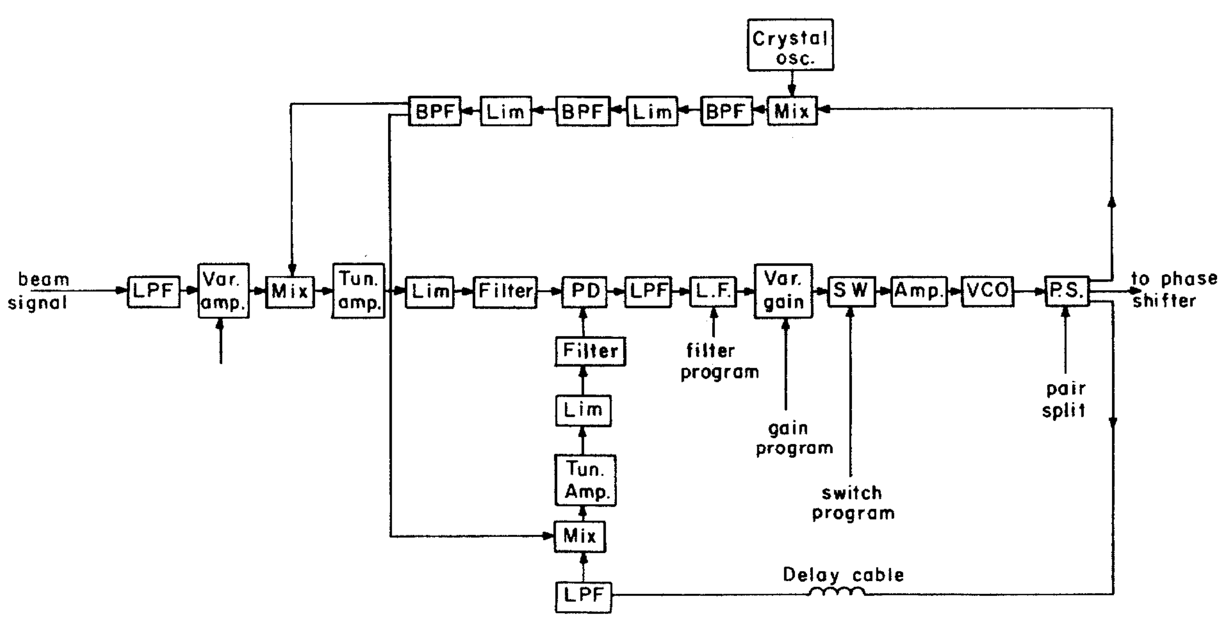

Figure 2. Frequency shifting Phase Lock Loop

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The low-pass wide-band radial position loop is to be used for correcting the average radial displacement of the bunches. A block diagram of the radial position loop is shown in Figure 3.

The radial position system is composed of four modules, radial position signal processor, tracking VCO, phase controller, and phase shifter. Amplitude to phase conversion is accomplished by quadrature hybrids following frequency mixing in the position processor module.[3] The dynamic range of the position processor is about 52 db/±3^{o}. The combined dc gain of the phase controller is about 20 with - 3 db roll-off at about 1 KHz, and this corner frequency can be adjusted manually in the phase controller. Various programs, such as the radial offset (ROFF), stable synchronous phase angle (ϕ_s), radial gain (RGAIN), etc. are delivered to the phase controller as required. The phase shifter has frequency response up to 100 KHz and has good linearity over its ± 90^{o}/± 10 V range. The radial feedback loop has sufficient potential gain to move the beam sufficiently to follow the radial offset curve (ROFF).

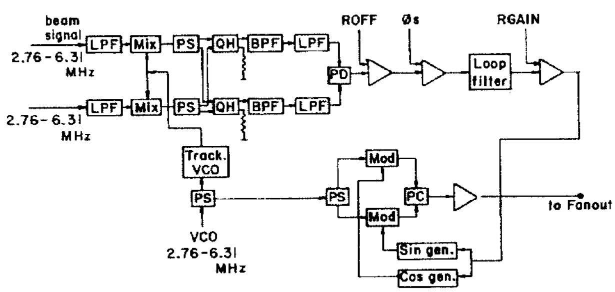

Figure 3. Beam Position Processing System

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