Self Triggered Single Pulse Beam Position Monitor

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Abstract

A self triggered beam position monitor (BPM) has been developed for the NSLS injection system to provide single pulse orbit measurements in the booster synchrotron, linac, and transport lines. The BPM integrates the negative going portion of 3 nS wide bipolar pickup electrode signals. The gated, self triggering feature confines critical timing components to the front end, relaxing external timing specifications. The system features a low noise high speed FET sampler, a fiber optic gate for bunch and turn selection, and an inexpensive interface to a standard PC data acquisition system.

I. INTRODUCTION

The BPM is designed as a stand alone, real-time diagnostic tool for tuning the linac, booster, and transport lines. High speed sampling units, located near the pick-up electrodes, process the short pulses and provide a signal readable by an inexpensive PC based data acquisition system. This allows the use of easy to use, well tested high level programming tools such as Visual Basic for DOS [1].

II. DESIGN

A. Specifications

The specifications for a single non-averaged measurement of a bunch with 10^9 electrons are as follows:

Beam current dynamic range:	30dB
Position dynamic range:	±30mm
Resolution:	100uM
Accuracy:	±500uM
Repetition rate:	.5s

B. System Design

The specifications are modest compared to the requirements of a storage ring beam position monitor therefore the design can be simplified and costs reduced. The system design is shown in figure 1.

* *Work performed under the auspices of the U.S. Department of energy.*

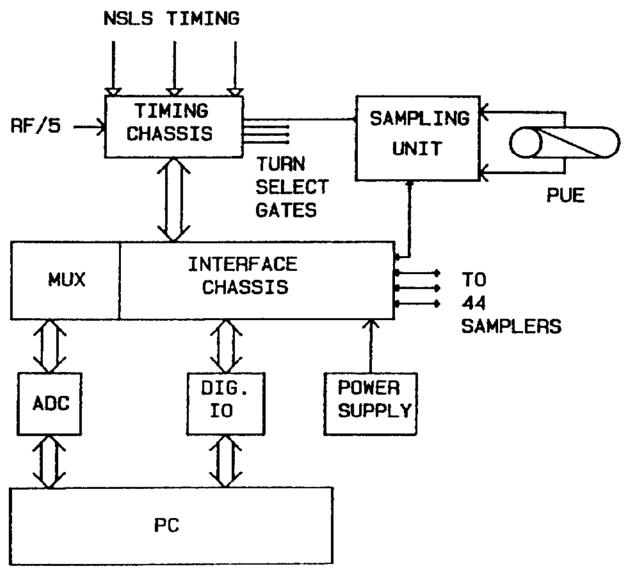

Figure 1
System block diagram

The timing chassis generates a gate corresponding to a selected turn in the booster. The timing chassis also interupts the PC at the beginning of a data aquisition sequence. The sampling units self trigger within the turn select gates and transmit the result to the interface chassis via 4-20 mA current loops. The PC reads the data with a 12 bit data acquisition card. All 88 analog channels are routed to the card with multiplexers located in the interface chassis. The PC initializes the timing chassis and externally triggers the sampling units to measure the pedestal. The turn select gates are transmitted over fiber optic cables and all other digital signals use opto-isolators.

C: Sampling Units

The sampling units are built around thick film hybrid samplers [2] shown in figure 2. Q_1 is gated to trap the charge from the second half of a bipolar PUE signal. The input is effectively integrated by C_1 since the capacatance is large and very little voltage is developed. The charge then slowly transfers onto C_2 with a time constant $T = R_1 * C_1 =$ 6.8uS. The op-amp and associated components function as a

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gated charge sensitive amplifier. The track and hold samples the output of the op-amp. The hybrid sampler is well suited to measuring very short pulses that occur infrequently. The primary limitations are the 700pS turn on time for Q_1 and the 47uS required to drain C_1 by 99.9%.

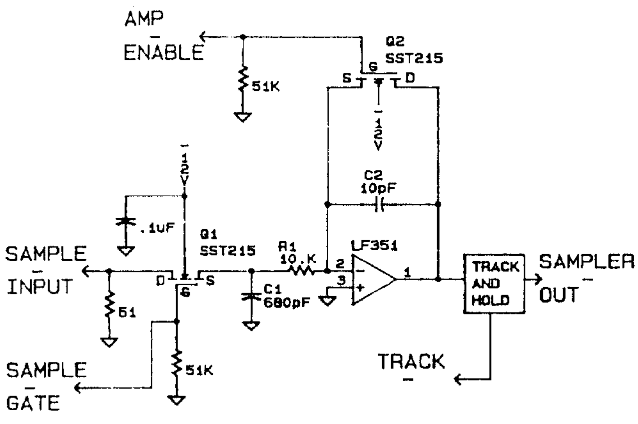

Figure 2
Thick film hybrid sampler schematic

The sampling unit block diagram is shown in figure #3. The rising edge of the turn select pulse triggers two one shots. The output of one shot #1 remains high 5uS longer than one shot #2 since the track and hold on the hybrid sampler must return to hold mode before the charge sensitive amplifier is reset. The zero crossing detector is enabled for the length of the 100nS turn select pulse. The RF hybrid processes the pick-up electrode (PUE) signals and sends sum and difference signals to the inputs of the hybrid samplers via delay lines. The delay lines compensate for delays in the trigger circuit.

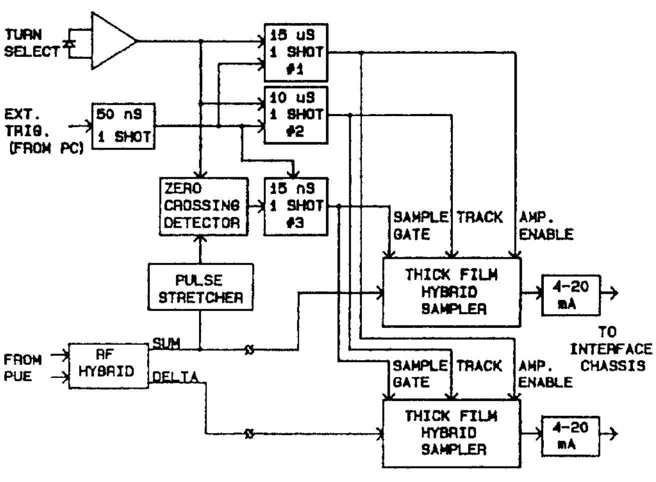

Figure 3
Sampling unit block diagram

The sum signal is split stretched and then run into the zero crossing detector. The output of the zero crossing detector rises when the input rises above 47mV and the output gives a falling edge when the input crosses zero. Since one shot #3 is negative edge triggered the sample gate is generated on the zero crossing, thereby making the timing of the sample gate insensitive to changes in the amplitude of the sum signal. The internal trigger functions as half of a constant fraction discriminator. Since the PUE signals are already bipolar it is not necessary to delay and recombine the pulse to generate a zero crossing. The external trigger generates precisely the same timing sequence as the internal trigger, allowing for an accurate pedestal measurement. The 4-20mA current loop drivers simply follow the output of the hybrid samplers.

III. PERFORMANCE

The prototype was tested using the circuit shown in figure 4. The monocycle generator produces bipolar pulses identical to those produced by the injection system PUEs. Attenuator 1 simulates changes in beam current while attenuators 2 and 3 simulate changes in beam position. Attenuators 2 and 3 are changed in such a way as to maintain a constant sum signal out of the RF hybrid.

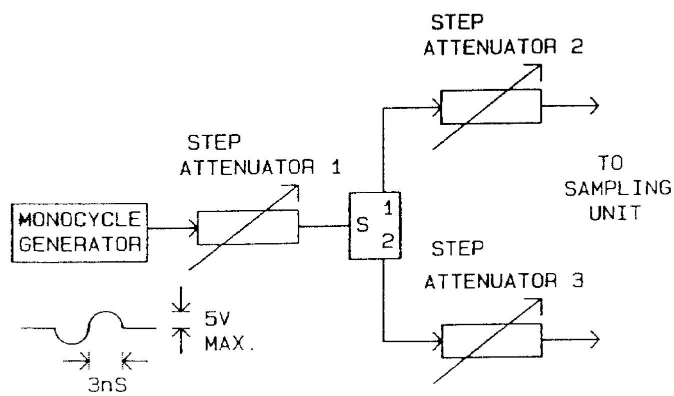

Figure 4
Test unit

Figure 5 shows the response of the sampling unit at three different currents. The amplitude of the sum signal is measured at the input to the hybrid sampler. While the output of the monocycle generator is $5V_{peak}$, losses in the attenuators and splitters limit the sum test signal to $1.5V_{peak}$. Also note that the delta/sum ratio is larger than one because the sum signal is split to provide the internal trigger. Changes in current have only a small effect on the position scale factor. The zero crossing detector minimizes timing walk. Since walk affects both the sum and delta samplers in the same way, the effect is normalized out. In precision applications the small scale factor change can be corrected in software.

30dB of current dynamic range is about the maximum practical without range switching. If additional dynamic range were needed, a stepped attenuator could be placed ahead of the pulse stretcher. No attenuators would be needed in front of the hybrid samplers since they have been shown to have a dynamic range in excess of 80dB [2]. As it stands the cable lengths must be minimized and pads used to avoid reflections that would lead to multiple triggers.

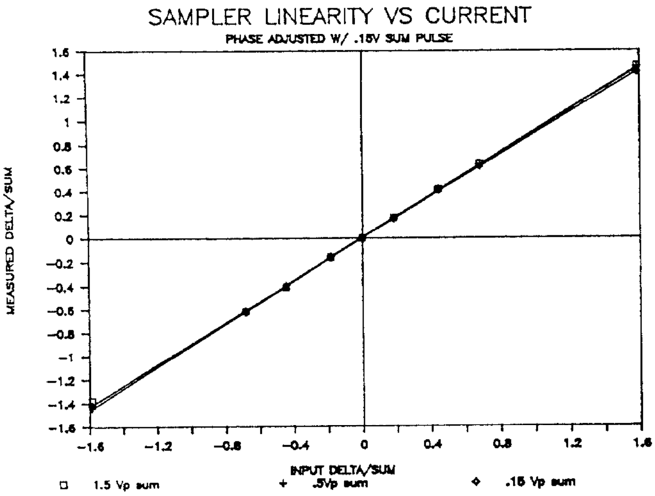

Figure 5
Sampler linearity

Resolution is limited by the 12 bit ADC. Linac beam position measurements show the same noise as measured on the bench. The resolution at the top of the dynamic range is 46.1mm/4096 = 11.25 uM, where the PUE scale factor = 46.1mm.

IV. PACKAGING

The sampling unit electronics are housed in commercially available aluminum "Compac" boxes measuring 4" x 5" x 2". All timing components are on a motherboard with the hybrid samplers mounted vertically. Noise is minimized by connecting the sampling units to the PUEs with short RF cables, mounting sensitive components inside an RF tight enclosure, using fiber optics and opto-isolators on all digital signals, and by reading the current loops with differential receivers. The self triggering feature simplifies installation since all critical timing components are contained in the sampling units. The units will function properly as long as the PUE signal arrives at any time during the 100nS gate select pulse.

V. REFERENCES

[1] Microsoft Corporation, "Visual Basic for Dos", One Microsoft Way Redmond, WA 98052-6399

[2] R.E. Meller, C.R. Dunnam, "Beam Position Monitors for the CESR Linac" Proc. of the 1989 IEEE Particle Accelerator Conference.

VI. ACKNOWLEDGMENTS

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