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BEAM DERIVED TRIGGER SYSTEM

FOR MULTIBUNCH TIME-OF-FLIGHT MEASUREMENT*

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Particle time-of-flight measurement requires accurate triggers in synchronism with each bunch, and occurring in a sequence which depends on the position of the observer around the storage ring. A system has been devised for tagging the colliding bunches at each interaction point; it allows one to record which pair of bunches is colliding at any time and any location around the machine.

Besides bunch identification, the time-of-flight triggers are also expected to have a time stability better than the bunch length itself. A system is presented here which exhibits time variations of less than 80 psec over a 20 to 1 range of beam current, while the jitter is at least an order of magnitude smaller.

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I. Introduction

The PEP bunches carry 10^{10} to 10^{11} particles in a Gaussian distribution having a σ of 2 cm. The pulses obtained from a small button pick-up electrode have the shape of a doublet, the extrema are separated by 130 psec and each impulse measures approximately 100 to 1000 volts depending on the bunch charge and its length.

The large amplitude variations in these signals preclude the use of fixed amplitude discrimination techniques, as the time slewing of such a discriminated signal would be large. A first approach to solving this problem might utilize an automatic gain control circuit to produce constant amplitude pulses for discrimination. However, PEP's variable operation with one to six bunches would still introduce time slewing unless the current is equally distributed in all bunches. The trigger system described in this note uses three independent AGC discriminator circuits and a gating system to control and calibrate them.

This system is made out of two companion modules, a bunch identifier which is computer controlled and generates a sequence of three gates,¹ and a triple beam induced pulse processing circuit.

The bunch identifier accepts timing information from the PEP^{*} master oscillator, and generates identification signals as a function of the region number. Identification signals are generated in a manner that allows observers in all interaction regions to agree on an unambiguous bunch identity.

The module has two modes of operation: a bunch identification mode and a calibration mode. In the identification mode, signals indicate

^{*} PEP, Positron Electron Project.

which of the three bunches of electrons and positrons are interacting and timing information about beam crossing is provided. In the calibration mode, three distinct gating signals are referenced to a selected bunch, allowing the three timing systems to be calibrated against a common standard.

The beam-induced pulse processing circuit, Fig. 1, receives the signal from a pick-up electrode located 20 meters from each interaction point. Six short bi-polar pulses appear for each machine period (7.3 μ sec), three of which are selected by the bunch identifier gates. Each channel consists of an AGC circuit (automatic gain control) which independently levels the pulse selected by its respective identifier gate; this constant amplitude beam pulse is then standardized and OR-ed with its two associates of the same beam to produce three equidistant triggers related to the three sets of e^+e^- interactions observed around the machine. Each set is made of three flavors: chocolate, vanilla and strawberry.

II. Transmission and Filtering of the Beam-Induced Pulses

The beam-induced signals from a pick-up electrode have the shape of a differentiated Gaussian, with a typical width of 130 ps and typical amplitudes between 100 and 1000 volts. Passive stretching of this pulse is necessary before it can be processed by any conventional electronics.

A simple way to achieve lengthening is to use a lossy coaxial line as a mean of transmission between the electrode and the trigger circuitry. For instance, one finds that 100 feet of RG 403, a double shield version of RG 196, has a T_0^2 of 10 nsec; it yields an impulse response that

Fig. 1. Block diagram of the beam-induced trigger processing circuit.

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rises in 2 nsec and with a doublet like our beam-induced pulse, the first excursion of the response is about 1 nsec wide and the loss of amplitude is of the order of 100.

When speed of transmission is a concern, the lossy cable can be replaced by a light foam or air dielectric coaxial line and the propagation time to the electronics decreases from 145 nsec to 112 nsec; however, filtering is then required, introducing a small additional delay. An attractive type of filter is a filter having a Gaussian impulse response³ because its response to a doublet is still a doublet and it allows the operation of the circuit with either electron-induced or positron-induced pulses. In the case of the lossy cable, a positron-induced signal would necessitate the use of an inverting transformer. For a filter response to our doublet having a positive or negative excursion with a 1 nsec FWHM,⁴ the filter 3 dB cut-off should be approximately 200 MHz; as for the propagation delay one can expect 5 to 8 nsec, bringing to 120 nsec the overall transmission time, a gain of 25 nsec over the lossy cable approach.

III. Principle of the AGC Discriminator

A good amplitude discriminator produces little time slewing and the most significant time walk of its output, as the input level varies, is of the order of the input rise time. If the pulse applied to the discriminator is maintained constant, one can expect a drastic reduction of the time slewing as long as the amplitude regulating element does not introduce significant phase shifts.

The circuit of Fig. 2 uses a simple transformer coupled diode

Fig. 2. AGC of a single bunch signal; the non-essential components have been omitted.

attenuator as the main component of a gain controlled loop. The attenuated pulses are amplified up to 300 mV in order to overcome some preset threshold; the threshold is switched in synchronism with a bunch identifying gate allowing operation of the AGC with selected beam pulses only. The low frequency current necessary to operate the attenuator is procured from the integration and diode detection of the time-over-threshold part of the signal. Since the time-over-threshold is rather short compared to the repetition period, a large gain is needed to make up for this loss as well as the one introduced by the control attenuator; most of this gain is provided at very low frequency. The excess gain, i.e., the system's loop gain, is well over 40 dB for the entire range of input levels. An output for the AGC circuit can be taken anywhere downstream of the attenuator; however, a convenient spot is the collector of the threshold transistor where the signal level is compatible with MECL standards. Figure 3 shows the time response of three channels as a function of the input signal amplitude.

IV. Principle of the Bunch Identifier

Figure 4 is a block diagram of the bunch identifier module. This module is constructed as a single width CAMAC module using conventional TTL and ECL components. Two particular features of interest are the techniques for region specific timing signal generation, and the digital compensation for the varying electrical phase length from the master oscillator to each of the six PEP interaction areas.

PEP's hexagonal geometry with three electron and three positron contra-rotating bunches produces bunch interactions such that experi-

Fig. 3. Typical time response of the Three Flavor Beam Trigger circuit.

Fig. 4. Bunch Box Block Diagram.

menters in different regions see different bunches interacting. The identification module identifies each bunch by sign (electron or positron) and flavor (chocolate, vanilla, or strawberry) in an unambiguous manner that allows all experimenters to agree on a unique bunch identity.

The digital phase compensation circuitry allows any module to be used in any region merely by resetting a thumbwheel switch, and eliminates tedious timing adjustments. A programmable read only memory in each module contains information about the electrical phase delay to each of the six interaction regions in PEP, and the timing logic is automatically adjusted in phase to provide bunch synchronous timing in all regions.

These two features are implemented in three functional logic blocks. Referring to Fig. 4, the timing generation logic accepts as an input a composite timing signal from the PEP master oscillator. This signal contains information at 36 times the revolution frequency and at the fundamental revolution frequency. Digital logic generates a 3x clock and a 1x clock that are adjusted in phase by a digital control word from the Prom Look-up table. The timing generation logic also generates a 2-bit bunch count which is used as an input to the Prom Look-up table. Timing signals from the circuitry have a typical 1 σ jitter of 180 ps.

The Prom Look-up table accepts as input the region number and the bunch count, and provides a region specific digital phase adjustment to the timing logic and two region specific bunch identification signals to the gate generation logic.

The gate generation logic accepts the two clocks and the two sets of bunch identification signals and produces the output gates in synchronism with the appropriate electron bunch. Light-emitting diodes

identify the corresponding colliding positron bunch. A special calibration circuit can be enabled which produces three coincident gates for a selected electron bunch. These coincident gates allow normalization and calibration of the time-of-flight discriminators and timing circuitry.

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REFERENCES

1. J. Fox, Stanford Linear Accelerator Center, PEP NOTE-344.
2. Q. Kerns, F. Kirsten, C. Winningstad, Lawrence Radiation Laboratory
File No. CC2-1B. Revised July 1966 by F. Kirsten and R. Wallace.
3. E. Higgins, Los Alamos Scientific Laboratory, PSR Technical
Note 36, Nov. 1979.
4. A. I. Zverev, Handbook of Filter Synthesis, (Wiley, New York, 1967).