THE TIMING AND DIAGNOSTIC SYSTEMS OF THE KICKER MAGNET PULSERS FOR THE STANFORD LINEAR COLLIDER *

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Summary

The Stanford Linear Collider (SLC) uses several very fast thyratron pulsers to drive kicker magnets. The pulsers operate at repetition rates of between 1 and 120 pulses per second as dictated by the operational mode of the SLC. Time jitter of typically 200 psec is achieved and the longer term effect of time drift is compensated by the use of a timing feedback device. Monitoring is provided to measure and display the average time and jitter for the thyratrons and magnets. Amplitude stability of better than 10^{-3} is required and this is measured and displayed by the use of an amplitude sampler. Measurements of the individual functions of each system are provided both locally and at the Machine Control Center so that it is possible to continuously track each pulser's performance.

Introduction

The kicker magnets are located in the positron and electron damping rings with one at the 2/3 point of the linac for positron production. Each magnet is connected to a pulser located in the service building above the damping ring or in the linac klystron gallery. Both damping ring service buildings contain three complete pulser systems, two being connected to the kicker magnets whilst the third is an uncommitted standby system. To the first approximation one CAMAC crate is used for each of the pulser systems. This provides access to the SLC's comprehensive machine timing system and diagnostic monitoring capability. The magnet requirements for the two damping rings are not the same [1] and subsequently there are two pulser types used. The positron damping ring pulsers use a Blumlein with a single thyratron as the energy discharge switch. The electron damping ring pulsers are of the delay line type and use a pair of parallel connected hydrogen thyratrons as the energy discharge switch.

The analog monitoring and data storage capability of the SLC is used to provide monitoring channels of system dc voltage signals. This allows continuous access to these monitor channels and also provides the capability to obtain a history of performance.

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The Timing System

The SLC beam repetition rate varies dynamically to protect certain components from damage by the beam. Thyratron anode delay can vary by tens of nsec if the pulse rate is changed, which is not tolerable. A CAMAC module provides up to 16 general use timing channels that can be programmed to generate either beam coded triggers, or base rate triggers that are unaffected by the beam code. Each channel can be adjusted in time with a step size of 8.4 nsec and a resolution of about 30 psec. Step sizes of 100 psec are available by adding a vernier delay CMAC module. Operation of the pulser at a constant repetition rate, whilst retaining the capability of being able to operate at between 1 and 120 pulses a second, is achieved by using two of the available trigger channels. One is set so that it produces a beam coded trigger and the other a base rate trigger. The base rate trigger is set so that it occurs 2 μsec after the beam coded trigger. An "or" function of these two triggers is carried out using a standard NIM module, the resultant output providing the raw trigger. This configuration provides the raw trigger pulse for the thyratron [2] and, in a similar manner, for the pulsed charger[3]. The pulsed charger trigger is set so that it occurs a nominal 100 μsec before the thyratron trigger. When a beam coded trigger is present both the pulse charger and the thyratrons are initiated at the time set by the beam coded channels. The base rate triggers that follow will have no harmful effects

Thyratron delay is also a function of filament and reservoir voltage, anode voltage, and age. A timing feedback module or stabilizer is constructed as a NIM module and one stabilizer module is used for each thyratron timing channel. The stabilizer is shown in block form at figure 1. Both input and output pulses conform to the NIM standard.

The raw trigger is patched to the stabilizer where it is used to generate a voltage ramp. The voltage ramp is compared with the voltage obtained from the DAC, which is a measure of the delay correction, to provide the delay trigger output. This trigger is routed via a NIM level convertor module to provide a TTL trigger for the thyratron trigger chassis [4]. The buffered thyratron current transformer signal is used in conjunction with a NIM discriminator to provide a time reference trigger that is patched to the stabilizer. A separate beam coded timing pulse is used to provide a reference input for the stabilizer. The reference trigger is adjusted so that the kicker magnet is powered to coincide with optimum beam performance. The time/analog convertor (TAC) produces a voltage with an amplitude determined by the time difference between the reference and feedback signals, within a range of 3 nsec. This is then compared to a reference and generates a logic control signal indicating which arrived first. The reference and feedback signals also provide a strobe pulse, provided that both signals are present. The logic control determines whether the scaler will count up or down, and the strobe initiates the process. The analog output from the DAC is set by the scaler and this provides the control voltage for the next pulse. If the time error is greater than the 3 nsec range of the TAC it is detected and flagged both locally and remotely as "out of window". The stabilizer has an active range of +/- 275 nsec, the amount of trigger delay being displayed on the front panel as well as available as a scaled analog voltage output. The stabilizer can be set to either the track or freeze mode with a logic high or low respectively. It is also possible to set the stabilizer to mid-range by a logic high pulse. Status indication is provided for out of window, out of range and track/freeze. The stabilizer is designed so that it does not introduce additional jitter into the thyratron trigger circuit by using emitter-coupled logic where appropriate.

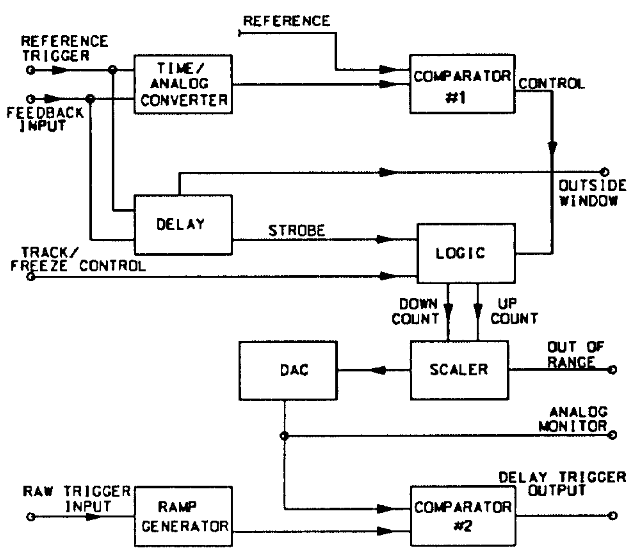

Fig.1 Stabilizer block diagram

The derived kicker timing signals from the current transformers and magnetic field obtained from the buffer module for all three systems are patched with delay lines so that they nominally coincide in time. These signals are routed to a CAMAC module TDC for system time measurement. Two of the SLC timing channels from each system are reserved for beam diagnostics and one of these trigger channels provides the TDC gate trigger.

Instrumentation is provided to monitor the performance of the timing system. The current transformer derived signal for each thyratron and the signal obtained from the magnet pick up coil are used for this. These signals are attenuated then applied to a buffer module which produces multiple outputs of each input function. The magnet pickup coil signal is integrated within the buffer module to provide monitoring capability of the kicker magnet field. One buffer module output channel for each of the thyratron current transformer signals and one magnetic field signal are applied to separate channels of a NIM module discriminator. The discriminator threshold is set so that the output pulse is independent of the input signal amplitude providing the pulser is operating above the 20% level. An output from each of the discriminator channels is connected to the "stop" control of Stanford Research Systems SR620 Time Interval Counters (TIC). A beam code trigger channel is buffered and its multiple outputs connected to each of the TIC "start" controls. This ensures that all of the TIC units are only initiated when the kickers are being operated under beam conditions and they do not respond in the standby mode. The TIC's are used to measure the time jitter and mean time over 100 machine cycles as preset at the TIC. The resultant measurements are displayed on the front panel and are also available as a scaled analog output voltage. These outputs are connected to a CAMAC module to provide data to the SLC monitoring system. The TIC can be addressed by the CAMAC crate GPIB data link so that various scale factors can be set and read remotely.

Amplitude Sampler

The basis of an amplitude sampler is a Comlinear 940 track/hold circuit that has an input range of +/- 2 volts and a drift of about 1mV. To improve the resolution a stable voltage of 20V is subtracted when a large signal is available e.g. from a thyratron current transformer. The magnet pickup coil signal, when integrated, is small enough to send directly to the Comlinear. The block diagram at figure 2 is for the high resolution channel of the amplitude sampler for the current transformer signals; the second channel has an integrator at the input and this signal goes direct to the track/hold circuit.

The output of the track/hold is gated using a FET switch to a low droop hold circuit. A buffered time constant output provides a measurement of the average current and a buffered rms output is also provided. The trigger input signal that is used to control the operational mode of the track/hold as well as the following FET switch is obtained from a SLC beam coded trigger channel. An output from the track/hold circuit is current limited to an output connector to provide pulse to pulse amplitude measurements. All the pulse output channels from the amplitude samplers for a given damping ring are patched to a gated ADC CAMAC module via pulse shaping capacitors. The second diagnostic timing channel provides the ADC gate command via a pulse stretcher NIM module. The gate width is set so that all of the pulse output signals can be monitored simultaneously. The amplitude signals can be measured over a number of machine cycles to give the short term amplitude stability.

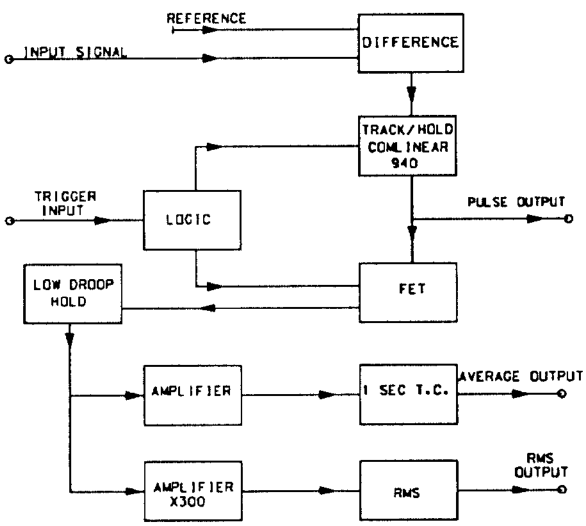

Fig.2 Amplitude sampler, high resolution channel.

Video Multiplex Oscilloscope

Pulse signal monitoring is also provided for each system. The individual monitor signals are routed to the purpose built buffer chassis which produces multiple output signals from each input signal. Each output channel is able to drive a 50 ohm load without compromising any of the similar channels. Output jacks are provided at the service building for monitoring. Another output channel of each signal is routed to a mux switch assembly. The mux output is connected to the input channels of an oscilloscope that has a video camera to provide remote monitoring. The oscilloscope and mux unit are also connected to the GPIB control system so that it is possible to select any of the mux channels with the correct oscilloscope settings. One of the beam coded trigger channels is used as a remote trigger for the oscilloscope. Dedicated function buttons on the SLC control panel are used to select the mux channel, set the trigger time, and recall a stored oscilloscope set up. A patch panel is used to match the pulser system being used for a specific kicker function so that the injection and extraction signals as seen at the display screens are correct.

Conclusions

The stabilizer, in its final form, has been operating successfully as part of the timing system since relocation of all of the electronics to the service building in 1990. A problem with electrical noise affecting the initialize control of the stabilizers used for the electron damping ring pulsers was initially encountered. This was corrected by the addition of noise rejection filters to these control lines. The original stabilizers built for this timing system used a 12 bit scaler. It was decided to develop a 16 bit version which could be used to either increase the delay range or increase the resolution. One of these modules has been built and is being tested in a development system pulser.

Installation of the amplitude samplers is now complete and final adjustments are being made to provide optimum performance. The capacitor coupling used between the pulse output monitor, which is positive polarity, and the ADC is to provide a negative signal for the ADC module.

The original intention for the high resolution amplitude sampler channels had been to use the voltage output from each current transformer and set the internal attenuators in the module to match its input voltage. We found that the voltage signal levels covered a wide range, and setting individual channels could cause problems and be confusing. It was decided to provide external attenuation of these signals where necessary so that the amplitude sampler offset is nominally 25 volts for every channel.

Initial results show that the kicker current stability obtained from the current transformers at the electron ring is a few parts in 10^4 and for the positron ring is about a part in 10^3.

Acknowledgements

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References

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