RHIC Transverse Injection Damper
System Overview

R. Michnoff
July 2007

Table of Contents

Introduction 3
Purpose of the System 3
System Block Diagram 5
Overview of Operation 6
Injection Damper Signal Conditioner Block Diagram 7
Auto Gain 8
Beam Trigger Timing 9
Injection Damper Module Configuration 13
Programmable Attenuators 16

Introduction

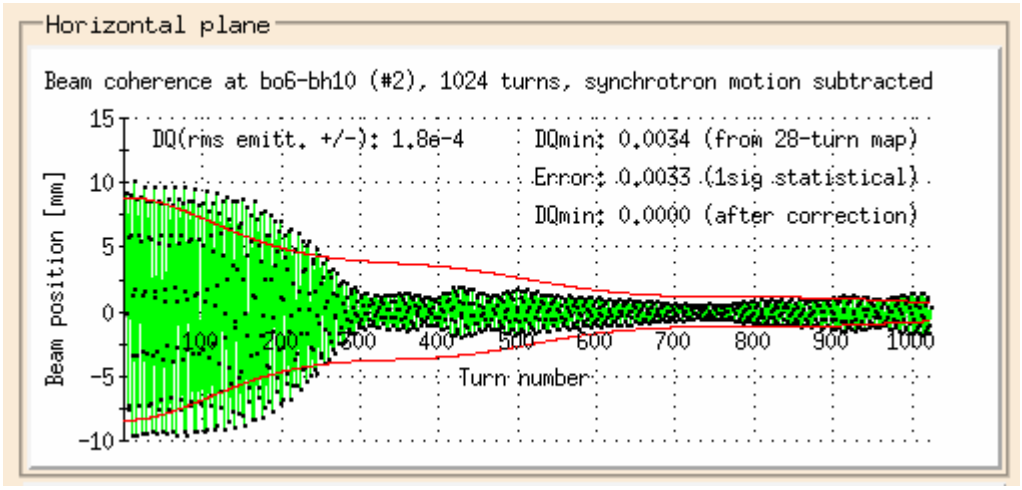
This document provides an overview description of the RHIC Transverse Injection Damper System.

Purpose of the System

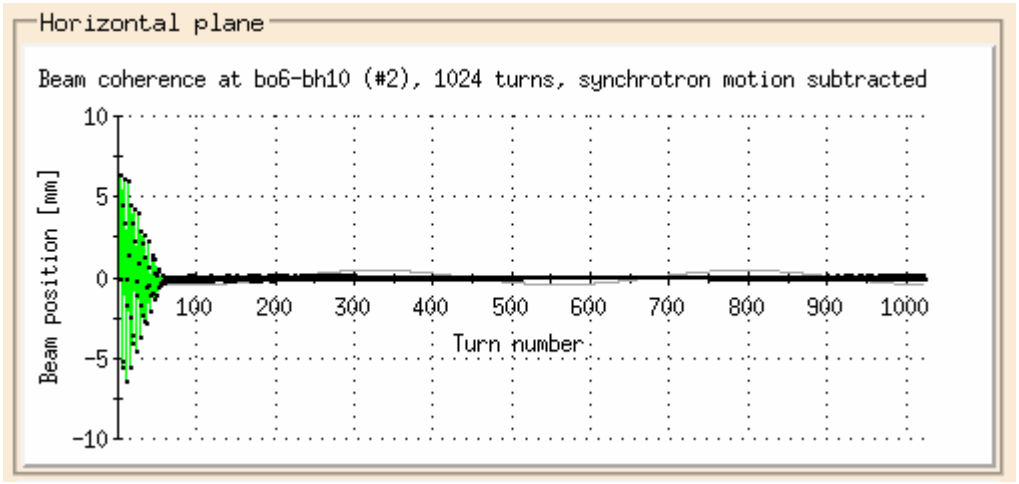
The amplitude and duration of beam injection oscillations is often higher than desirable. Negative effects of this condition include beam emittance growth, which directly affects luminosity. Fine machine tuning and improved injection matching can help decrease the injection oscillations but requires significant ongoing effort.

The purpose of the RHIC Transverse Injection Damper is to damp the injection oscillations as quickly as possible for each injected bunch and decrease the machine fine tuning and injection matching effort.

The two plots below show the typical affect of the system. The first plot is the first injected 1024 turns of the blue horizontal Beam Position Monitor (BPM) signal for bo6-bh10 with the injection damper OFF, and the second plot is the same BPM signal with the injection damper ON. Note that when the injection damper is OFF, the injection oscillation amplitude is +/- 10 mm and naturally damps down to about +/- 2 mm after turn number 300. When the injection damper is ON, the beam oscillations damp to a barely measurable value within the first 50 turns. This helps prevent emittance blowup thus providing increased luminosity.



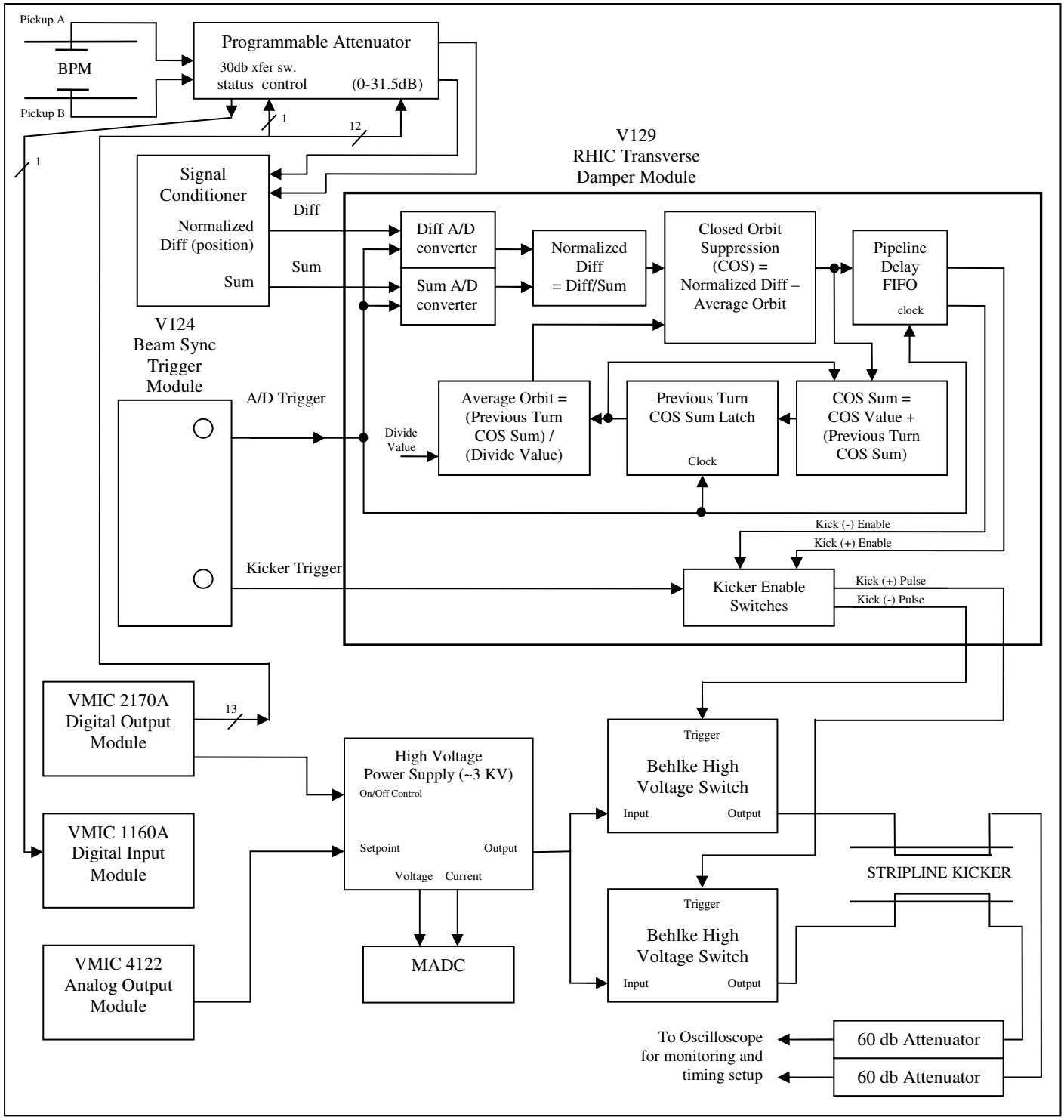
bo6-bh10 Blue Horizontal BPM signal for first 1024 turns
with Injection Damper OFF



bo6-bh10 Blue Horizontal BPM signal for first 1024 turns
with Injection Damper ON

System Block Diagram

A block diagram for a single plane of the RHIC Transverse Injection Damper system is provided below. The complete system is comprised of four planes total – blue horizontal, blue vertical, yellow horizontal and yellow vertical.



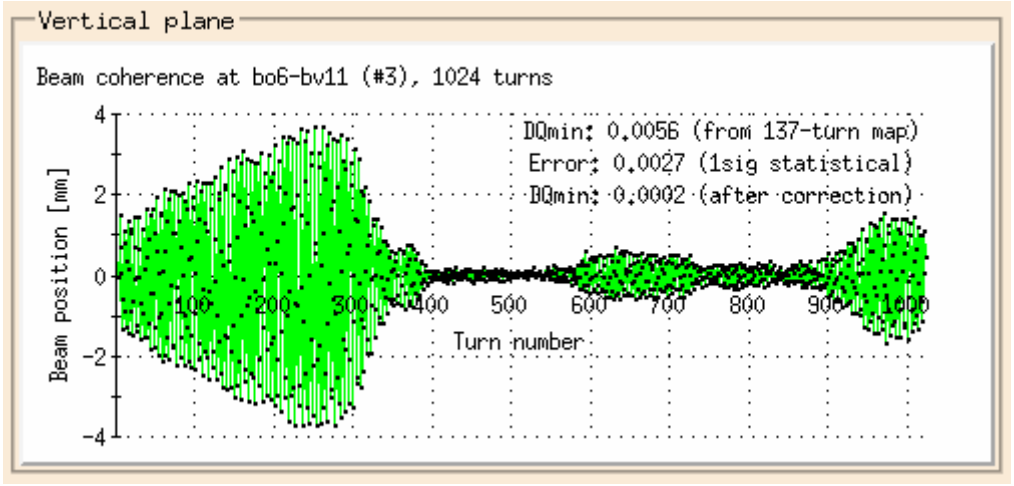
Overview of Operation

The RHIC transverse injection damper vertically and horizontally damps each bunch as it is injected into RHIC. The injDampTrig ADO uses the RTDL (Real-Time Data Link) parameter rt-b[y]nextbucket to automatically change the selected bucket. The system is capable of damping one and only one bucket at a time.

A programmable attenuator enclosure provides a 30 dB attenuation transfer switch and 0-31.5 dB programmable attenuation of the BPM (Beam Position Monitor) signal. The signal conditioner module then produces a normalized difference signal and a sum signal that is controlled to 1 V by an auto-gain circuit. The V129 module uses two Edge Technology, Inc. 700140 ten bit, 20 MHz ADCs to digitize the sum and difference signals. The mathematical calculations for the algorithm as shown in the block diagram are performed in an Altera EPF10K200 gate array using combinatorial logic.

The V129 RHIC Transverse Damper module is a modified version of the V127 AGS Transverse Damper module. The major difference is that the AGS damper provides analog kicker output signals, while the RHIC damper generates digital pulses to trigger the Behlke High Voltage switches. The V129 module uses the BPM sum and difference signals to compute a normalized, intensity-independent average orbit position value as shown in the block diagram. If the current turn measurement is outside a programmable average orbit deadband value then a kicker pulse will be generated on the next turn in attempt to kick the beam into the deadband limits. The direction of the kick, positive or negative, is dependant on the measured position relative to the average orbit value, the phase advance between the BPM and the stripline kicker, and the machine tune space (0-0.5 or 0.5-1.0). Only one kick, positive or negative, is generated for each turn. If the position measurement is within the average orbit deadband then no kick is generated.

The system provides a configurable parameter to invert the kick direction as required. If this parameter is set incorrectly an anti-damping symptom will occur as shown below. Note that the amplitude of the beam oscillations grows until turn 300 when the injection damper is turned off.

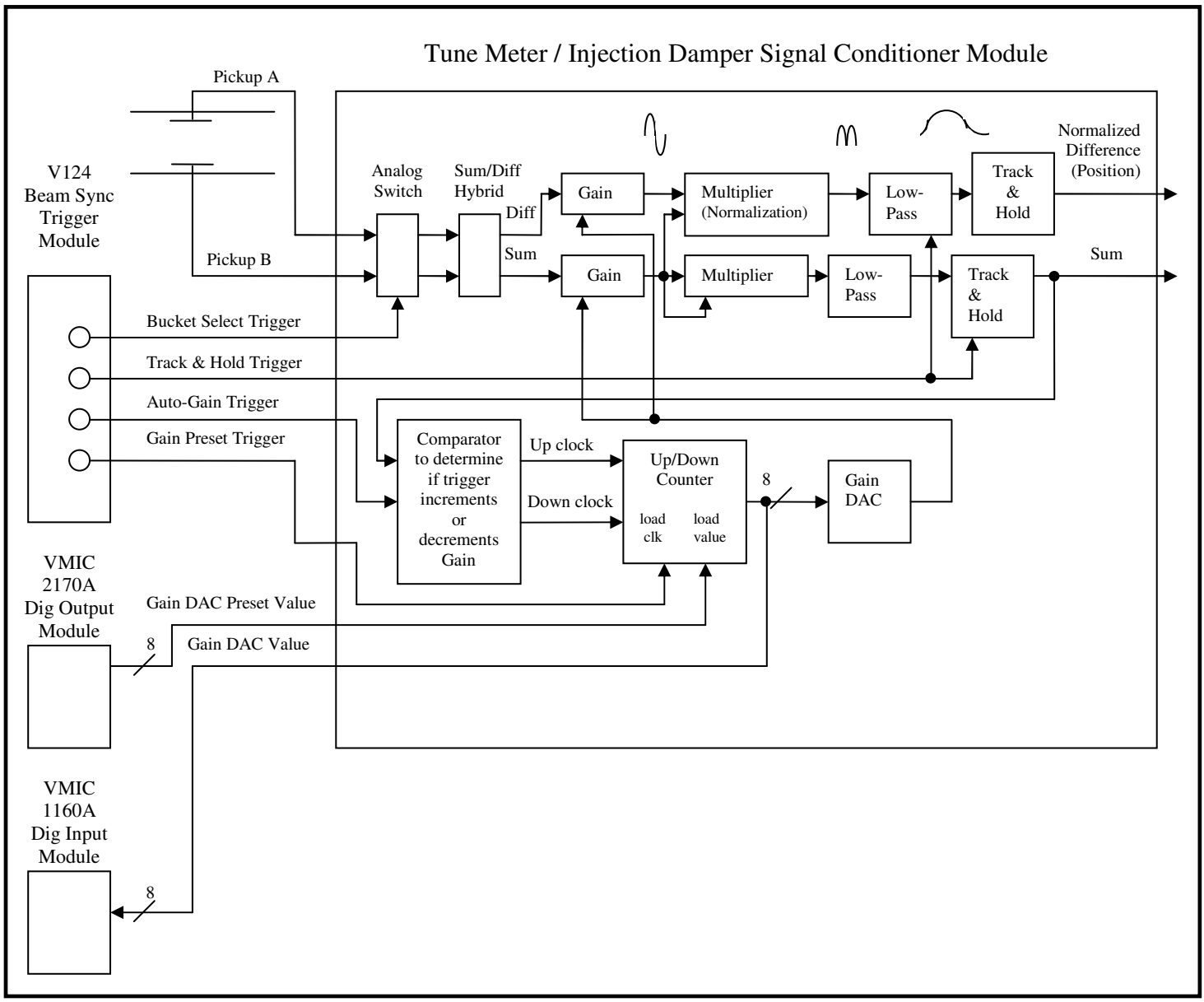


Example of Anti-Damping

Behlke High voltage switches with a pulse width of 150 nanoseconds are used to fire the stripline kicker with a voltage of about 3 KV. Standard VMIC VME modules are provided and controlled by an ADO to configure the High Voltage Power Supply. The voltage and current of the power supply are monitored with standard RHIC MADC (Multiplexed Analog to Digital Converter) channels.

Injection Damper Signal Conditioner Block Diagram

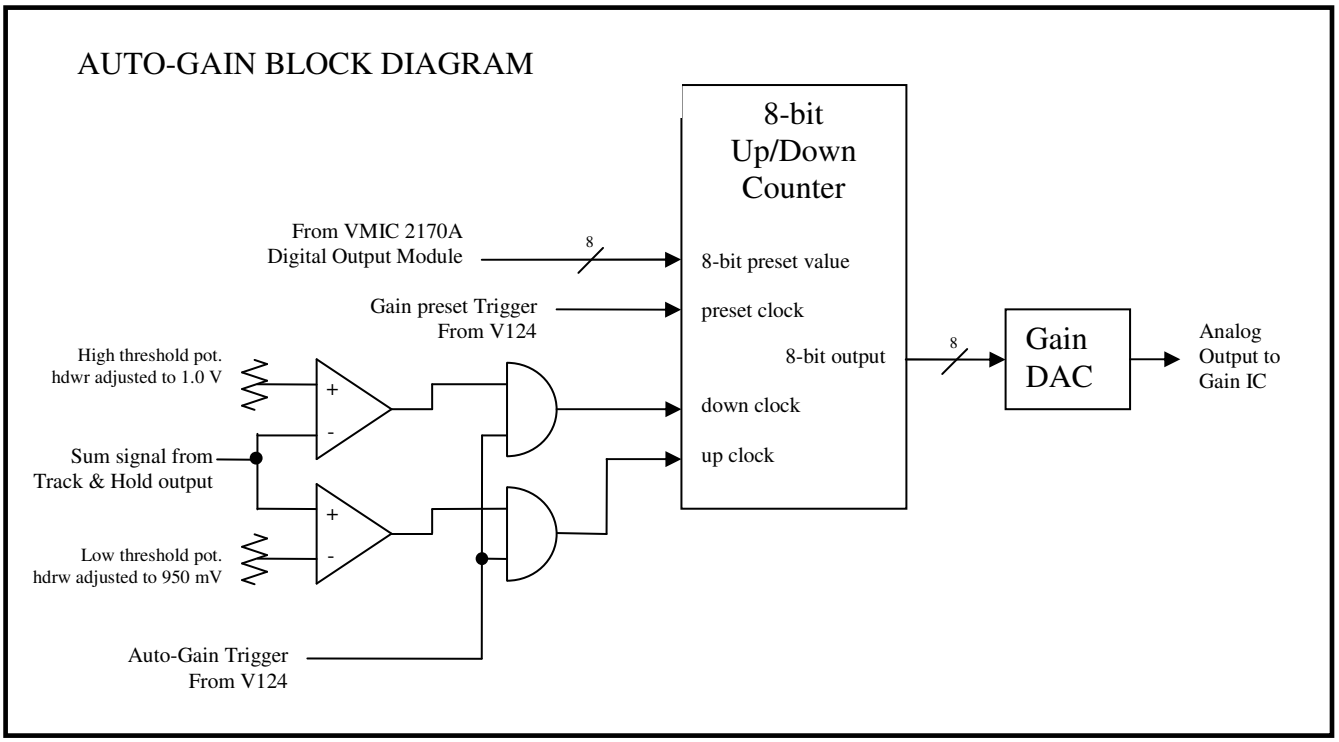
The block diagram for the RHIC Tune Meter and Transverse Injection Damper Signal Conditioner including associated control signals is shown below.



Auto Gain

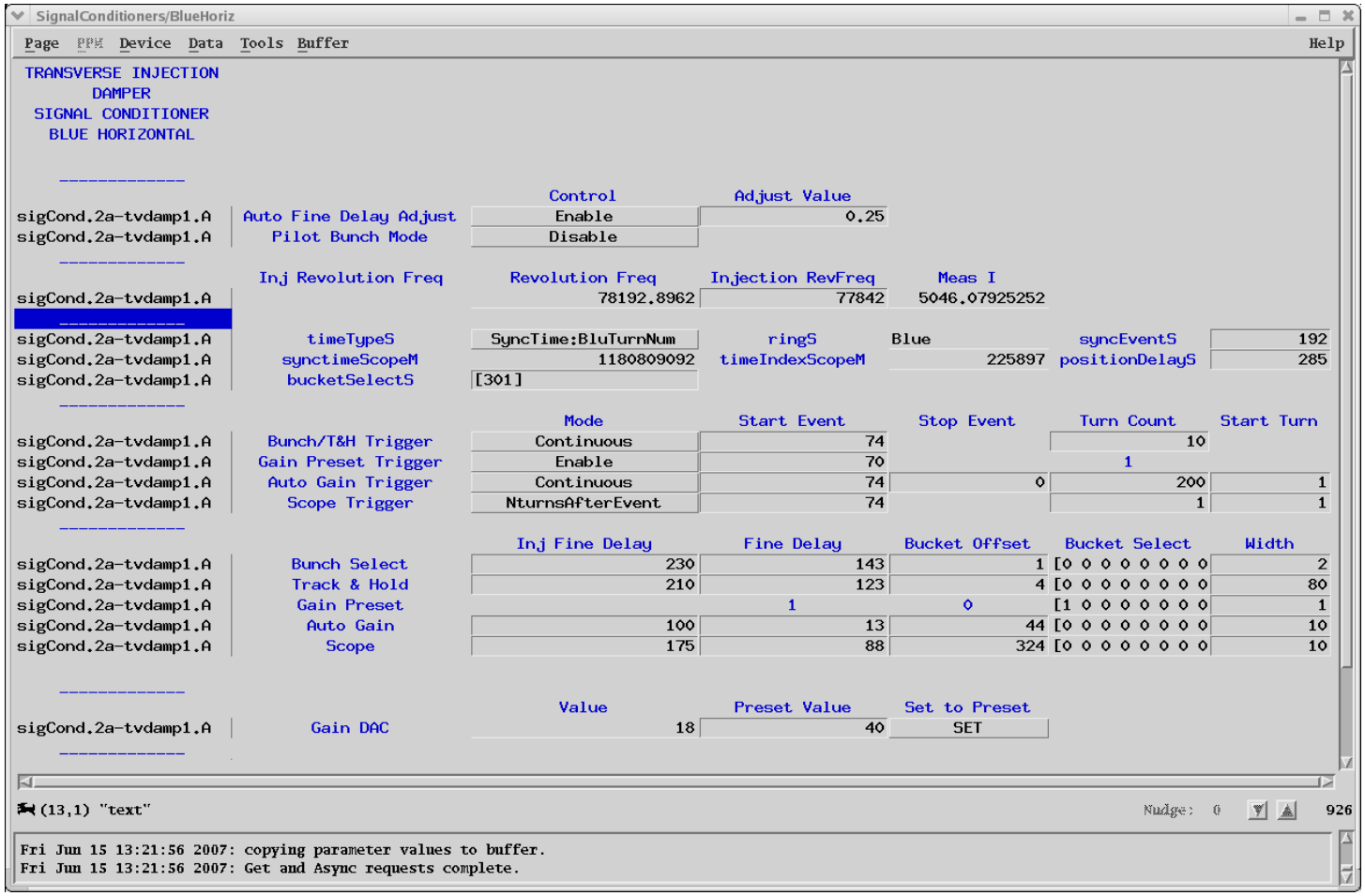
A block diagram of the auto gain circuit is shown below. The circuit increments or decrements the gain DAC value each turn to hold the BPM sum signal to a value between 950 mV and 1.0 V. Two hardware adjusted potentiometers are used to set the high and low values as shown in the diagram. On occurrence of the V124 auto-gain trigger, the up clock will be generated if the BPM sum signal is below 950 mV and the down clock will be generated if the BPM sum signal is above 1.0 V. Neither clock will be generated when the sum signal is between 950 mV and 1.0 V. The hysteresis of 50 mV may be configured to a tighter window if required.

When there is no beam in the machine, the auto-gain circuit attempts to continuously increase the gain setting. This results in a wraparound when the gain setting is incremented from 255, the maximum 8-bit value. In order to provide a reasonable gain setting when beam is injected, a gain preset value is used. The VMIC 2170A digital output provides a setting that is clocked into the counter on the occurrence of the V124 gain preset trigger, which is typically configured to the FEBbunch event. A very accurate preset value is difficult to achieve since it is dependent on intensity.



Beam Trigger Timing

The following pet page (located in the pet tree at RHIC/Instrumentation/InjectionDamper/SignalConditioners/BlueHoriz) is used to configure the Blue Horizontal Transverse Injection Damper signal conditioner V124 timing. The pet page configuration is similar for all signal conditioner modules.



Four triggers are used to control each signal conditioner module as follows:

1. Bunch Select Trigger – This trigger is used to select the bunch or bunches to be used by the signal conditioner.
2. Track and Hold Trigger - This trigger drives the track and hold, and is configured to the peak of the low-pass filtered bunch signal.
3. Gain Preset Trigger - The gain may be initialized on the occurrence of an event.
4. Auto Gain Trigger - This trigger generates the auto gain clock and is configured to occur during the hold period of the track and hold output.

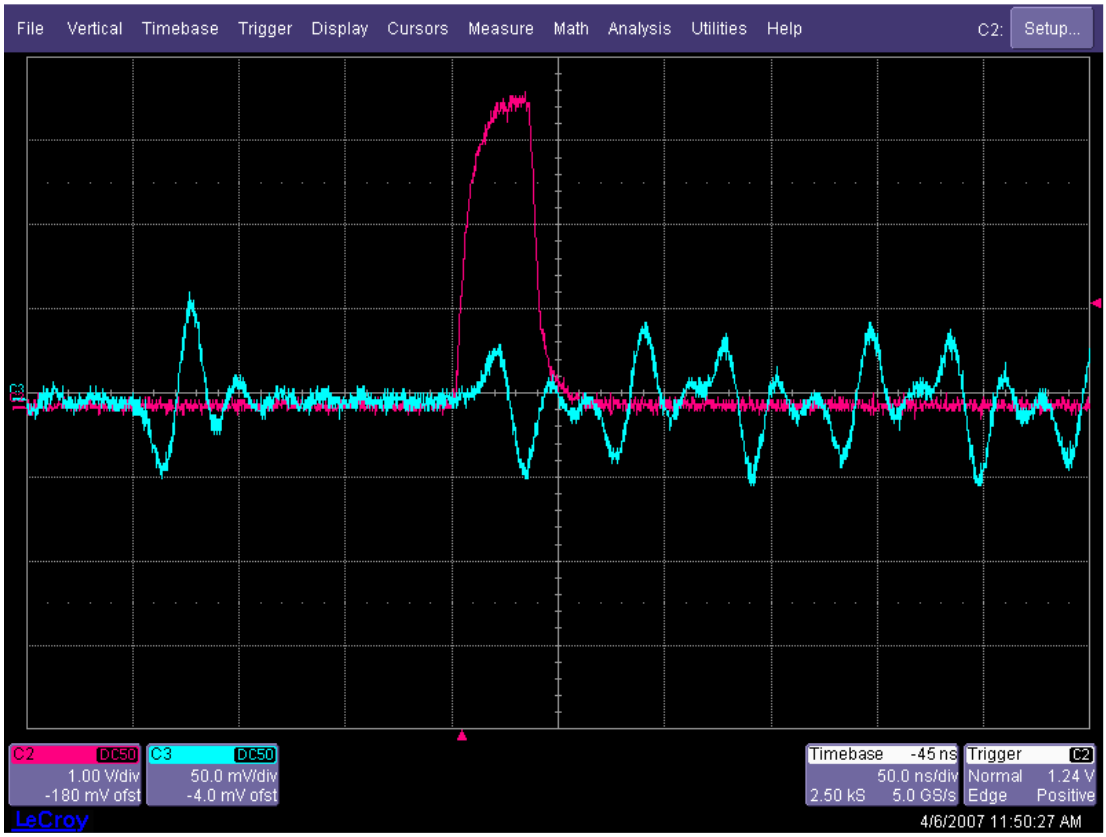
The configurable timing ADO parameter values for the triggers are:

Parameter Name	**Legal Values**	**Description**
bunchSelectInjFineDelayS trackAndHoldInjFineDelayS autoGainInjFineDelayS	1-255	Fine delay setting at injection. 1 count equals 0.5 nanoseconds.
bunchSelectFineDelayS trackAndHoldFineDelayS autoGainFineDelayS	1-255	Currently used fine delay setting. 1 count equals 0.5 nanoseconds. When autoFineDelayS is Enabled, this parameter is automatically updated every second and indicates the calculated fine delay value.
bunchSelectBucketOffsetS trackAndHoldBucketOffsetS autoGainBucketOffsetS	0-359	The trigger outputs are shifted by this number of rf clocks.
bunchSelectPulseWidthS trackAndHoldPulseWidthS gainPresetPulseWidthS autoGainPulseWidthS	1-357	The width of the trigger pulse in number of rf clocks.

Additional ADO parameter settings that are common to the module include:

Parameter Name	**Legal Values**	**Description**
autoFineDelayAdjustS	Enable, Disable	The fine delay timing values may be modified to track beam during the ramp. The equation is: fineDelay = injFineDelayS – (fineDelayFactorS * (revFreqM - injectionRevFreqS)). This parameter Enables or Disables the function. Since the 10 Hz IR Feedback system is normally configured to operate at store only, the timing is set for store conditions and this parameter is typically set to Disable.
fineDelayFactorS	Positive floating point value	See autofineDelayAdjustS.
syncEventS	1-255	The 0.25Hz sync event code for resetting the timestamp. (Typically configured to 192)
positionDelayS	1-359	The bucket 1 position indicator is delayed from the revolution event (event code 1) by this number of rf clocks before each channel configuration delay. This value is common to all channels on the module.
bucketSelectS	Array of 1-120 values, where each value is a number between 1 and 360. Spacing between bucket numbers in the list must be 3 or greater.	The list of buckets that are selected for trigger generation.

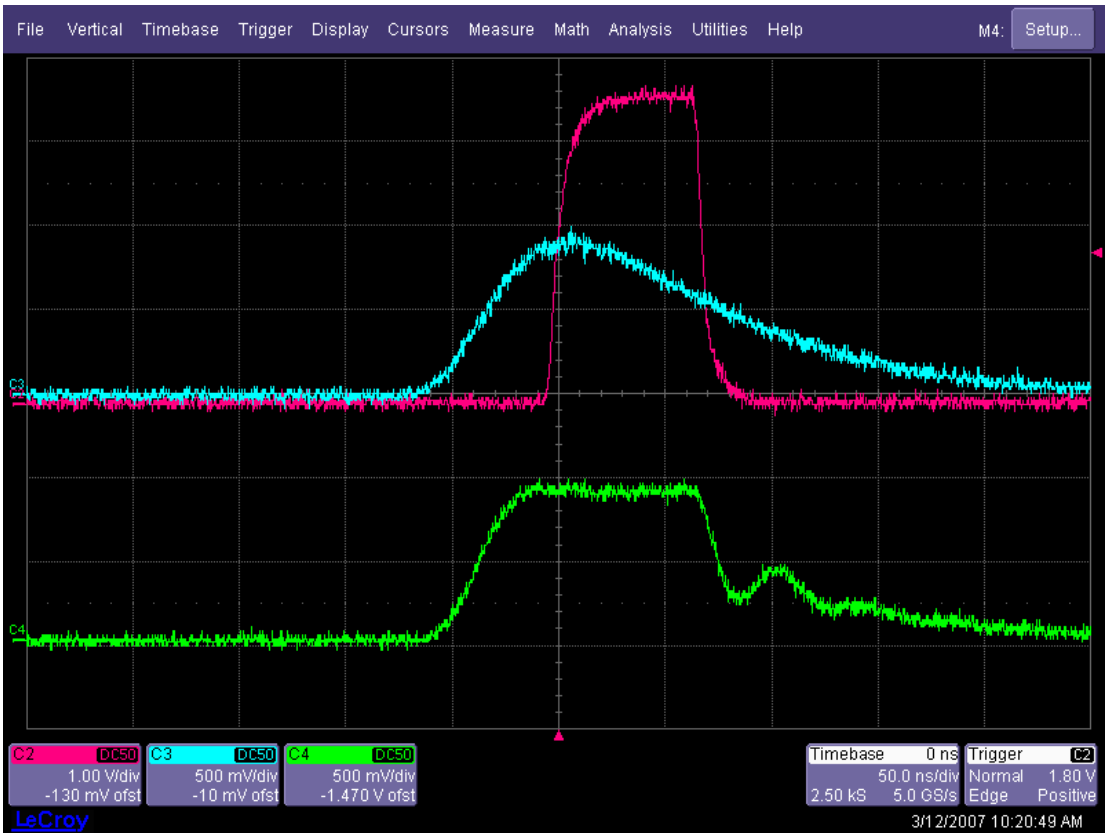
The scope image below shows proper bucket select timing for the blue 5 o'clock DX 10 Hz signal conditioner. The bucket select trigger (channel 2) overlays the first blue bunch. The blue bunches are the positive going doublet pulses, while the yellow bunches are the negative going doublet pulses. The abort gap is to the left of the bucket select trigger.



Channel 2: bucket select trigger
Channel 3: Blue 5 o'clock DX BPM input signal with gold beam

The following scope image shows proper track and hold timing for the blue 5 o'clock DX 10 Hz signal conditioner. The rising edge of the track and hold trigger (channel 2) is timed to the peak of the track and hold input signal (channel 3). Note that the track and hold output level (channel 4) is held constant until the falling edge of the track and hold trigger.

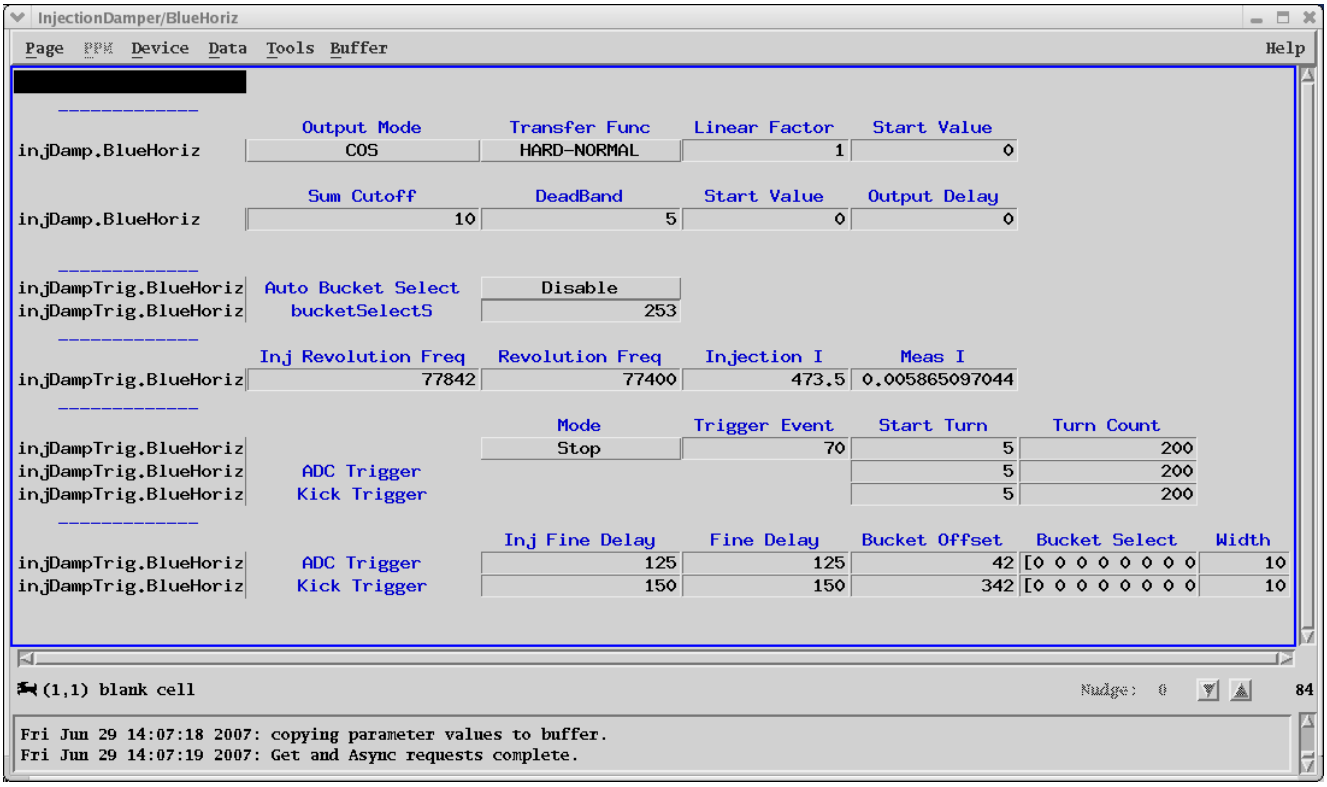
The track and hold trigger for the image shown was configured to a width of 2 rf clocks. However, when one bunch is selected, which is typical for the injection damper, the track and hold trigger would be configured to a width of 40 rf clocks.



Channel 2: track & hold trigger
Channel 3: track & hold input signal
Channel 4: track & hold output signal

Injection Damper Module Configuration

The following pet page (located in the pet tree at RHIC/Instrumentation/InjectionDamper/BlueHoriz) is used to configure the Blue Horizontal Transverse Injection Damper V129 module and associated V124 timing channels. The pet page configuration is similar for all four Transverse Injection Damper planes.



The ADO parameter settings are described in the following table.

Parameter Name	Legal Values	Description
outputModeS	OFF COS STT (unused)	The output mode. OFF disables the outputs, and COS sets the output pulses to control based on the closed orbit suppression algorithm. STT is unsed.
transferFuncS	HARD-NORMAL HARD-INVERSE LINEAR_NORMAL(unused) LINEAR_INVERSE(unused) N_X_LINEAR_NORMAL(unused) N_X_LINEAR_INVERSE(unused)	The function output used for the algorithm. HARD-NORMAL generates a positive kick when the beam position is on the positive side of the average orbit deadband window, and HARD-INVERSE generates a negative kick when the beam position is on the negative side of the average orbit deadband window. All others are unused on the V129. The gate array provides linear output functions that are available on the V127 only, which provides analog outputs for the kickers.
sumCutoffS	0 to 1023	The sum cutoff is used to inhibit the algorithm calculation when beam is not present. The control is disabled when the sum signal is less than the sum cutoff value. The units for this value are A/D converter counts.
deadBandS	0 to 127	The deadband is used to prevent output pulses when the position difference signal is within the range of averageOrbit - deadband and averageOrbit + deadband. The units for this value are A/D converter counts.
fifoReadPtS	0 to 31	The output delay in number of A/D clocks. Since one A/D clock is generated for each revolution for the RHIC transverse injection damper, this parameter is typically set to 0. This will send the output pulse on the next turn.
autoRtdlNextBucketS	Enable Disable	This parameter is used to Enable or Disable automatic modification of the selected bucket based on the RTDL distributed parameter rt-b[y]nextbucket.
bucketSelectS	1 to 359	The selected bucket. When autoRtdlNextBucketS is set to Enable, this parameter indicates the currently selected bucket based on the RTDL distributed parameter.
modeS	Stop FebBunch OtherEvent	The event trigger mode. Stop disables the ADC and Kicker triggers. FebBunch configures the triggers to occur on the FebBunch event, and OtherEvent allows selection of a different event for trigger generation.

triggerEventS	0 to 255	When modeS is set to FebBunch this parameter is forced to 70 – the FebBunch beam sync event. Any event code between 0 and 255 may be entered when modeS is set to OtherEvent.
startTurnS	1 to 65535	The kicker output pulses will begin this number of turns after the beam sync event code triggerEventS is detected.
turnCountS	1 to 128000	The kicker algorithm and kicker output pulses will be generated for this number of turns, beginning at startTurnS turns after the beam sync event code triggerEventS is detected.

The configurable timing ADO parameter values for the Injection Damper ADC and Kicker triggers are:

Parameter Name	**Legal Values**	**Description**
adcTrigInjFineDelayS kickTrigInjFineDelayS	1-255	Fine delay setting at injection. 1 count equals 0.5 nanoseconds.
adcTrigFineDelayS kickTrigFineDelayS	1-255	Currently used fine delay setting. 1 count equals 0.5 nanoseconds. When autoFineDelayS is Enabled, this parameter is automatically updated every second and indicates the calculated fine delay value.
adcTrigBucketOffsetS kickTrigBucketOffsetS	0-359	The trigger outputs are shifted by this number of rf clocks.
adcTrigPulseWidthS kickTrigPulseWidthS	1-357	The width of the trigger pulse in number of rf clocks.

Programmable Attenuators

The following pet page (located in the pet tree at RHIC/Instrumentation/InjectionDamper/Attenuators) is used to configure the BPM signal attenuation for all four Transverse Injection Damper planes. Each plate of each BPM is independently configurable with a value from 0 to 31.5 dB in increments of 0.5 dB. The 30 dB transfer switch control is common for each for each programmable attenuator module, where one module is used for each RHIC ring. Additionally, a test bit setting and status indication are provided for each programmable attenuator module to indicate that the power supply is ON and operational. The test bit setting and status bits are not shown on the system block diagram above.