Nuclear Instruments and Methods in Physics Research A 484 (2002) 690–694

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

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Hall C raster veto/flag generator

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Received 3 May 2001; received in revised form 3 August 2001; accepted 28 August 2001

Abstract

Due to the high intensity and small size of the continuous electron beam produced at Jefferson Lab,[1] one must raster it over the target to keep the properties of the target stable during an experiment. Rastering the beam using sign-wave control signals to produce a Lissajous pattern, however, causes the beam to remain at the edges of the target longer than the center. In these regions, the local heating can be much higher than the central region generating considerable luminosity losses affecting the quality of the data. This circuit tracks the X and Y raster waveforms and sends out NIM and TTL VETO/FLAG pulses when $X^2 + Y^2$ is greater than a user set threshold based on the percentage of the peak voltage on the Y input. The VETO/FLAG can be used to limit the acquisition/analysis of the data to a circular region in the center of the raster pattern. This circuit automatically compensates for changing frequency and voltage to maintain a constant percent trigger from 0.4 to 5 V peak to the peak of the raster waveform. © 2001 Elsevier Science B.V. All rights reserved.

PACS: 29.27.Bd; 29.27.Fh; 29.90.+r

Keywords: Target; Beam; Raster

1. Introduction

Cryogenic targets (liquid hydrogen and liquid deuterium) have been used for electron-scattering experiments at Jefferson Lab end stations A and C for many years. The longitudinal size of target cell ranges from 5 to 15 cm. The electron beam produced by our accelerator is extremely small having a transverse dimension of only 0.1 mm. Along the tiny beam trajectory, the average beam energy loss is about 5.2 MeV cm^2/gm. This continuous heat deposit along the trajectory causes local boiling to occur changing the target density. Thus, a raster system must be used to increase the transverse dimension of beam size. For a rastered beam size of about 1 mm, the raster frequency must be higher than 18 kHz.

The present raster system used consists of two 250 W power amplifiers driving two raster magnets through high-Q ($Q > 100$) resonance loops under two different free-run frequencies (24/17 kHz). Under such a frequency ratio, there is no standing pattern on the Lissajous. Due to the intrinsic

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[1] The Southeastern Universities Research Association (SURA) operates the Thomas Jefferson National Accelerator Facility for the United States Department of Energy under contract DE-AC05-84ER40150.

PII: S0168-9002(01)01998-2

behavior of the power resonance loop, the magnet current waveforms are purely sinusoidal. Unfortunately, a severe energy-density enhancement is generated along the boundaries and, especially, at the four corners of the pattern. In these regions, the local heating effect can be up to 10 times higher than the central region, which generates considerable luminosity losses. This is not acceptable for cross-section determination experiments at beam currents higher than 35 uA. An effective passive method has been developed to veto/flag events produced from these regions. The veto/flag signals are used as either an on-line strobe or as an off-line identifier to eliminate those events limiting the analysis to data from the area of uniform beam density.

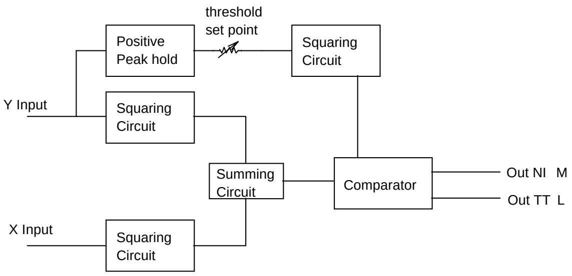

Fig. 1. VETO/FLAG circuit block diagram.

2. Circuit description and results

Figs. 1 and 2 show the block and circuit diagrams. The X and Y inputs are squared using a precision analog multiplier. The squared waveforms are then added together and passed to the comparator. The original Y input is also used to sense the peak amplitude of the driving waveform giving a DC voltage of the same value as the peak voltage. A user set percent of this peak amplitude (T) is then also squared and sent to the comparator. Thus, the comparator triggers

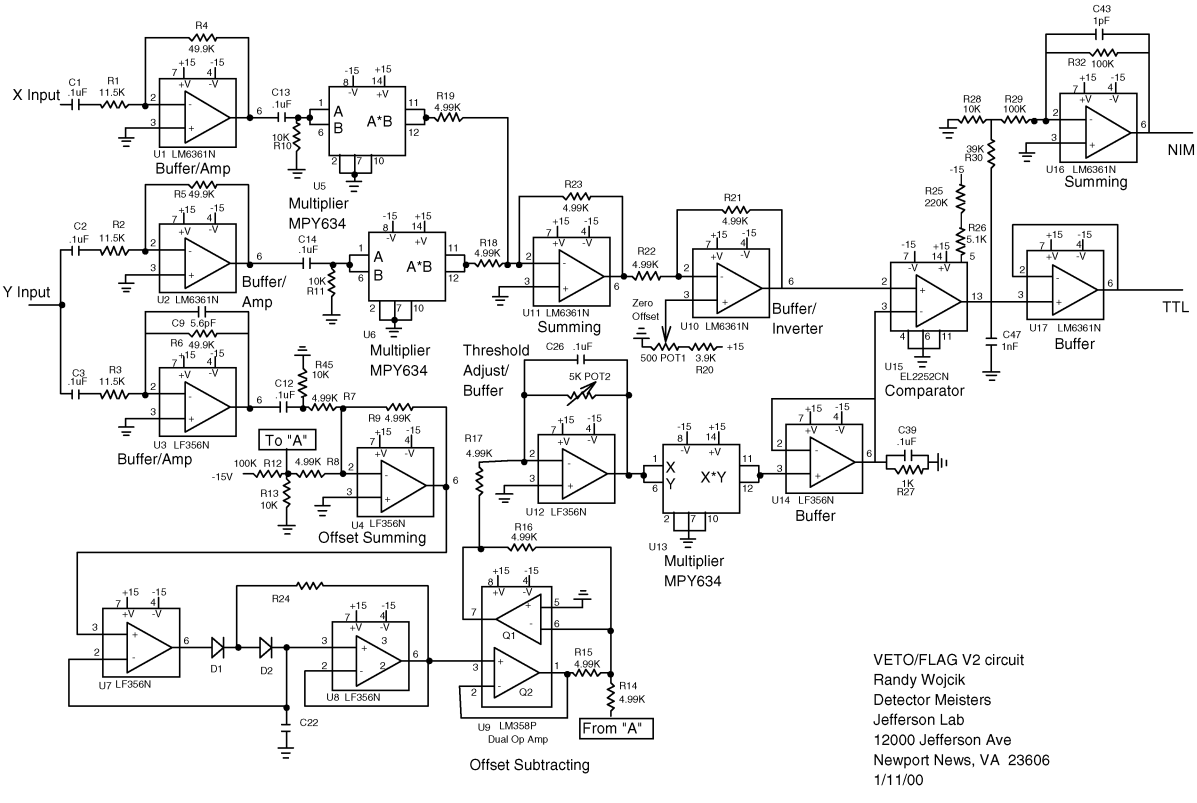

Fig. 2. VETO/FLAG circuit diagram.

whenever

$X^2 + Y > T^2$.

Thus, a VETO/FLAG occurs any time X and Y are outside a circle of radius T.

The heart of the circuit is the precision analog multiplier MPY634 from Burr-Brown[2] or, similarly, the AD534 from Analog Devices.[3] These chips run on ± 15 V and the input and output voltage range is ± 12 V with an offset of about ± 50 mV. The bandwidth of the chip is 10 MHz, however, the slew rate is only 20 V/μs. The basic transfer function of the chip is

$$\text{Output} = \frac{(X_1 - X_2)(Y_1 - Y_2)}{10V} + Z_2.$$

In this case, we set X_2, Y_2 and Z_2 to zero and put the same signal in both X_1 and Y_1. Tuning the dynamic range can be a problem. The expected dynamic range of the driver waveforms is 4–5 V peak–peak (pk–pk). If we put this into the multiplier directly, we would have an output of 4 mV to 625 V. Note that the squaring of the signal takes the negative portion of the peak and makes it positive. Thus, the equation becomes

$$\text{Output} = \frac{1}{10}\left(\frac{V_{\text{pk}-\text{pk}}}{2}\right)^2 = \frac{V_{\text{pk}-\text{pk}}^2}{40}.$$

Four mV is in the noise of the circuit and the VETO/FLAG becomes unstable. There are three ways to adjust the dynamic range. The first is by just amplifying the input signal to reach the maximum output of the chip (12 V for an input of 21.9 V pk–pk). This gives us an output of 77 mV to 12 V.

The second way to adjust the dynamic range involves the scale factor (SF) built into the chip. Instead of dividing by a SF of 10 V, you can choose a smaller devisor. With this method, the input voltage is limited to a maximum of 1.25SF and the smallest SF is 3 V. Using the smallest SF, we would get an output of 20.8 mV to 2.08 V. Amplifying the input waveform to the maximum input voltage of 7.5 pk–pk, gives an output of 30 mV to 4.69 V.

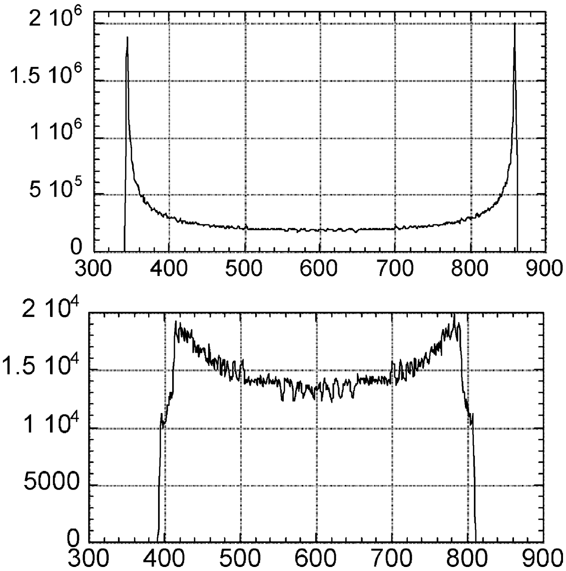

Fig. 3. The top portion shows a slice though the original input $X - Y$ plot at 2.5 V pk–pk. The bottom shows a cut though the $X - Y$ plot with a VETO/FLAG TTL cut. Overall 50.9% of the original data is included in the cut.

The third way to adjust the dynamic range is to use an attenuator feedback connection suggested by the manufacturer to obtain an SF of unity. Amplifying the input to reach the maximum output of the chip, we again obtain an output of 77 mV to 12 V as in the first method. Unfortunately, this method is accompanied with a reduction in bandwidth and an increase in offset voltage. Thus, the first method was chosen to obtain the best signal to noise ratio at the lowest voltage while staying within the dynamic range of the chip.

A very important chip is the comparator. Most fast comparators (<80 ns response time) run on 5 V and thus, cannot be used with 12 V input signals. Only the Elantec[4] EL2252CN with a 7 ns response time was found to work on a 15 V supply.

The peak-sensing circuit is out of an electronics book [1], however, the input signal is offset by a positive voltage to allow operation down to 4 V pk–pk. Peak-detection circuits need at least a 1 V peak input to operate due to the break-down

[2] Analog Devices, Norwood, MA 02062.

[3] Burr-Brown Corporation, Tucson, AZ 85734.

[4] Elantec Semiconductor Inc., Milpitas, CA 95035.

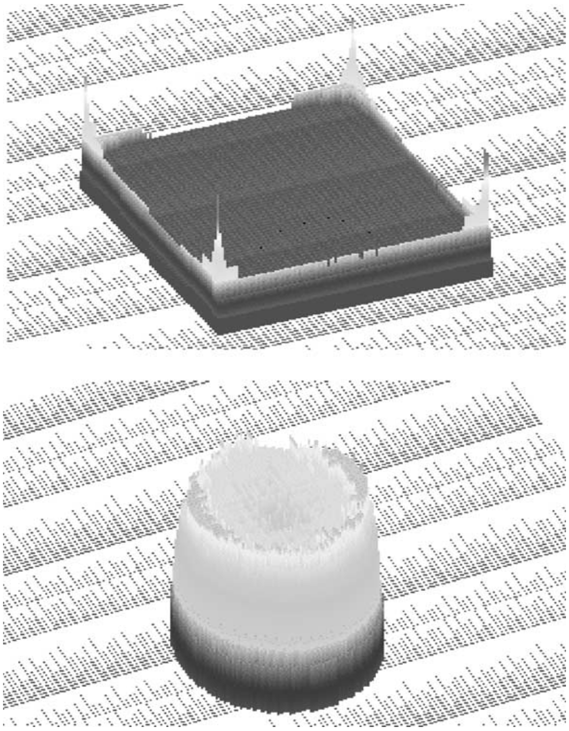

Fig. 4. $X-Y$ plots of the input raster pattern at 2.5 V pk–pk. The top is the original pattern; the right portion is with the VETO/FLAG.

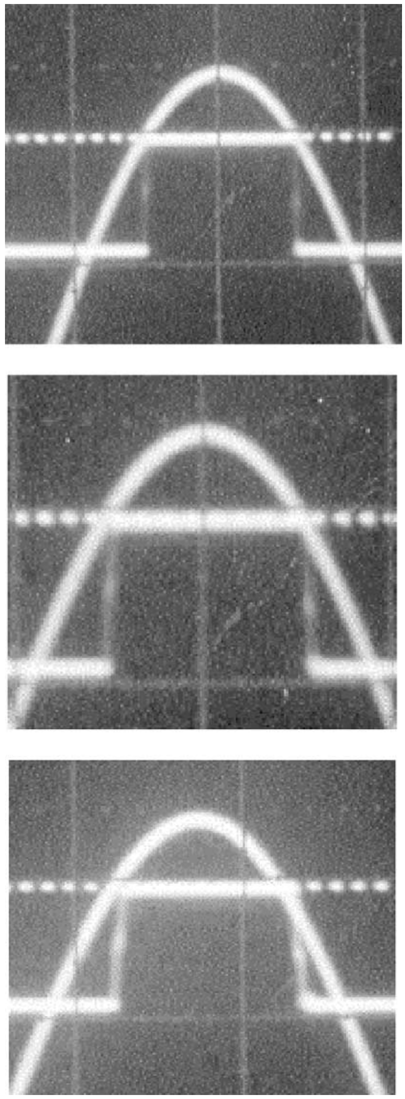

Fig. 5. Delay of TTL pulse. Top, signal frequency is 20 kHz, time-scale is 10 μs/div. Middle, signal frequency is 40 kHz, time-scale is 5 μs/div. Bottom, signal frequency is 80 kHz, time-scale is 2.6 μs/div.

resistance of the diode. The circuit charges up to the peak of the input waveform and holds that voltage value with a slow decay. Another OP AMP subtracts the same offset voltage added to the original signal. A potentiometer is used in the feedback loop of the threshold adjust OP AMP to change the gain from zero to one. This sets the percent of peak voltage threshold from zero up to the input voltage which is sent to the multiplier and then to the comparator. The TTL output from the comparator is sent to a buffer OP AMP to supply the TTL signal to the front panel and to an NIM conversion circuit.

The VETO/FLAG circuit was adjusted to produce a VETO/FLAG pulse at 90% of the peak signal. The X and Y sine inputs were obtained from two Wavetek[5] model 29 function generators. The X-signal frequency was 24.2 kHz and the Y frequency was 24.0 kHz. pk–pk voltages of 0.4, 2.5, and 5 V were used without any adjustments to the VETO/FLAG threshold. A Phillips[6] 794 gate delay generator running at about 10 kHz provided a pseudo-random pulse to trigger the data acquisition system. The outputs of signal

[5] Wavetek, San Diego, CA 92123.

[6] Phillips Scientific, Mahwah, NJ 07430.

generators were split with a part going to the VETO/FLAG module and a part to a National Instruments[7] BNC2110 interface box. This interfaced the signals to a National Instruments NI6110E PCI 4 channel ADC board in a Macintosh G3 computer. KMAX[8] software was used to collect the data. Two-dimensional $X-Y$ plots were made of the original signal and of the signal with the TTL cut.

Fig. 3 shows a horizontal slice through the center of the original $X-Y$ input and a slice through the center of the $X-Y$ input with the TTL cut on the data for a 2.5 V pk–pk input waveform. The input data ranges from 340 to 864 channels while the cut data ranges from 390 to 812 or from 9.5% to 90.0%. Since the cut is a circular region, we can use the standard πr^2 formula to find that this includes 50.9% of the original data. With smaller cuts, one can greatly increase the data included, however, the data even then becomes less stable. Fig. 4 shows the original $X-Y$ plot and the $X-Y$ plot with the VETO/FLAG cut. With a 0.4 V pk–pk input, the measured cutoffs were 11.4% and 88.6% and at a 5 V pk–pk, the cutoffs were 9.4–90.0%.

The speed of the multiplier was found to play a roll in the output timing of the VETO/FLAG especially at a 5 V pk–pk input. Since the frequency is doubled by squaring the input signal, above 40 kHz, a time delay in the VETO/FLAG pulse is apparent (Fig. 5).

3. Future work

Another way to obtain a more uniform energy deposit in the target is to use a sawtooth scanning waveform, however, in practice, at the high beam rigidity (in the level of GeV/c) used at Jefferson Lab, it is difficult to design such a high voltage/high current switching system. We are working on an H-bridge-based power switch circuit, which will produce a triangular raster pattern with a very limited turning time and hope to report on this work in the future.

References

[1] P. Horowitz, W. Hill, The Art of Electronics, Cambridge University Press, New York, 1986.

[7] National Instruments, Austin, TX 78730.

[8] Sparrow Corporation, Mississippi State, MS 39762.