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A Pulse Height Resolution Meter*

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ABSTRACT

An analog circuit has been constructed which measures the rms width of a pulse height distribution and provides a continuously updated meter display.

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Most nuclear experiments involve the acquisition of pulse height distributions where the pulse height represents the magnitude of some measured quantity (energy, time, position...). Often these pulse height distributions contain isolated peaks whose width reflects the quality of the experiment and is desired to be as small as possible. Unfortunately, the task of adjusting system parameters to minimize the width of a peak can be very tedious

since it involves a search where one changes a parameter, accumulates a pulse height distribution, determines a peak width and tries again. This process can be greatly facilitated by having a continuous reading of the peak width. Then one can simply "tune" the system. We describe here a device which can isolate a region of a pulse height distribution and determine, in real time, the root-mean-square (rms) deviation of pulses about the mean. The result is displayed by a meter movement or other readout.

Instead of computing the mean pulse height and then the rms deviation of pulses about it, we have chosen to take the rms average of the difference between each pulse height and the height of the previous pulse. In this way, we minimize our sensitivity to changes in the mean. That this rms pulse difference is related to the rms deviation about the mean is easily shown. Let M be the result for N pulses of height X_i, then

$$M^2 = \frac{1}{N}\sum_{i=1}^{N-1} (X_{i+1}-X_i)^2 \simeq \frac{1}{N}[2\Sigma X_i^2 - 2\Sigma X_{i+1} X_i]$$

$$\simeq \frac{2}{N}[\Sigma X_i^2 - \Sigma(\bar{X}-(\bar{X}-X_{i+1}))(\bar{X}-(\bar{X}-X_i))]$$

$$\simeq\frac{2}{N}[N\overline{X^2}-N\bar{X}^2+\bar{X}\ \Sigma(\bar{X}-X_{i+1})+\bar{X}\Sigma(\bar{X}-X_i)-\Sigma(\bar{X}-X_{i+1})(\bar{X}-X_i)]$$

If N is sufficiently large and X_i and X_{i+1} are uncorrelated the sums above are zero leaving

$$M^2 = 2\overline{X^2} - 2\bar{X}^2 \equiv 2\sigma^2$$

where σ is the rms deviation about the mean. In practice N will not be arbitrarily large because N is the number of pulses in the averaging period and this averaging period determines the response time of the instrument. At high data rates N can be quite large thus giving an error free result, but at low rates one must compromise between short response time and high precision

A simplified diagram of the device is shown in fig. 1. The basic functions can be divided into two parts: (1) selection of pulses whose height falls between two voltage levels defined by a level and a window setting; (2) determination and display of the width and centroid of the selected region of the pulse height distribution. The biased amplifier at the input of the circuit substracts a voltage defined by the level setting from the stretched input pulse and amplifies the difference ten times. This signal goes to two sample and hold (S/H) amplifiers that are controlled by the selection logic. This logic will cause the signal to be sampled if the top of the biased pulse falls within an adjustable window, fig. 2. A delay of about 500 ns is introduced from the start of the input pulse to the sampling time to allow for the rise time of the biased amplifier. For a selected pulse, the output voltage of S/H amplifier 2, after sampling, will be linearly related to the level of the input pulse;

and S/H amplifier 1 will latch a voltage equal to the difference of the level of this pulse and the output of the delay line, which represents the level of the previous pulse held in S/H amplifier 2. The output of S/H amplifier 1, representing the variations $(X_{i+1}-X_i)$ of the input pulses, is amplified and submitted to the rms to DC converter (Analog Devices 440K)[1) whose output then represents the width of the pulse height distribution. The variable gain of this amplifier is compared to the window setting and a warning light is turned on if the gain is set too low relative to the window setting. The averaging capacitor for the rms to DC converter is switch selectable to allow a choice of averaging periods from a fraction of a second to several seconds.

For monitoring purposes, the output of S/H amplifier 2, representing the deviation of each pulse height with respect to the level setting, is amplified and observed with the averaging meter M2 (zero center) and a live display. The gain of the amplifier is coupled to the window setting so that the plus and minus full scale (FS) readings of M2 correspond to the upper and lower limits of the window. The display consists of five lights each associated with a range of voltage of the output of the amplifier. Each time a valid input pulse is detected the appropriate light is intensified briefly thus displaying an image of pulse rate and pulse height relative to the lower and upper window levels.

The circuit shown is designed to accept positive, rectangular pulses whose width is greater than 3 μsec.; other types of signals must first be processed by a stretcher. The unit will process pulse heights ranging from 100 mV to 10V and produce full-scale width readings for distributions whose FWHM lies between 10 mV and 500 mV. An additional biased amplifier or attenuator may also be used to extend the dynamic range of the instrument.

As previously mentioned one must choose between accuracy and response time for low count rates. The rms width meter fluctuations are shown in fig. 3 as a function of count rate for two different averaging periods of the rms to DC converter. The relative meter accuracy is inversely proportional to the square-root of the number of events in the averaging period and the response time is proportional to the averaging period. With a slow response time one can achieve 10% accuracy at 30 Hz. (fig. 3 curve b) but with a ten times shorter response time one needs 300 Hz. to get the same accuracy. The accuracy is determined by the information content of the events within the averaging period and the algorithm used to extract it; the response time is determined by the averaging period and the characteristics of the rms-to-DC converter. It was found that the falling response time of the rms-to-DC converter used was about 9 times longer than the rising response time with the averaging time somewhere between the two. To determine the statistical accuracy of the algorithm used, a computer study was done using normal distributed random numbers and applying equal weighting to all events in the averaging period. The results were consistent with the actual performance of the unit. It was found that if we had evaluated the width by the more standard technique of $\sigma^2 = \overline{X^2} - \bar{X}^2$ we would obtain the same accuracy with only 30% fewer events, and the same would be true if σ had been evaluated directly by

$$\sigma^2 = [\sum_{i=1}^{N} (X_i - \bar{X})^2]/(N-1).$$

This last expression would be quite simple to construct but the quantity $\bar{X}$ would correspond to the average of X in an earlier time period. Thus one would expect that the result would be sensitive to changes in the value of $\bar{X}$ on the time scale of the averaging period.

REFERENCES

1. Analog Devices, Route 1 Industrial Park; P.O. Box 280; Norwood, Mass. 02062

FIGURE CAPTIONS

Fig. 1.--Simplified diagram of the pulse height distribution width meter.

Fig. 2.--Schematic of input wave forms and selection criteria.

Fig. 3.--The rms meter fluctuations relative to the mean is plotted versus mean count rate for two different averaging capacitors which produced the following rising and falling response times: a) $T_r \approx 1$ sec, $T_f \approx 9$ sec; b) $T_r \approx 0.1$ sec, $T_f \approx 1.0$ sec.

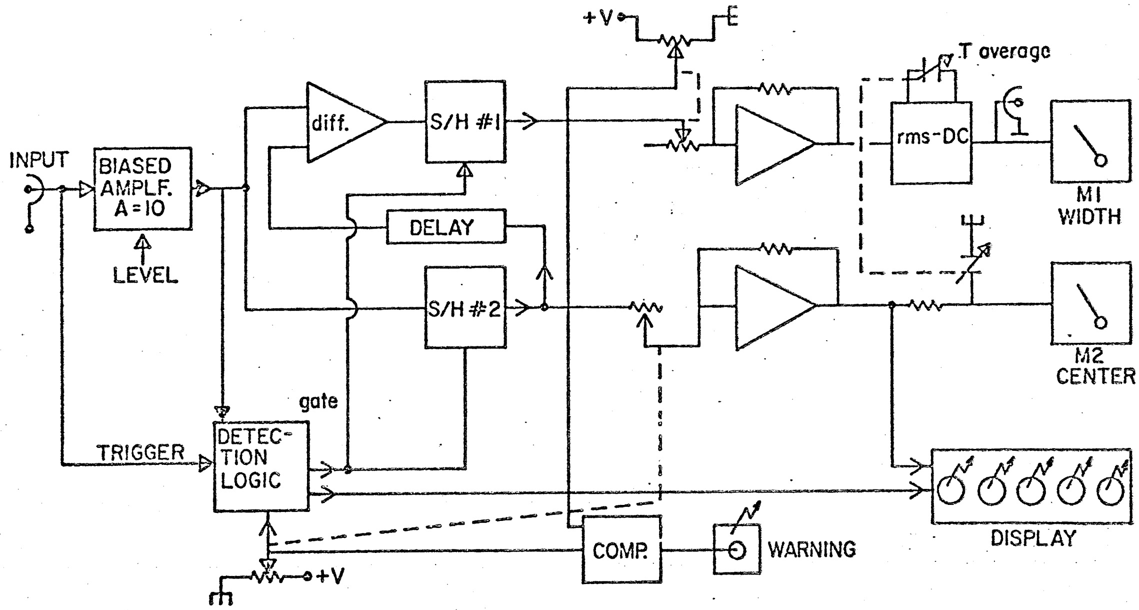
+V
T average
INPUT
BIASED
AMPLF.
A=10
LEVEL
diff.
S/H #1
DELAY
S/H #2
rms-DC
M1
WIDTH
M2
CENTER
gate
TRIGGER
DETEC-
TION
LOGIC
DISPLAY
COMP.
WARNING
+V

Fig. 1

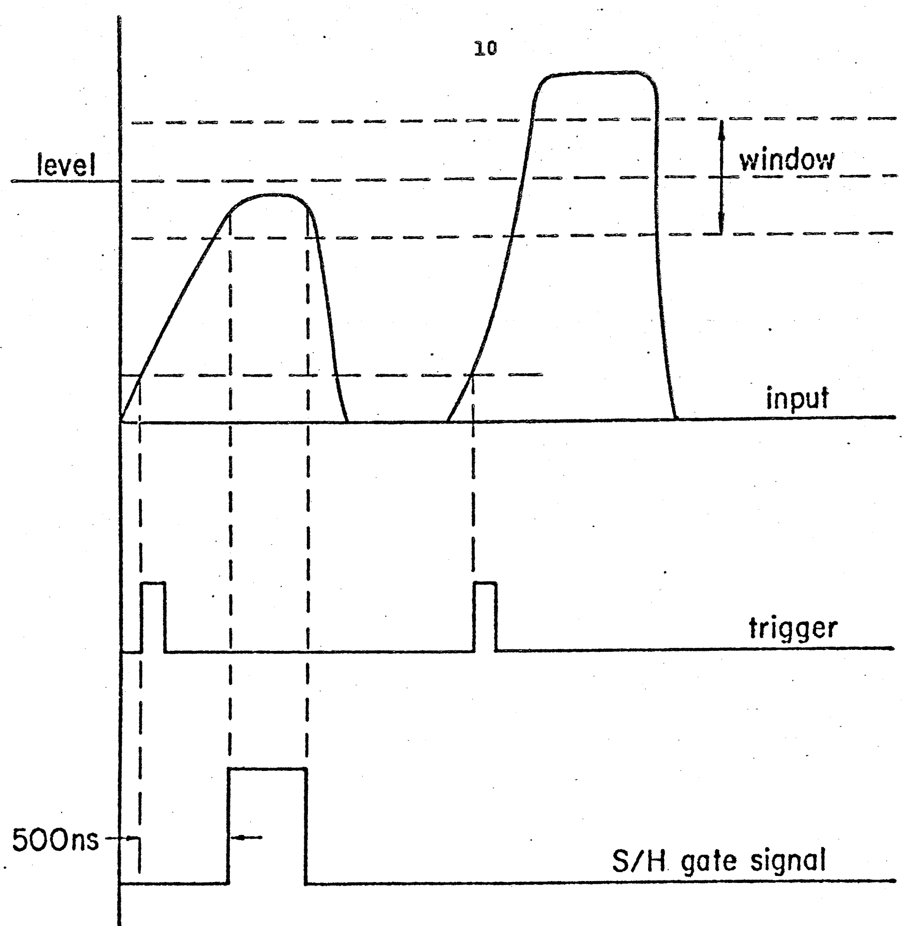
level
window
input
trigger
500ns
S/H gate signal

Fig. 2

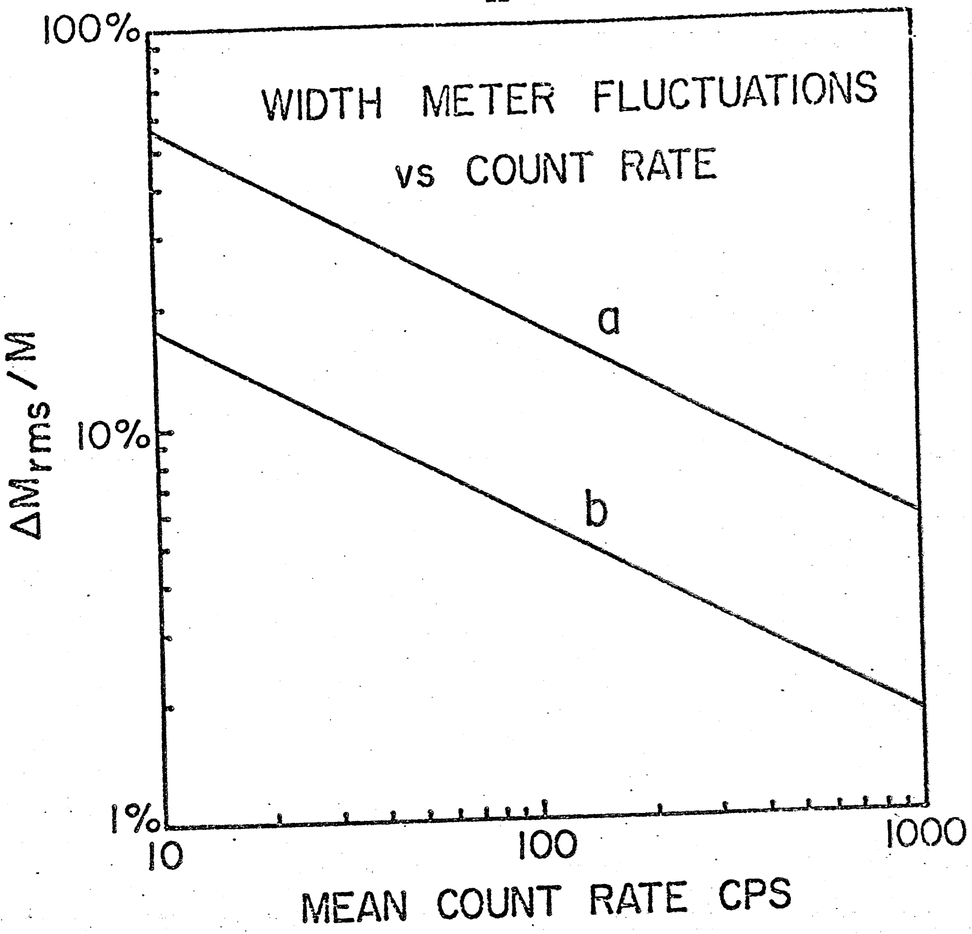
WIDTH METER FLUCTUATIONS
vs COUNT RATE
a
b
100%
10%
1%
$\Delta M_{rms}/M$
10
100
1000
MEAN COUNT RATE CPS

Fig. 3