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PERFORMANCE OF A TIME-VARIANT FILTER IN THE PRESENCE OF DOMINANT  $1/f$  NOISE

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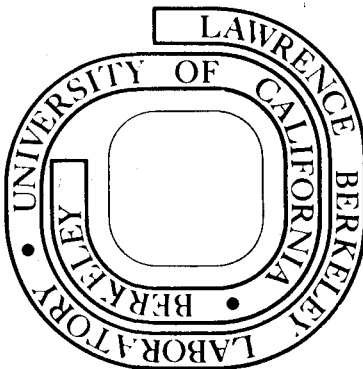
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PERFORMANCE OF A TIME-VARIANT FILTER IN THE  
PRESENCE OF DOMINANT  $1/f$  NOISE\*

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The performance of a gated integrator filter has been compared to that of a typical pseudo-gaussian filter for the case of a high resolution Si(Li) detector-opto feedback FET system. It has been found that the theoretically predicted better filtering of the former for series and  $1/f$  noise is borne out in practice and that the effect can be as significant as a 15 eV reduction out of 90 eV (FWHM) at long time constants.

Introduction

In a previous publication<sup>1)</sup> it was shown that filters with a pseudo-gaussian step response did not provide a very good approximation to an optimum filter for the case of dominant  $1/f$  noise in high resolution pulse-light feedback X-ray spectrometers. It was also shown that, under these conditions, use of a matched filter cusp tailored to the specific noise spectrum of a detector-FET combination could result in a 10% electronic noise reduction at long peaking times, when compared with a 7th order pseudo-gaussian filter. Furthermore, a theoretical analysis showed that a gated integrator filter design reported by Kandiah, Smith and White<sup>2)</sup> could provide even better filtering for  $1/f$  and series noise than the optimum cusp. In this letter we report the experimental

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confirmation of the latter theoretical result by direct quantitative comparison between a 7th order pseudo-gaussian filter and the gated integrator of Kandiah, et al, with two different detector-FET combinations.

### Experimental Methods

The noise spectrum of a detector-FET combination working at its optimum point was measured in frequency domain by the techniques reported in Ref. 3. By this method, absolute values of the noise parameters  $I_L'$  (parallel component),  $r_s C_{in}^2$  (series component) and  $A_{1/f}$  (1/f component) are obtained. From these three parameters it is then possible to compute the noise line width (NLW) of a system by the use of a simple formula<sup>3)</sup> involving the noise factors of the filter under study:

$$NLW(FWHM) = \frac{2.35 \epsilon}{q} \{q I_L' \langle N_S^2 \rangle + 2 kT r_s C_{in}^2 \langle N_{\Delta}^2 \rangle + A_{1/f} \langle N_{1/f}^2 \rangle\}^{1/2} \quad (1)$$

The NLW of the time-invariant 7th order gaussian filter (LBL 848) connected to the same detector-FET combination as above was next measured by means of an RMS voltmeter and by a pulse-height analyzer (PHA). The results of the calculations of Eq. (1) were checked with the RMS and PHA results for consistency. The noise factors  $\langle N_S^2 \rangle$ ,  $\langle N_{\Delta}^2 \rangle$  and  $\langle N_{1/f}^2 \rangle$  given in Ref. 3 for the LBL 848 filter were used in the calculation.

Next, the time-variant filter of the Kandiah design was connected to the detector-FET combination operating under identical electrical and thermal conditions as before and the NLW was measured as a function of gated integration time  $\tau_0$  with a PHA (no linear output exists which can be connected to an RMS

voltmeter). The results were then compared to the ones calculated by Eq. (1) using the noise factors of Ref. 1 for the time-variant filter.

### Results

Figure 1 shows the frequency domain data and mathematical fit (solid line) for a Si(Li) detector-FET combination of good quality. The fitted noise parameters are indicated in the figure in their dominant regions.

Figure 2 shows the NLW vs  $\tau_0$  (peaking time or gated integration time, depending on the system) for the same detector-FET in the two filter configurations. The consistency of measured and calculated results in both cases is apparent, indicating the validity, within better than 10%, of the theoretical values for  $\langle N_{\Delta}^2 \rangle$  and  $\langle N_{1/f}^2 \rangle$  for the time-variant filter obtained in Ref. 1. It is possible to break down the noise into the three components of Eq. (1) and this has also been done in Fig. 2 for both filter systems. For the purpose of comparing overall filter performance, it must be pointed out that the total time used by a 7th order pseudo-gaussian filter in completing one measurement is approximately (2.35 x peaking time). Since the gated integrator takes approximately the same total measurement time (2.5 x gated integration time), a comparison of the results of Fig. 2 in terms of a single  $\tau_0$  for both systems is quite valid.

A second set of measurements was also carried out with another system. In this case the detector was larger and the three noise components were substantially higher than in the previous case. The results of the measurements and calculations are shown in Fig. 3. The consistency of the results is again quite evident.

### Conclusion

The results presented here show that there exists a confirmed valid method

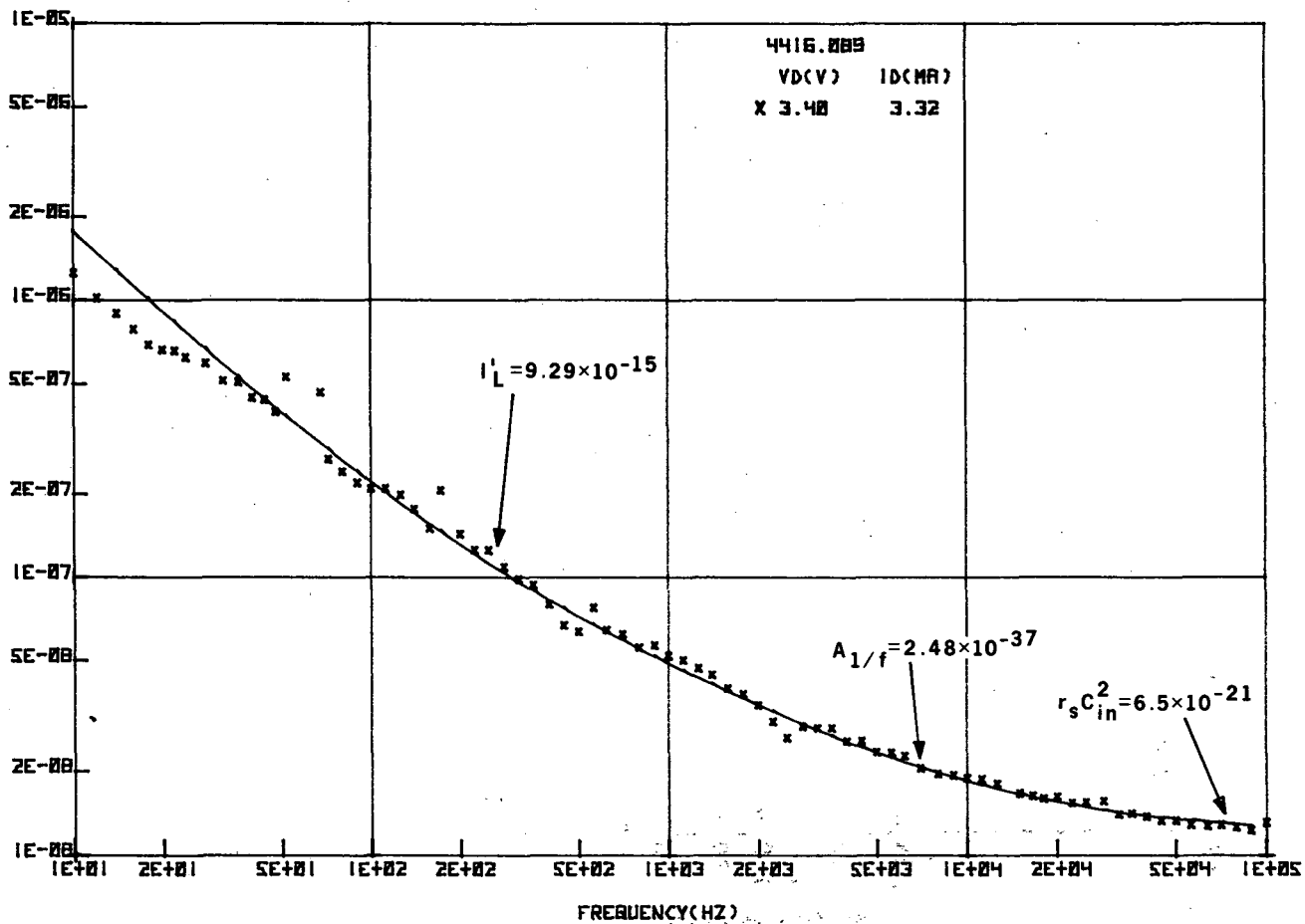
for the theoretical analysis of  $1/f$  performance of time-variant filters, in addition to the better known methodology for parallel and series noise components, and that there is at least one gated integrator circuit that performs much better on series and  $1/f$  noise than a conventional pseudo-gaussian filter. It is felt that the analysis method of Ref. 1 should, therefore, open the way to a more thorough investigation of the field of time-variant filters for low energy, high resolution systems, where optimum filtering in the presence of dominant  $1/f$  noise is of great importance.

The authors are indebted to Link Systems, Ltd. for the loan of the Kandiah-type pulse processor which made the above measurements possible, and to F. S. Goulding and D. A. Landis for their advice and cooperation.

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VNOUT(RMS)

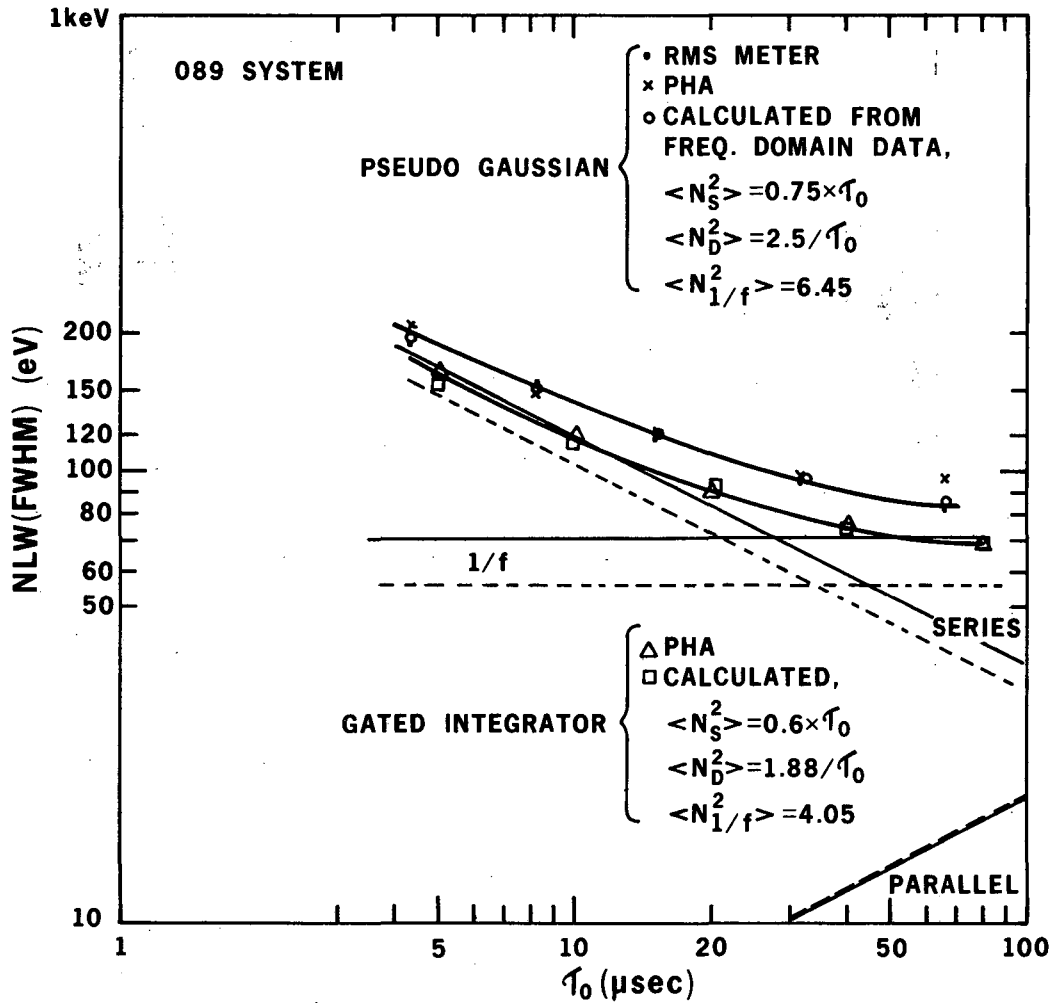


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Fig. 1. Frequency domain voltage noise spectrum and mathematical fit (solid line) at the output of preamplifier loop for 089 detector-PET system. Fitted noise parameters are indicated.

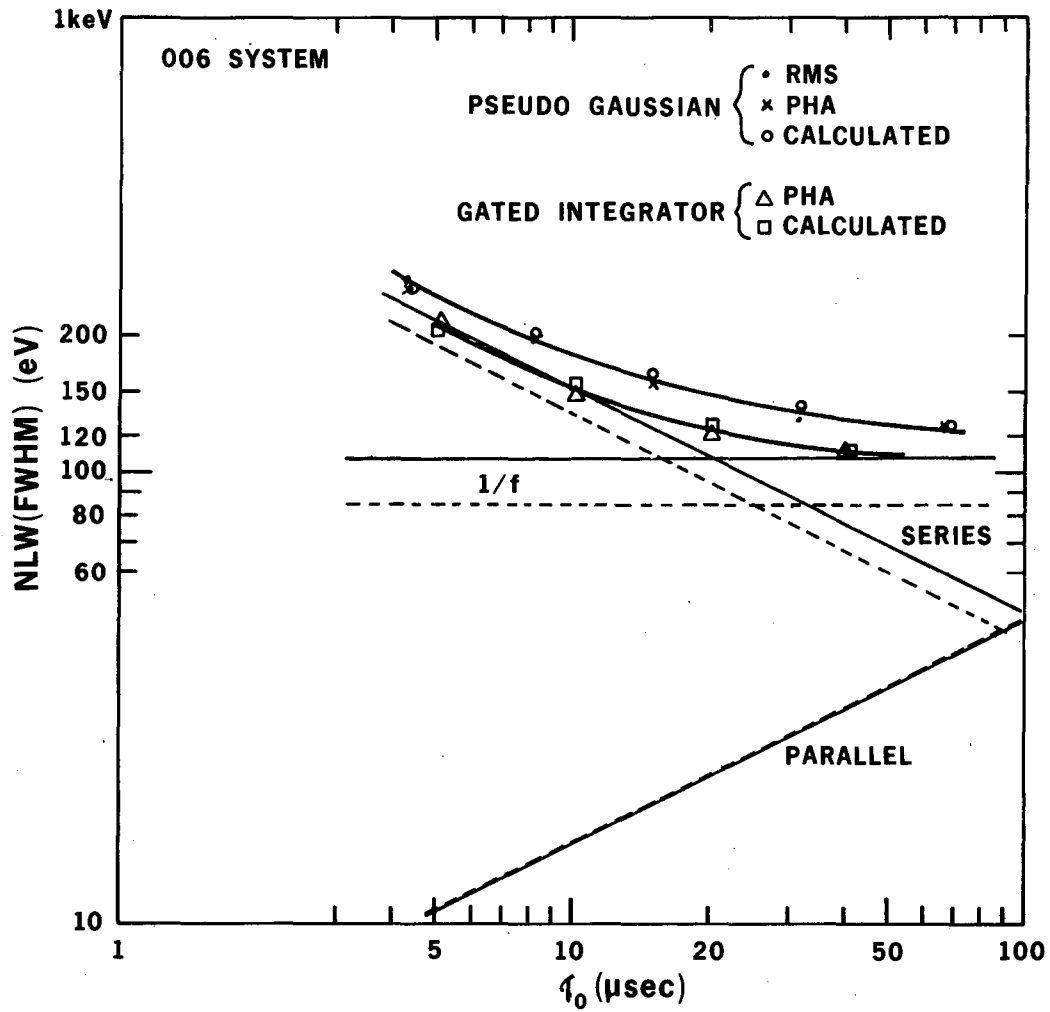
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Fig. 2. Noise line width (NLW) vs peaking or integration time for 089 system using a 7<sup>th</sup> order pseudo gaussian filter and a gated integrator. The contributions to total noise are shown for both cases (solid line for pseudo gaussian filter).



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Fig. 3. Same as Fig. 2, for a noisier system (larger detector).

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