Starnote # 173

A new Preamp/Shaper for use in TPC and Drift Chamber applications

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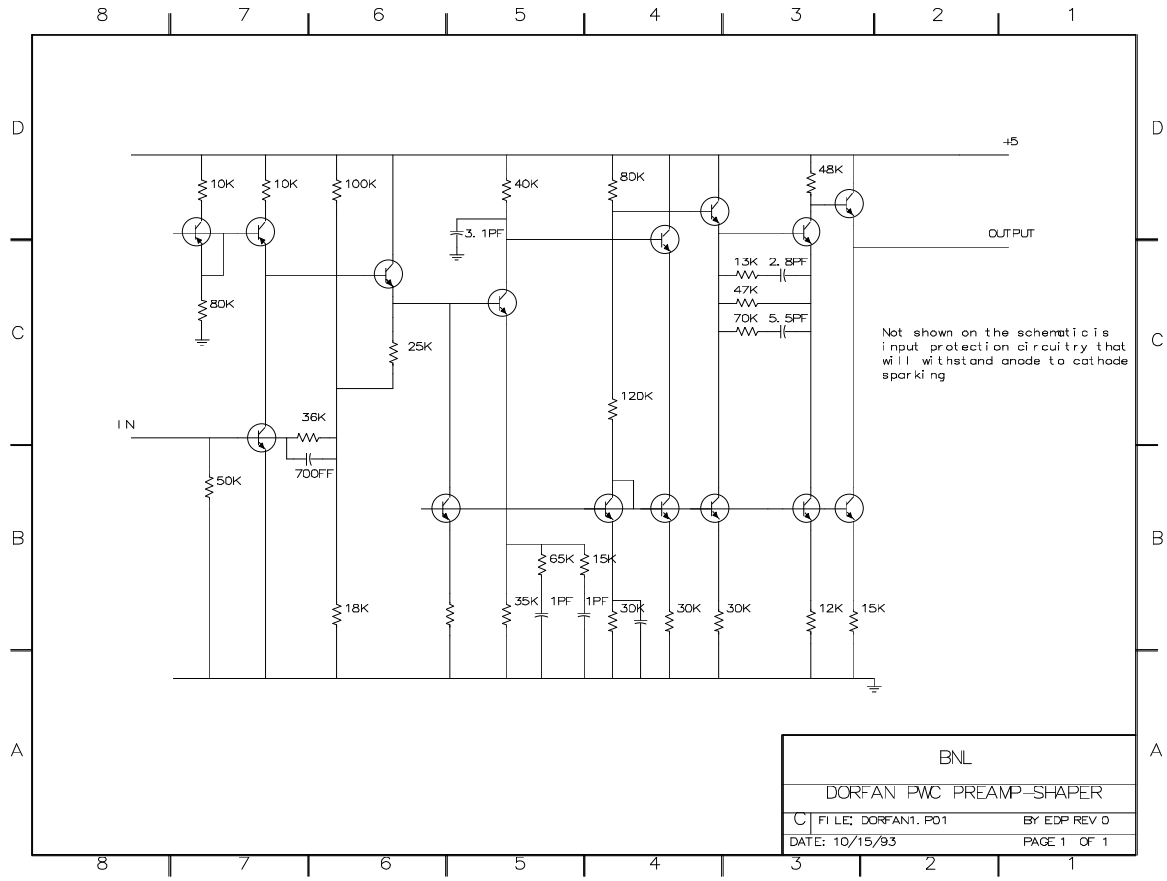
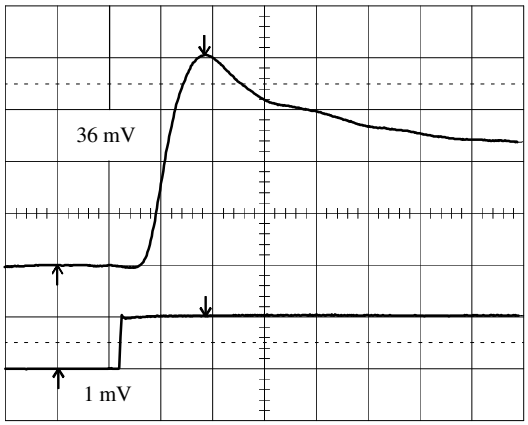
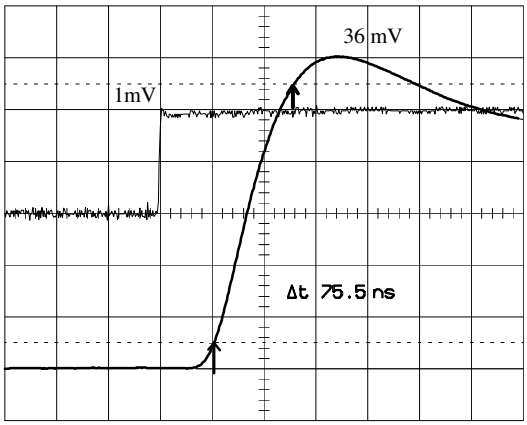
A new preamp/shaper was designed by Dave Dorfan at UC Santa Cruz to meet the waveform conditions of the E810 TPC. This device has 32 channels and draws 2 mV/channel from a single 5 volt supply as can be seen from this schematic.



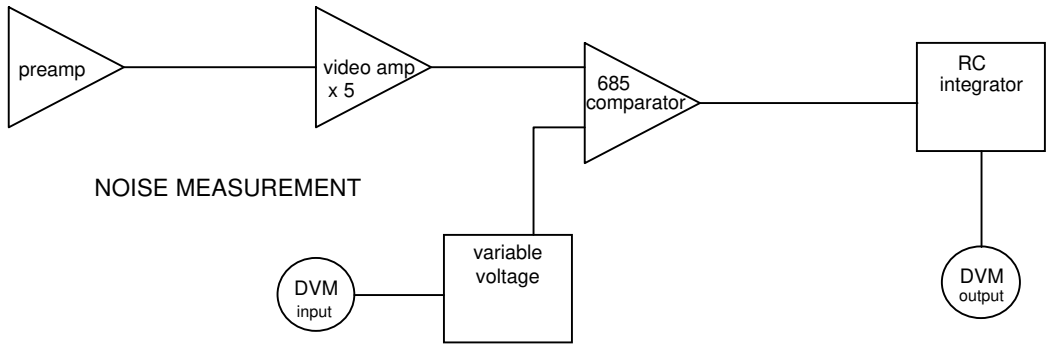
We have performed a short series of tests on the Santa Cruz preamp/shaper as a part of a feasibility study for STAR. Our principle goal was to determine the noise levels of these devices, our tests also measured the gain and risetime of each device. The rated gain is 200,000 with a noise of less than 5 nA, expressed as sigma of the noise gaussian. The following two figures show the Santa Cruz preamp output from a 1 mV square pulse, the pulse on the left shows the gain, while the figure on the right shows the rise time. We measured a 75 nS rise time, David Dorfan says that he can set the rise time to any value we specify down to a few nanoseconds. The output wave form shows an overshoot since the shaping electronics expect a 1/t dependence on the input pulse. To test the gain, a square pulse of known amplitude was applied through a resistor in series with the input to get a current pulse. The square pulse was of 1 mV amplitude, 500 nS duration, and repetition rate of 1.25E+5 /sec, and was terminated into 50Ω at the preamp input, and then to a 0.1μF capacitor in series with a 5kΩ resistor. The output of the preamp went to an emitter follower and then to an oscilloscope that was terminated in 1MΩ. A 1 mV input pulse across 5.5 kΩ gives 181 nA input current, the output was measured to be 36 mV on the oscilloscope. If we divide the output by input current we get a gain of 198,000 which is consistent with the expected gain of 200,000.





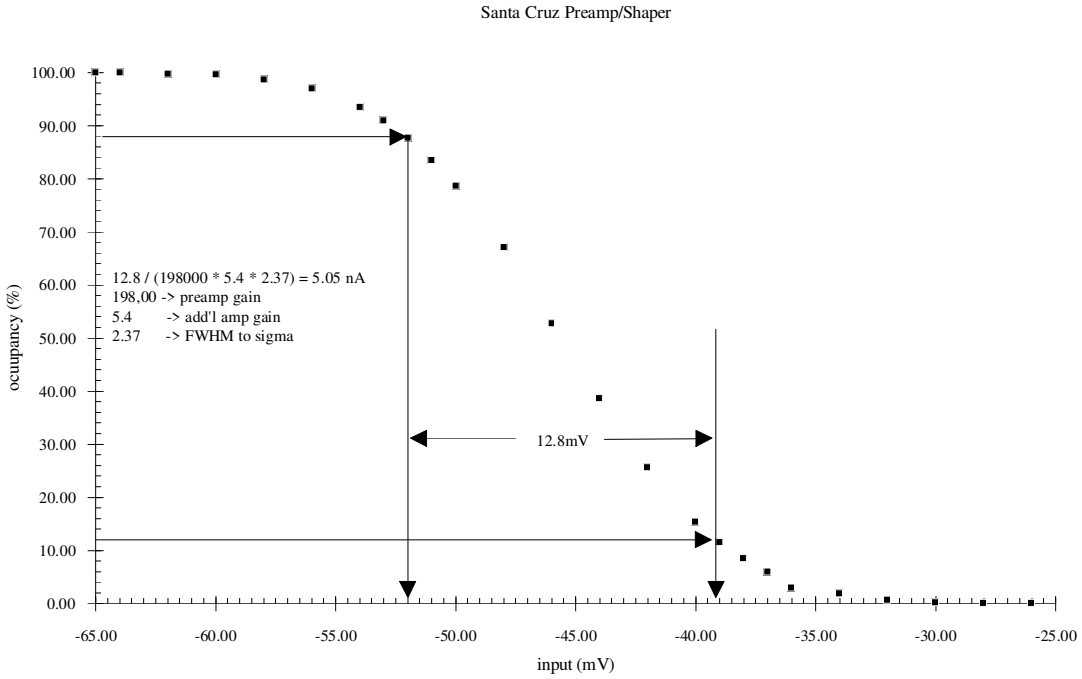
A rough determination of the noise level of the preamp was done using the oscilloscope and the merging gaussian technique. The output of the preamp was sent to two oscilloscope inputs each with the same termination and gain. The oscilloscope is set to auto trigger, the resultant traces are brought together until the distinction between them just disappears. Assuming that the noise is gaussian and that we have chosen an area of the trace that is "white", the separation between the centers of the two traces (also the peaks of the corresponding gaussians) is 2σ. This separation is measured by switching the two channels to ground and reading off the distance between the traces. In our case we saw a separation of 2 mV, dividing by two and by the gain of the preamp gives a noise current at the input of 5.05 nA.

We were interested in a more quantitative test and decided to duplicate a technique of J. Rahn *et al*. from Santa Cruz (SCIPP 93/02 FEB 93). In this paper they describe their testing procedure for the TEKZ amplifier/comparator used in the ZEUS LPS system. In our adaptation we sent the output of the preamp to one side of a comparator, the other side of the comparator was connected to a variable voltage source. The output of the comparator then went to an RC integrator with a τ of about 10 mS. The principal component is a Plessey SP 9687 dual comparator of which one was used, this comparator is compatible with ECL logic levels. A variable DC voltage is applied to one side of the comparator, the preamp output to the other. When the input voltage is low enough the comparator output stays high, above a certain level it stays low. We are interested in the intervening region , the voltage source is ramped across this region. As the input voltage is raised from a point where the comparator is always high some of the output pulses from the preamp go below the input and the comparator will fire low. The comparator fires more frequently low as the input voltage is increased until finally none of the preamp pulses is larger than the input voltage. The 5x amplifying stage was necessary to expand the range of the transition area to accommodate the precision of the digital voltmeter, this is divided out of the final result and so is not a problem.

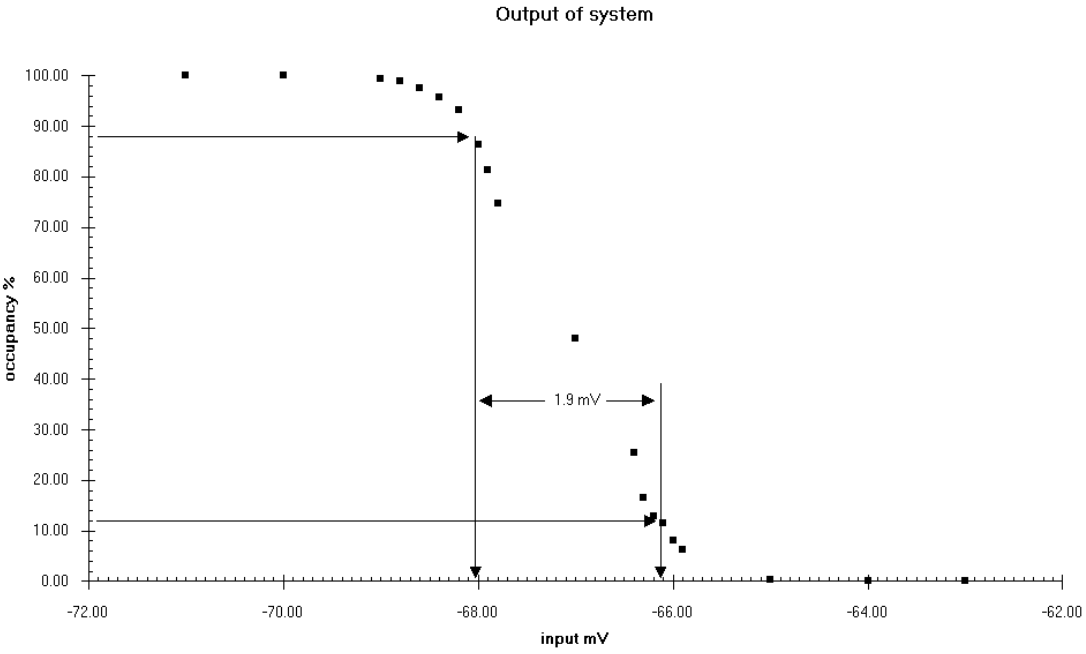


The data taken are the DVM readings of the integrator for a range of input values, these points are normalized to the ECL logic levels such that an ECL high gives 100%. Expressing this value as a percent addresses the issue of noise pulses meeting a particular threshold requirement. This occupancy is graphed as a function of the input voltage, since the noise is gaussian this graph is the integral of a gaussian. This means that the 12% and 88% points represent the FWHM of the original gaussian, this is expressed in

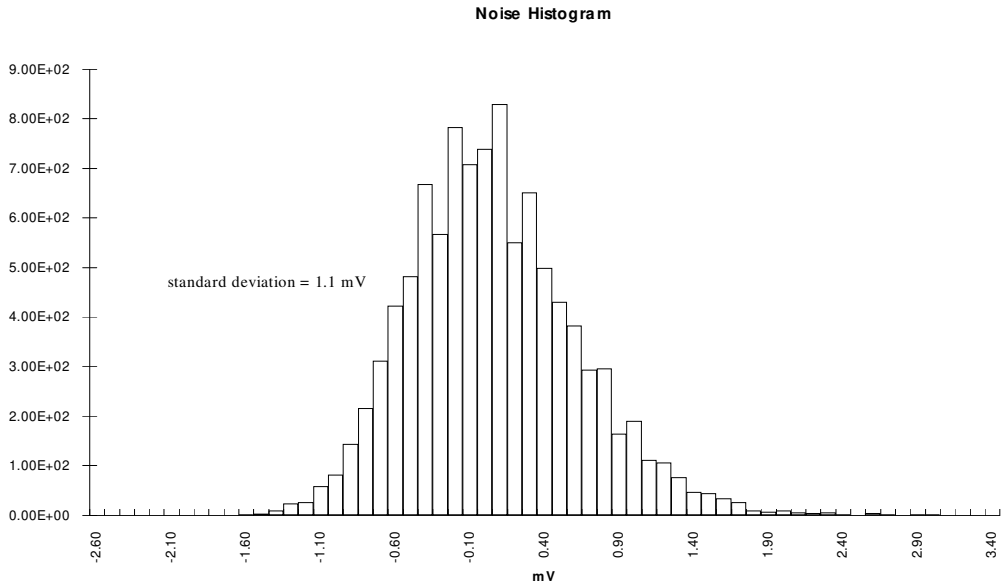
millivolts as taken from the x axis. To convert back to noise at the input (nano amps) this value is divided by the gain of the preamp, the gain of the extra amp stage from the above figure and by 2.37 to convert FWHM to sigma.



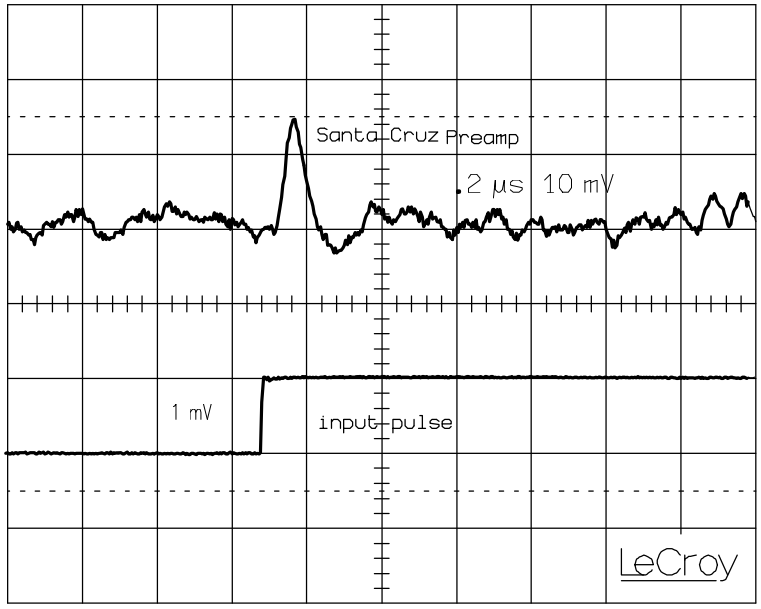
In the above picture the FWHM is 12.8 mV, dividing this by the preamp gain, 198,000, the video amp gain, 5.4, and then 2.37 we get a noise value of 5.05 nA. The plot below shows that the system itself had a negligible contribution to the noise measurement.



Throughout these tests we have assumed the noise to be gaussian, of course one wonders if this is indeed true. To test this assumption the output of the Santa Cruz preamp, with no input, was histogrammed on a Lecroy 7200 digital oscilloscope. The waveform was saved read into EXCEL® as an ASCII file and plotted as shown in the next figure. No fit was done since the plots was deemed to be sufficiently gaussian in appearance.



An additional test was performed, the 5 kΩ resistor and 0.01 µF capacitor were replaced with a 3.3 pF capacitor in series with the input. This means that a charge is injected into the preamp instead of a current pulse. A 1 mV input pulse into a 3.3 pF capacitor gives a charge of 3.3 fC the output pulse height was 15 mV with a risetime of 50 nS, with an area of 891.1 pVs(pico Volt seconds). The standard deviation of the noise for the output trace was determined in two ways, the 7200 can measure it directly, or the waveform can be read into EXCEL® , as an ASCII file, which can also calculate the standard deviation. The value obtained were the same for both techniques, the Santa Cruz preamp had a standard deviation of 1.2 mV, if one divides this number by the gain the previously stated noise levels are returned (plus an additional amount from EMI produced by the digital oscilloscope). But one has to remember that the pulse height is the significant aspect of the output. The following figure is a screen dump of the 7200 showing the preamp output and the input pulse which is 1 mV.



The results of this testing can best be judged by comparing them to the performance of a standard wire chamber preamplifier, the LeCroy TRA402. This preamp is used extensively, for example, at the MPS facility here at Brookhaven. A TRA402 was tested in a similar manner to the Santa Cruz preamp as a

control to insure that our testing was not biased. The results, along with the Santa Cruz preamp, are summarized in Table 1 below.

	Gain	Risetime	Noise	Power	Density	Cost	Shaping time constant for TPC
Santa Cruz	200,000	75nS	4.72nA	2mW/ch	32ch/die	$1.50/ch	yes
TRA402	25,000	3nS	65nA	65mW/ch	4ch/DIP	$4.00/ch	no

One can easily conclude that the Santa Cruz preamp is an order of magnitude improvement over the TRA402.