Investigation of Logarithmic Amplifier Output Response

The following information was gathered in an attempt to better understand the input/output relationship of logarithmic amplifiers. Since logarithmic amplifiers provide a generally linear response over a wide dynamic range, they are used in BPMs throughout Fermilab to determine position and intensity. They are typically used to convert an input signal (voltage) of wide dynamic range to its decibel equivalent. Log amps have been used in the Recycler Ring for some time now and have recently been installed in the Mini Boone extension. The application of log-amps is rather straightforward in determining position and/or intensity (see figure 1 below). The main point of the information contained within this paper is to analyze how a log amp responds to a transient input as opposed to a steady state condition and answer some of the following questions.

1. If a log amp sees a bunched signal at the input, how does it respond during those times between bunches when a zero state is present?
2. How close are the manufacturers specifications to test results of response time and noise floor numbers?
3. How, if at all, have we affected the log amp's response time/characteristics via external biasing resistors and capacitors?
4. How long can the zero state of a transient response input be before affecting the output of the log amp?

These are obviously just a few questions that were asked and represent a general direction for this research. Observations were made recently with a log amp based RF board that showed a response to a bunched signal that was less than ideal. During moments between bunches, excessive noise became the controlling factor and the position was illegible. However, when there was a signal present, the noise was not an issue and the position was easily identifiable.

The following results were obtained using an RF board that utilizes two Analog Devices AD8307 log amps per input. Since these log amps use six 14.3dB 900MHz amplification stages, their response is slightly periodic with a variance of approximately _ dB. To correct for this, we split an input and reduce one leg by 7.15dB. We then add this reduced magnitude signal to the original for a much more linear response over the operating range. We also have added external potentiometers and capacitors to enable adjustments of the slope and intercepts of individual log amps. Close matching (slope and intercept) is required for particular op amps in a single channel in order to take advantage of their linear capabilities and to match the overall scale factor from board to board. Shown below is the general setup of the board used. We observed the outputs of each log amp and the combined sum after the AD830. The results, along with some explanation and a bit of thinking aloud, follow.

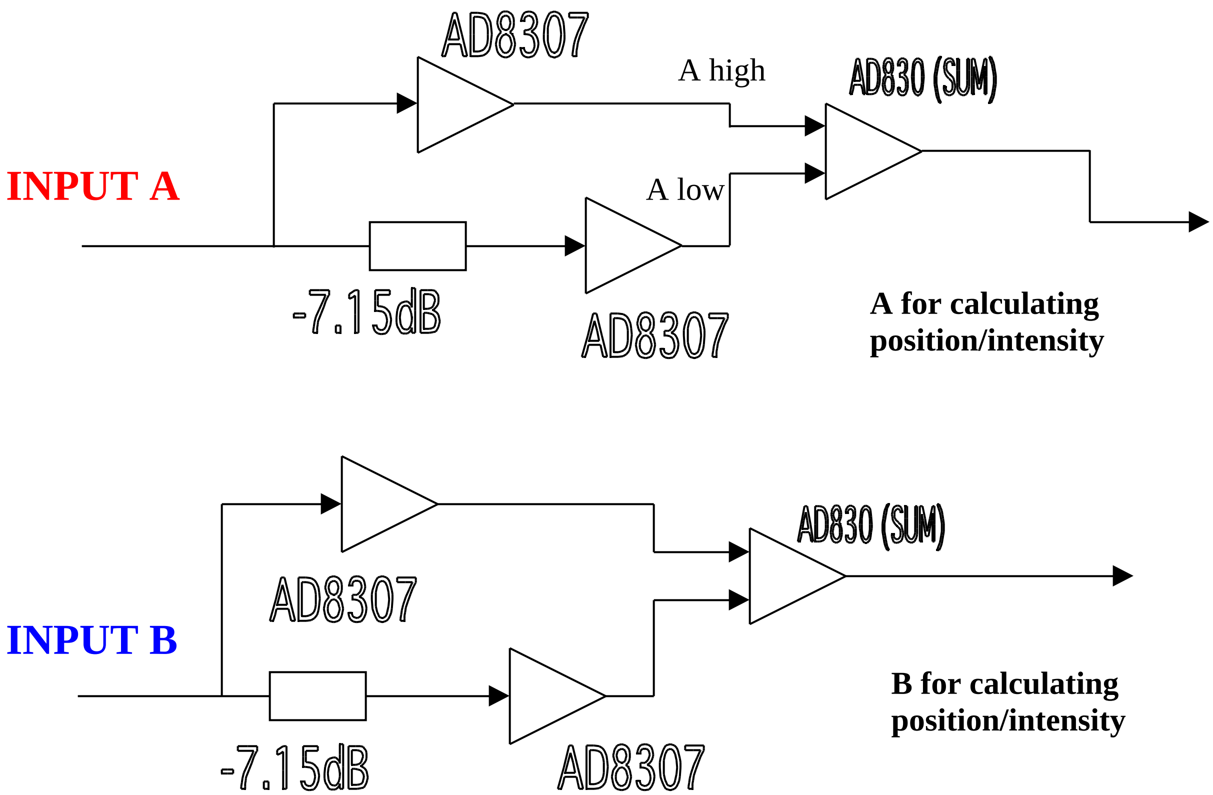
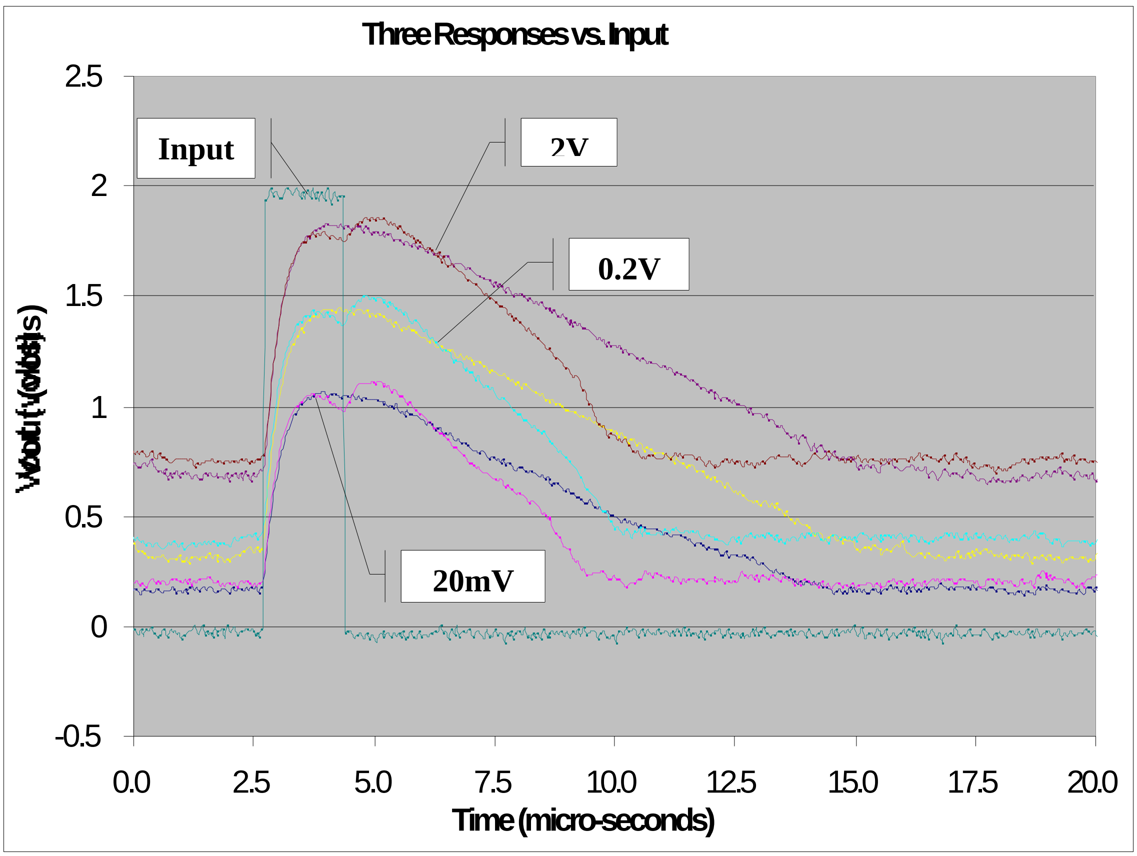


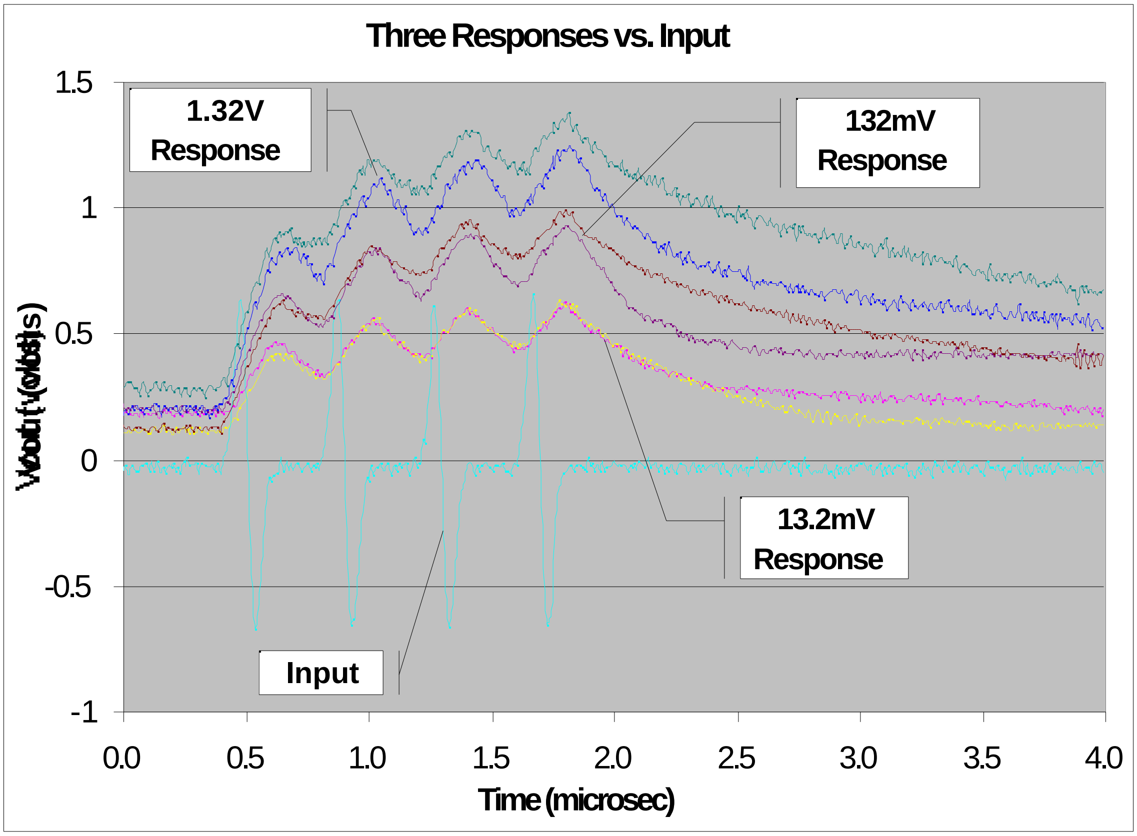
FIGURE 1.

The first input used was a single square wave that was 1.6 μs in length with a magnitude of 2 volts. Each log amp then processed this signal and the output was observed. We then lowered the input level by successive 20dB drops to see the effect at the output. The first setup can be seen below with A-high and A-low reacting to the square wave input. Immediately, we noticed that the outputs differed in their responses and that they returned to a zero input stage at different rates. We expected a slightly different response from A-high and A-low due to the attenuation that is taking place on the front end for A-low. Most intriguing and unexpected was A-low appearing to increase in intensity after the input signal returned to zero. Amplitudes of both A high and A low were within 10% of expected levels. The “bump” that characterized A-low’s response will be investigated a little later in this paper by observing the differential inputs at the log amp.

The graph below shows the response of the AD8307 logarithmic amplifiers with similar input conditions varying only the intensity of the input signal. As can be seen, the input is a step function that is 1.6µs in length. The pair of traces marked 2V represents the A high and A low outputs of a single channel to an input of 2 volts in intensity. The other two pairs of traces represent the A high and A low responses to inputs of corresponding intensities. In an attempt to keep the graph area reasonably clutter free, only the 2 volt input is shown.

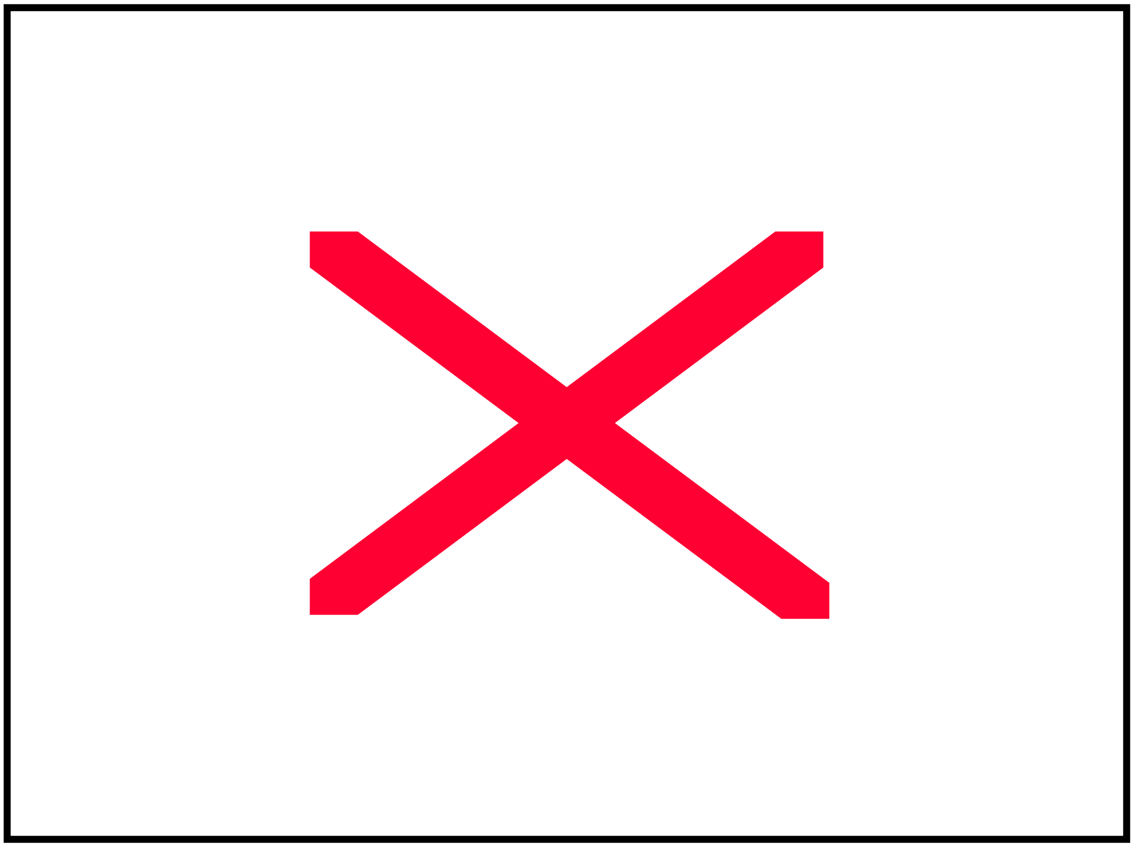


From the step input case, we can clearly see that the response of the AD8307 log amp is extremely close to the manufacturers specifications. They reach 90% of the final value in approximately 500ns. (Their quick reaction time is one of the reasons they were chosen in their current application). At this point, there haven't been many surprises and all seems to be operating as anticipated. The next step was to change the type of input signal to something more representative of actual beam conditions. We used a 4-bunch 2.5MHz spaced signal that is approximately 1.6µs in length. The intensity of this input signal was initially set at 1.32Vp-p and the log amp outputs were observed. We then reduced the intensity of the input by a factor of 10 (132mVp-p) and observed the outputs. This process was repeated one final time with the input at 13.2mVp-p. The log amp outputs were observed and plotted below along with only the largest intensity (1.32Vp-p) input signal.



You can see from the graph that the log amp's response is quick enough to begin decreasing when the input has a zero state between bunches. This is the area of concern with respect to using log amps in the Recycler Ring and other applications that present a transient input. We also noted that the overall gain of the log-amp was reduced when compared to a signal that had an intensity that stayed consistent for the entire 1.6µs (as in the previous example). This makes perfect sense since the log amp's output is reduced between bunches and must regain some of that lost amplitude. Of even more interest was the fact that the log-amps responded quite differently to signals that only slightly differed in composition. We'll spend a little more time investigating that phenomenon and discuss it a bit more in detail in the conclusion.

Now that we have seen the response of the AD8307 log amps to both a step function and a bunched signal, lets take a look at the differential inputs at the log-amps. Since we are AC coupling the inputs, the actual signal seen by the log amp might give some insight as to their response. The following graph illustrates the signal at the inputs of the log amp. Additionally, the absolute value of the difference of the inputs is also plotted along with the overall response of the log amp output. We can see, simply by observing the absolute value of the difference plot, why the overall response of the log amp seems to exhibit a slight gain post input signal. This seems to be an artifact of the differential inputs. The graph can be seen on the following page.

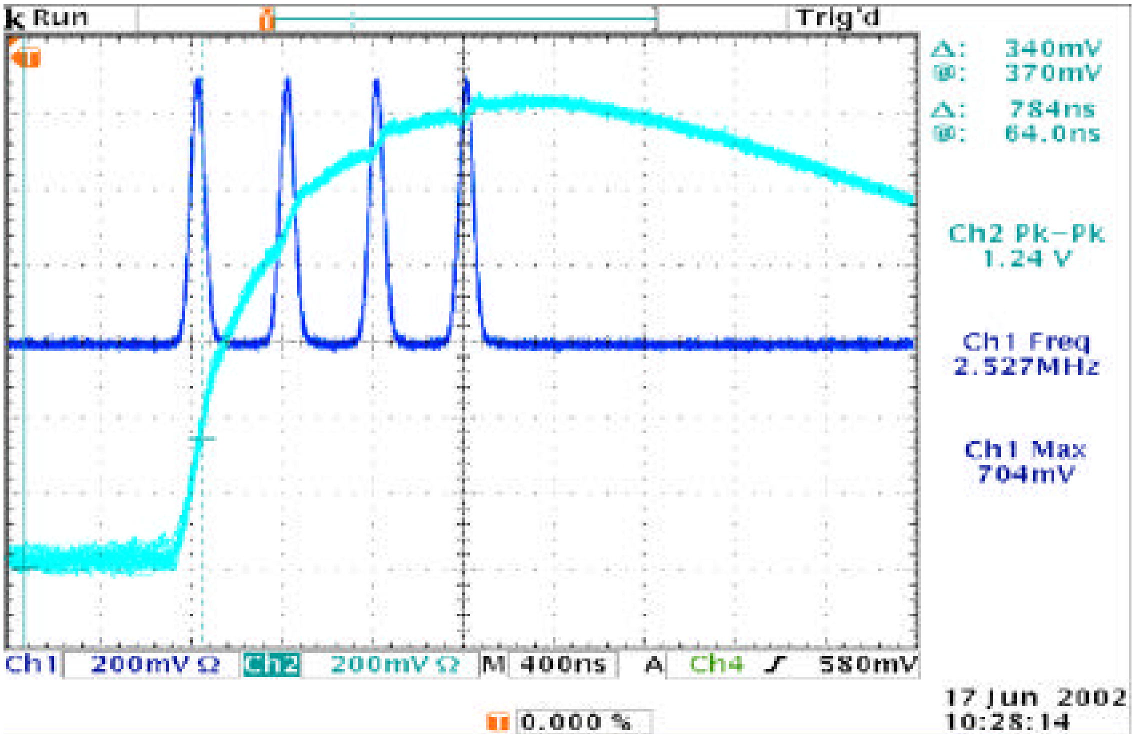


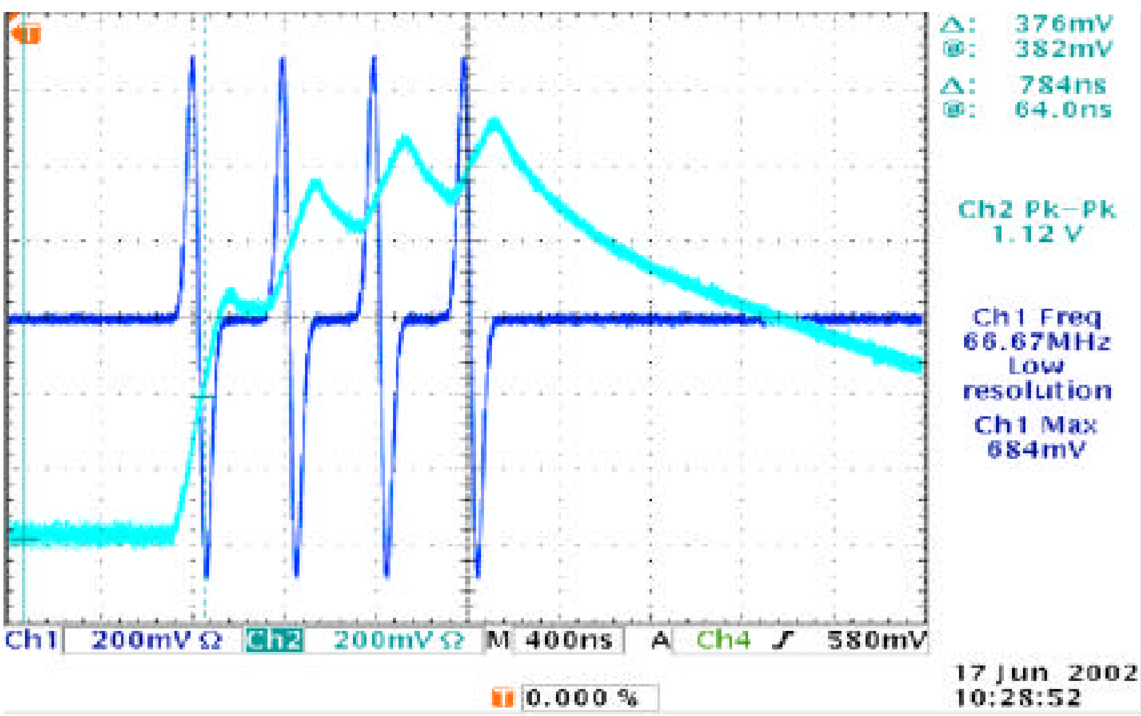
Differential inputs at log amp

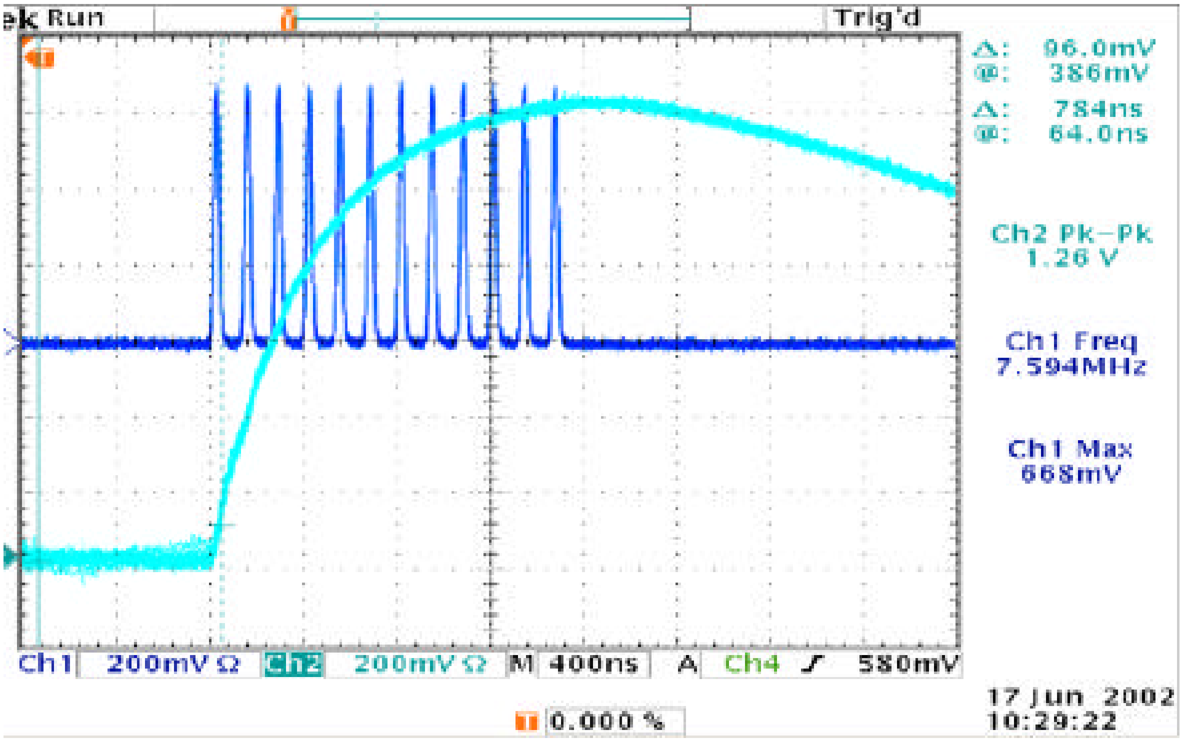
Conclusion:

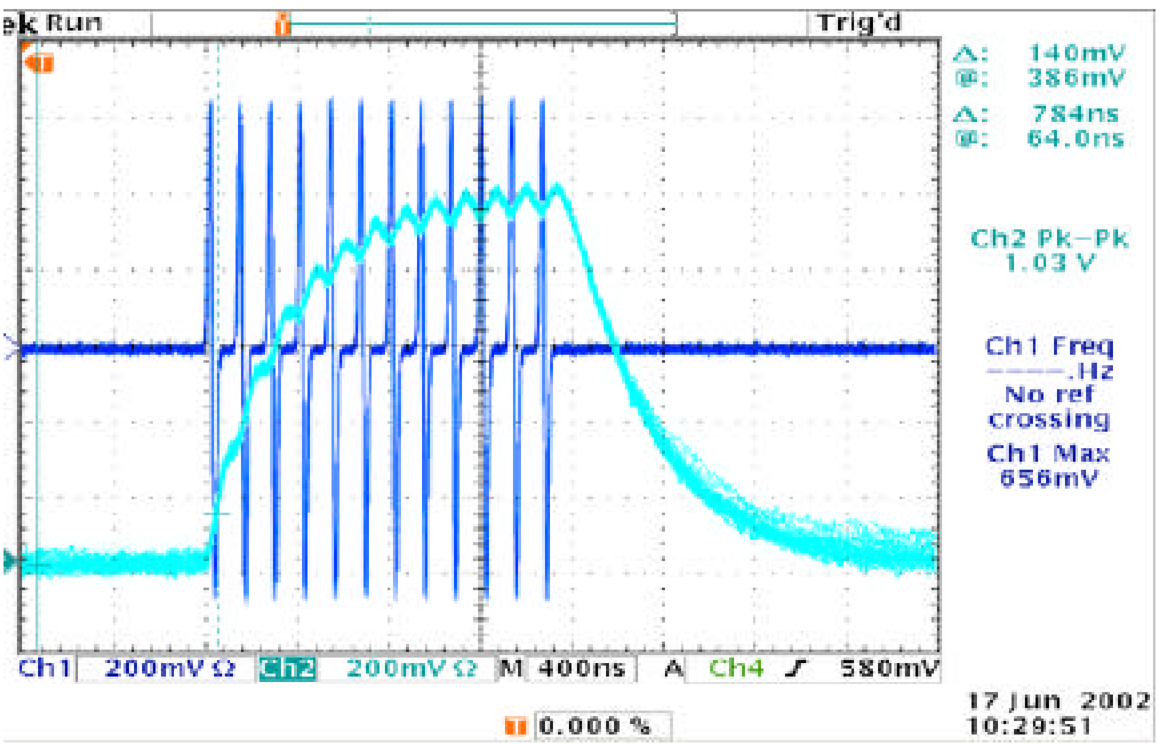
The above graph gives an indication as to why the response appeared to increase in intensity after the input signal ceased. While the –input reacts in a traditional manner, the +input's response adds the bump with a slight gain beyond the input signal's end.
What initially appeared to be the log amp responding to a zero input between bunches turns out to be a response to the negative portion of the input signal. We replaced a bunched signal that had negative components with an equivalent (for the most part) signal without negative components and the response was enlightening. It's apparent (from the series of graphs below) that the log amp has a less than desirable response to an input that includes negative components. Additionally, the overall gain is reduced when the input has portions in the negative region. It appears that the negative portions accelerate its response towards zero and a lack of a negative region allows it to maintain its position. This is seen clearly when compared to the input without the negative region.
The manufacturer of these log amps lists an operating noise floor of –78dBm and a rise time of approximately 500 ns. Our test results verify these numbers.
Since we have used resistor and capacitor values that the manufacturer recommends, the log amp's response time/characteristics have not been radically affected. The log amp appears to be operating as expected, for the most part. Obviously, more investigation is required for a deeper understanding of log amps and to ultimately optimize their use here

at Fermilab. We will continue to analyze their usefulness in a variety of applications and take advantage of their flexibility.









Adim J. Yousif
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