HYPERLABS' Linear Amplifiers and Transition Time Converters for 10Gbaud PAM4 Applications

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OVERVIEW

Measurements will be presented in this application note to show that HYPERLABS' broadband linear amplifiers perform exceptionally well in PAM4 applications at 10Gbaud. It should be noted that the HL5867 (35kHz to 30GHz) and HL5887 (42kHz to 40GHz) amplifiers have three to four times more bandwidth than is needed for PAM4 signaling at 10Gbaud. Equally, if not more important, these amplifiers have a flat time domain step response. The measurements presented in this note will show that these amplifiers respond to 10Gbaud PAM4 input signals in the 75mVp-p to 340mVp-p range without adding distortion to the time domain eye diagrams. We will also highlight the use of HL9452 Transition Time Converters to optimize the time domain response of a system for operation at a specific baud rate of interest. Lastly, we will show why limiting amplifiers, such as the HL5877, are not suitable for PAM4 applications.

MEASUREMENT SYSTEM

Our measurement setup is shown in *Figure 1*. A high speed MICRAM DAC4 is used to produce a 10Gbaud PAM4 eye diagram. The DAC4 has about 40GHz analog bandwidth. The DAC4 output signal is (optionally) sent through a HYPERLABS Transition Time Converter (TTC) thus reducing system bandwidth to a more realistic value in the 7-10GHz range. Model HL9452-29 and HL9452-47 TTCs are used to reduce the 10%-90% risetime of the DAC4 signal source to 30ps and 48ps respectively. These risetimes are representative of a real-world 10Gbaud communication system. Even if the system response is significantly greater than 10GHz, a TTC will often improve BER by reducing the overshoot and ring that results from excessive peaking or brick wall roll-off in the frequency domain. The outputs will be measured with a 20 GHz Lecroy Sampling Scope.

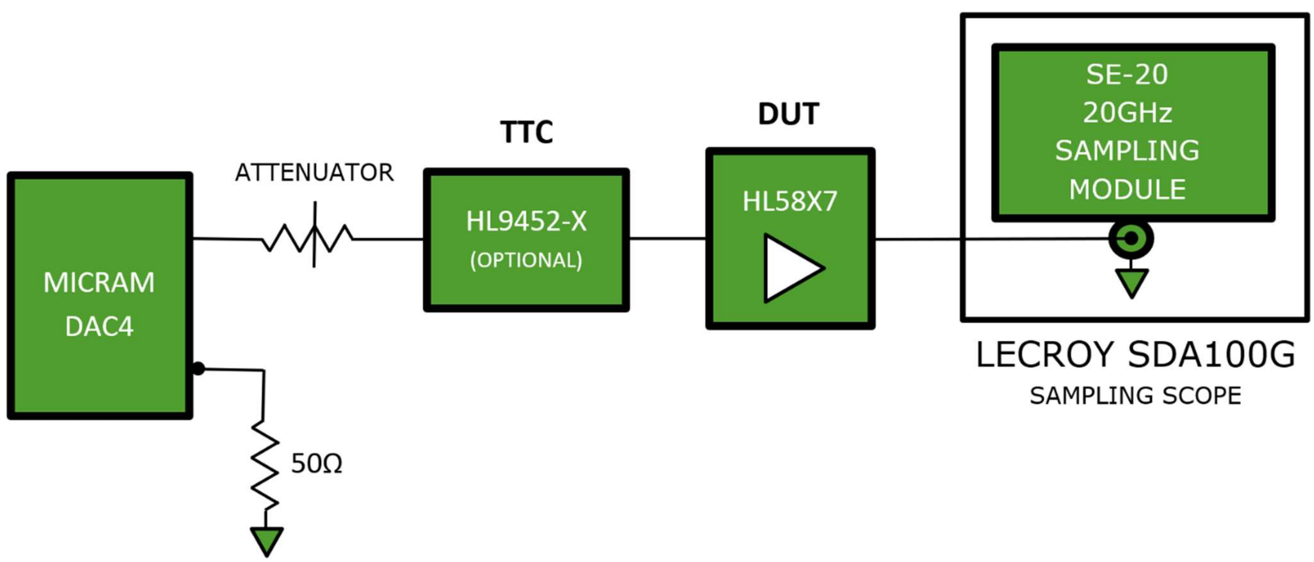

Figure 1: Measurement Setup for 10Gbaud PAM4 Amplifier Evaluation.

In *Figure 2* we have three versions of 10Gbaud PAM4 input signal at 75mVp-p amplitude. This level of signal is used to measure the small signal time domain response of the amplifiers under test. *Figure 2a* is the PAM4 data source measured on the 20GHz sampler without any TTC. In this case, the system bandwidth is dominated by the 20GHz sampler. *Figure 2b* is the same data source with a 29ps TTC (HL9452-29). *Figure 2c* is the data source with a 47ps TTC (HL9452-47).

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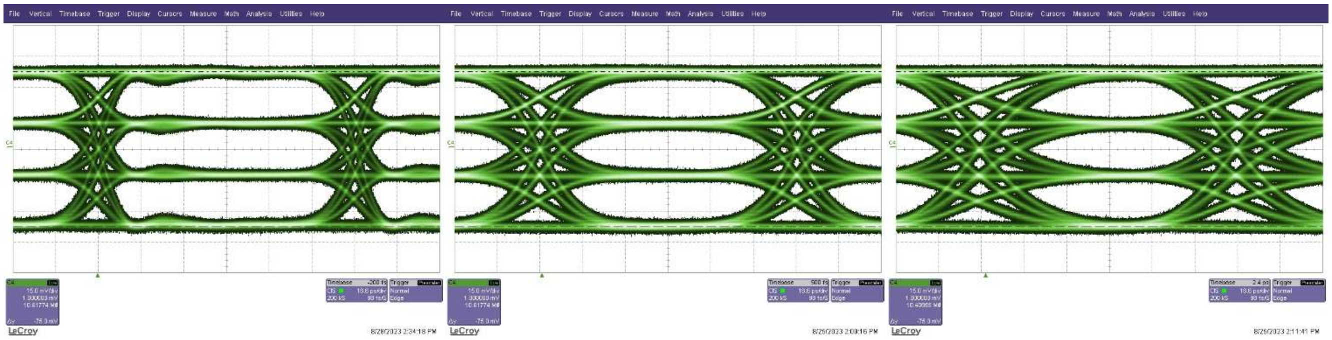
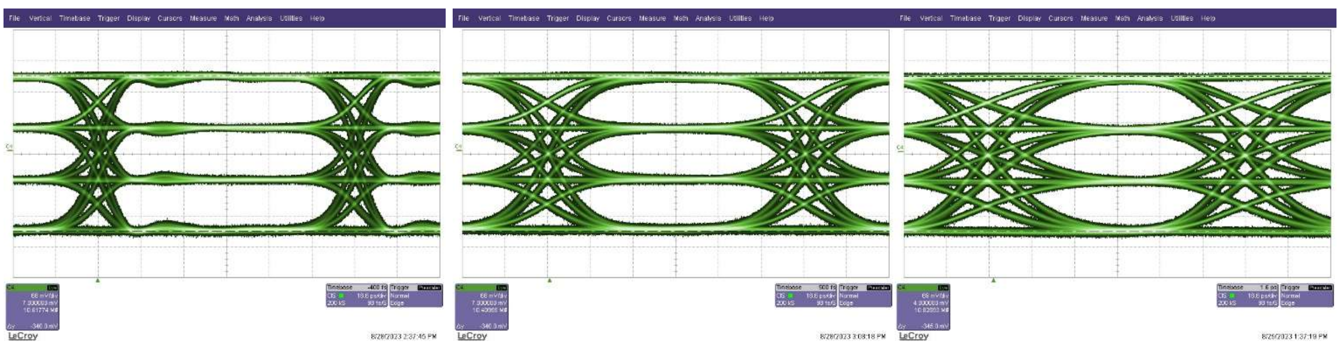


(a) *(b)* *(c)*

Figure 2: 75mVp-p, 10Gbaud PAM4 Input Signal measured with System Bandwidths of 20GHz (a), 10GHz (b), and 7GHz (c)

In *Figure 3* we have three versions of 10Gbaud PAM4 input signal at 340mVp-p amplitude. This signal is used to measure the medium-to-large signal response of the amplifiers under-test. From left-to-right these images represent no TTC *(a)*, 29ps TTC *(b)*, and 47ps TTC *(c)*, respectively.

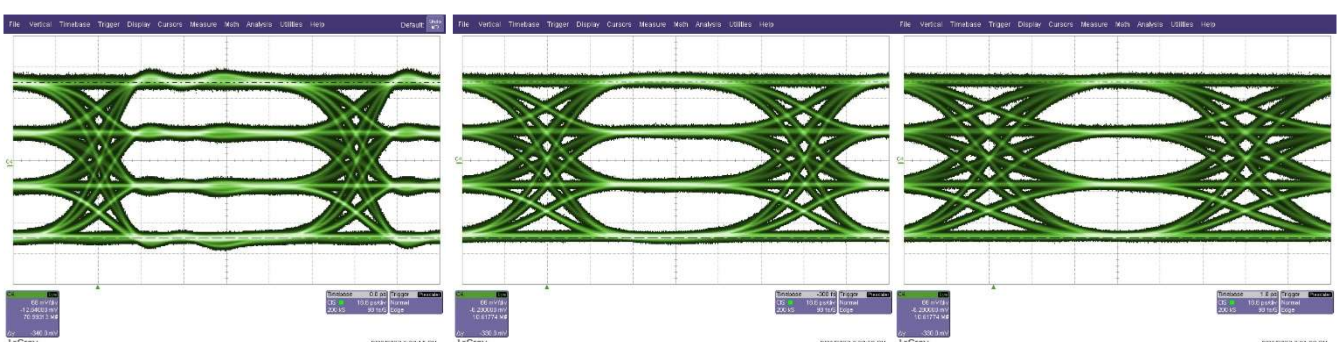


(a) *(b)* *(c)*

Figure 3: 340mVp-p, 10Gbaud PAM4 Input Signal measured with System Bandwidths of 20GHz (a), 10GHz (b), and 7GHz (c)

HL5867 AMPLIFIER MEASUREMENTS

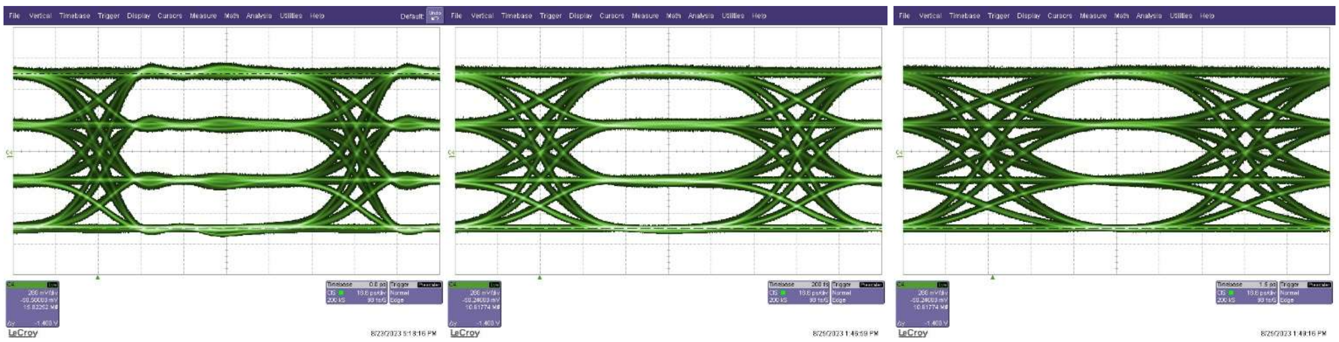
The model HL5867 amplifier has 13dB of gain and 3dB bandwidth from 35kHz to 30GHz. *Figure 4* shows the output of the HL5867 amplifier driven at 75mVp-p. From left-to-right these images represent no TTC *(a)*, 29ps TTC *(b)*, and 47ps TTC *(c),* respectively. As shown below, the HL5867 amplifier exhibits a slight amount of overshoot and ripple when evaluated in a 20GHz system bandwidth. These aberrations are undetectable at system bandwidths of 10GHz and 7GHz. The output amplitude is approximately 340mVp-p.



(a) *(b)* *(c)*

Figure 4: Output of HL5867 Amplifier driven at 75mVp-p. System Bandwidths of 20GHz (a), 10GHz (b), and 7GHz (c)

Figure 5 shows the output of the HL5867 amplifier driven at 340mVp-p. From left-to-right these images represent no TTC *(a)*, 29ps TTC *(b)*, and 47ps TTC *(c)*, respectively. Once again, topline aberrations visible at 20GHz system bandwidth are undetectable at system bandwidths of 10GHz and 7GHz. The output amplitude is approximately 1.4Vp-p.

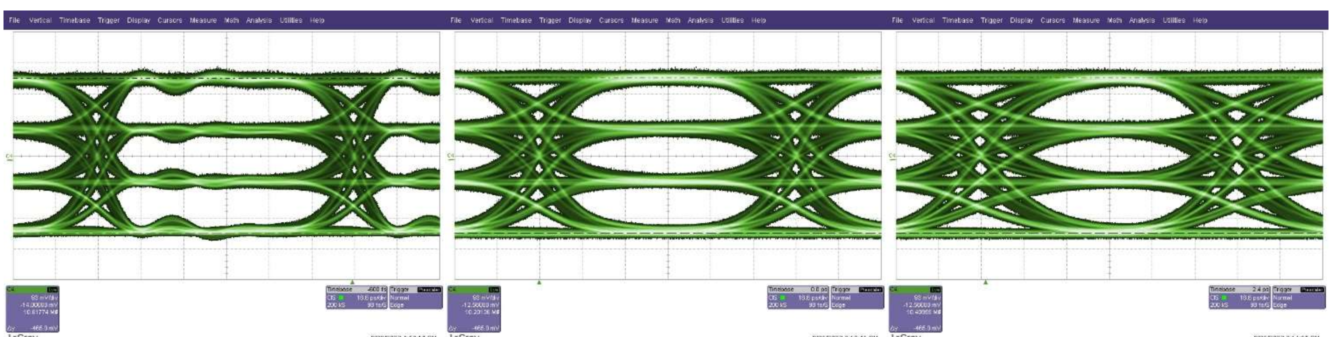


(a) *(b)* *(c)*

Figure 5: Output of HL5867 Amplifier driven at 340mVp-p. System Bandwidths of 20GHz (a), 10GHz (b), and 7GHz (c)

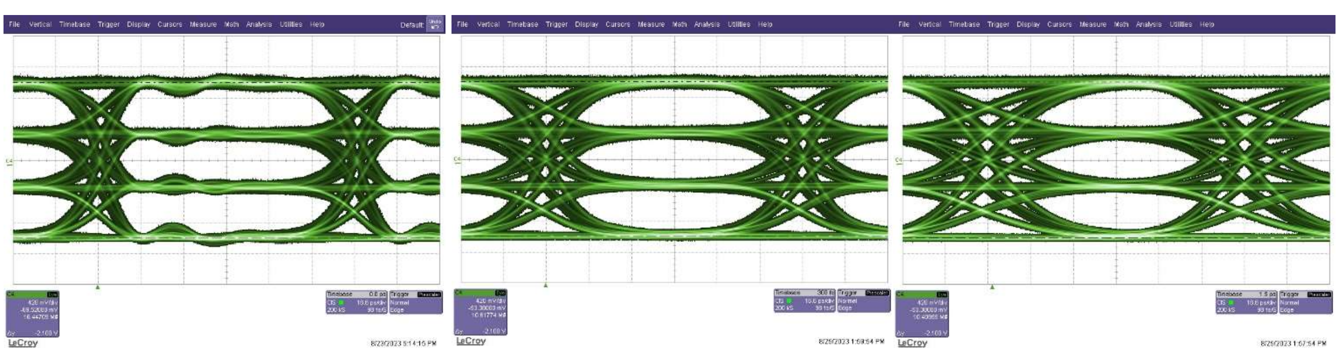
HL5887 AMPLIFIER MEASUREMENTS

The model HL5887 amplifier has 15dB of gain and 3dB bandwidth from 42kHz to 40GHz. *Figures 6 and 7* show the output of the HL5887 amplifier driven at 75mVp-p and 340mVp-p respectively. From left-to-right these images represent no TTC *(a)*, 29ps TTC *(b)*, and 47ps TTC *(c)*, respectively. The HL5887 amplifier exhibits slightly more ripple than HL5867 when evaluated in a 20GHz system bandwidth. These aberrations are undetectable at system bandwidths of 10GHz and 7GHz. The output amplitudes are approximately 470mVp-p in *Figure 6* and 2.1Vp-p in *Figure 7*.



(a) *(b)* *(c)*

Figure 6: Output of HL5887 Amplifier driven at 75mVp-p. System Bandwidths of 20GHz (a), 10GHz (b), and 7GHz (c)

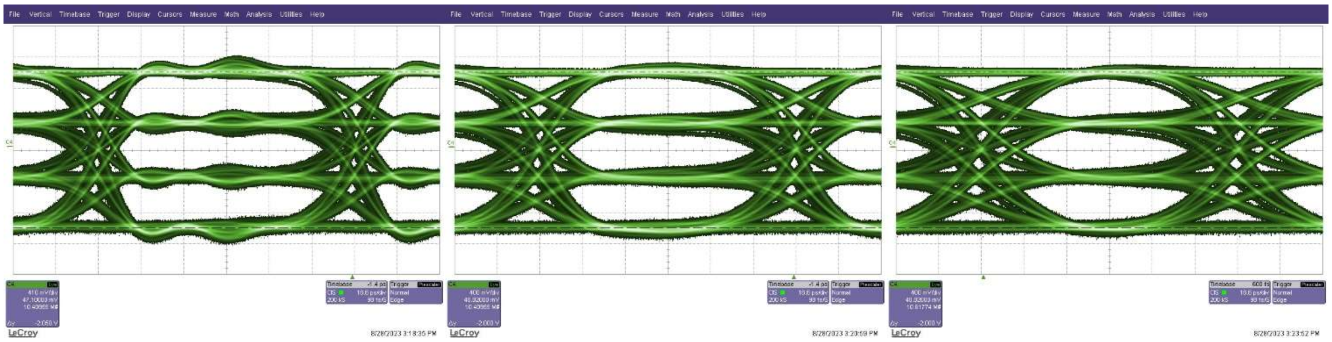


(a) *(b)* *(c)*

Figure 7: Output of HL5887 Amplifier driven at 340mVp-p. System Bandwidths of 20GHz (a), 10GHz (b), and 7GHz (c)

CASCADED AMPLIFIER MEASUREMENTS

Next, we show the combined response of HL5867 and HL5887 cascaded in series. The HL5867 amplifier is used as the first stage receiver, while the HL5887 is used as the second stage driver. The pair of amplifiers have 28dB of total gain in cascade. *Figure 8* shows the output of the cascaded pair driven at 75mVp-p. From left-to-right these images represent no TTC *(a)*, 29ps TTC *(b)*, and 47ps TTC *(c),* respectively. The cascaded amplifier response exhibits more ripple than either of the individual amplifiers. This is most apparent in *Figure 8a* where no TTC was used. The output amplitude is approximately 2.0Vp-p.

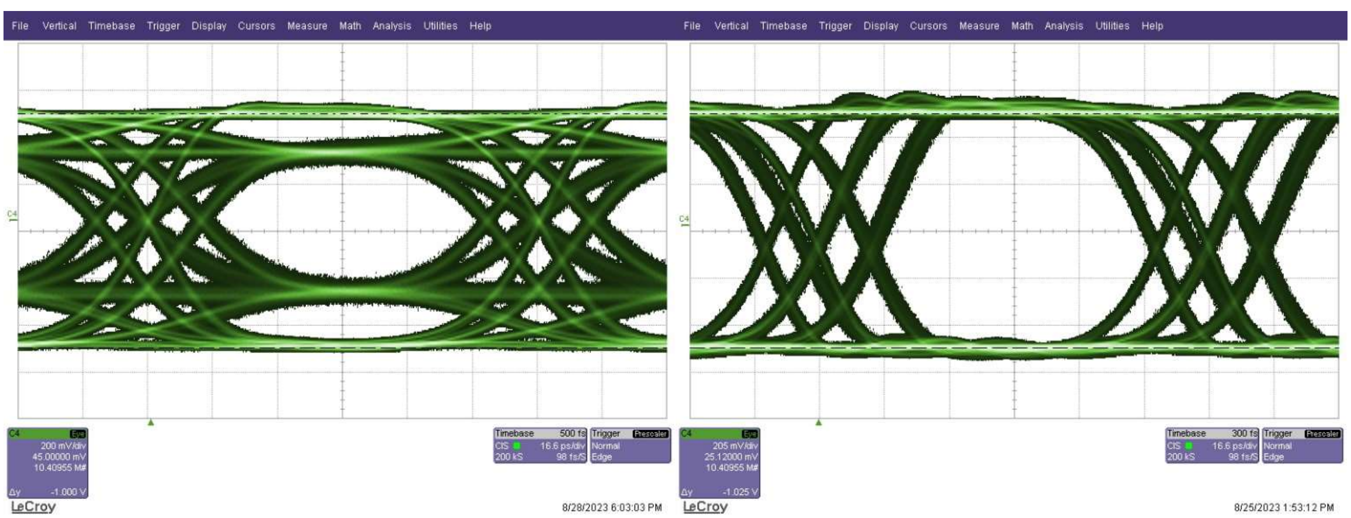


(a) *(b)* *(c)*

Figure 8: Output of HL5867 + HL5887 Cascaded Pair driven at 75mVp-p with no TTC (a), 29ps TTC (b), and 47ps TTC (c)

HL5877 AMPLIFIER MEASUREMENTS

The model HL5877 amplifier is a high-gain limiting amplifier with 27dB of small signal gain. It delivers a consistent output amplitude of 1Vp-p over a wide input amplitude range from 50mVp-p to 850mVp-p. When driven at 100mVp-p, the effective gain is 20dB. At this drive level, top-line aberrations are compressed by 7dB. This non-linear behavior is desirable for some binary applications. The HL5877 is not suitable for use in multi-level signaling applications such as PAM4 because it converts the 4-level signal into a 2-level (binary) signal as shown below in *Figure 9* resulting in loss of data information.



(a) *(b)*

Figure 9: Compressed Output of HL5877 Amplifier driven at 75mVp-p (a) and 340mVp-p (b)
(PAM4 Input Signal with HL9542-47 TTC)

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