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NRZ vs. PAM

Options exist today on which coding technique to use at higher speeds on the backplane. At speeds up to 3.125Gb/s, familiar NRZ (non return to zero) codes have been universally accepted. This code produces the familiar eye diagram, where there are 2 states, high and low. As data rates have increased to 6.25Gb/s for the backplane, and are looking toward 10Gb/s, the lossy transmission line environment is causing users to examine alternatives. Pulse Amplitude Modulation is one alternative that is getting attention today. Channel loss increases with frequency. Comparing NRZ codes to PAM codes requires discussing the tradeoffs that are made over today's channels.

A "101010" data pattern in NRZ will produce the highest frequency pattern, which will be $\frac{1}{2}$ the data rate. A 6.25Gb/s data transmission will therefore be most concerned about loss at 3.125GHz.

PAM is a multilevel code. 4PAM and 5PAM are two versions that have been published. This comparison will use the 4PAM, which has 4 levels, and as a result, 3 eyes. An attribute of the 4PAM code is that the frequency of interest is $\frac{1}{2}$ that of a NRZ code. Therefore at 6.25Gb/s, a 4PAM code is most concerned about loss at 1.5625GHz.

The argument made by the PAM advocates is that this is a good thing. Since loss increases with frequency, halving the frequency permits higher data rates to be achieved in lossy channels.

However, there is no such thing as a free lunch. While the frequency of concern is half, the "eye height" is divided into three. For NRZ, there is one eye, while for PAM, there are three. Since V_{dd} did not change, the voltage available for the eye is $\frac{1}{3}$. This results in an equivalent reduction in the equivalent margin of -10dB .

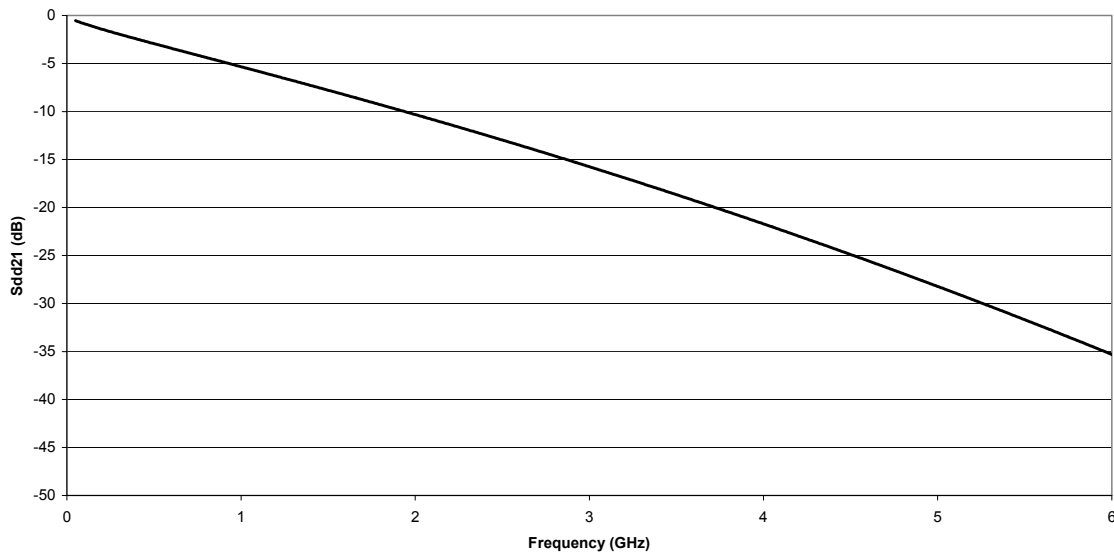
So, the short answer is, if the loss between 3.125GHz and 1.5625GHz is less than 10dB, PAM is not indicated. If it is more than 10dB, then PAM may offer something.

Let's look at some data. Attached is a curve that is intended to model a modern backplane connection. It's loss at 3.125GHz is -17dB . It's loss at 1.5625GHz is -8dB . So, before any other considerations are taken, PAM vs. NRZ is a wash. Of course, if the curve is steeper, then the difference between the loss at these two points will be greater. The advantage of PAM vs. NRZ, which is said to start from operating at $\frac{1}{2}$ the bit rate, must first be studied in the context of the fact the voltage is divided into multiple eyes.

Other issues of interest include crosstalk. As above, crosstalk for 4PAM is better than for NRZ only if the crosstalk at 1.5625GHz is again at least 10dB lower than the crosstalk at 3.25GHz. In addition, channel reflections must also be at least 10dB lower than for NRZ, due to the very real impact that the 1/3 smaller eyes must also deal with reflections.

All of the above is true if the 4PAM does not use more than half the frequency spectrum of NRZ, meaning that the transition times in the 4PAM signal are no faster than $\frac{1}{2}$ the transition times of the NRZ signal. If this were true, the rise/fall times would limit the eye height of the top and bottom eyes, with the middle eye being larger than the other two. Therefore many 4PAM implementations speed the edges to deliver matched eye widths, reducing the expected benefit since this increased edge rate increases the high frequency content of the signal.

Our estimation is that 4PAM is not indicated unless the channel loss at the $\frac{1}{2}$ frequency point is at least 15 to 20dB less than would be required for NRZ. And, except for very old, or very bad backplane designs, PAM does not provide a benefit.



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