

Application Note:

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Choosing AC-Coupling Capacitors

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Maxim Integrated Products



Choosing AC-Coupling Capacitors

When using AC-coupling in optical transceiver design, care should be taken to minimize the pattern-dependent jitter associated with the low-frequency cutoff of the AC-coupling network. When NRZ data containing long strings of identical 1's or 0's is applied to this high-pass filter, a voltage droop occurs, resulting in low-frequency pattern-dependent jitter (PDJ). This can be understood as illustrated in Figure 1.

In order to limit the low-frequency droop associated with AC-coupling, the location of the lower 3dB cut-off frequency should be set properly. The step response of a first-order RC high-pass filter is given by:

$$v(t) = V_{\infty} - (V_{\infty} - V_{0+})e^{-\frac{t}{RC}}$$

AC-coupling into a 50Ω load results in equal swings above and below the common-mode voltage. Normalizing the voltage swings to V_{p-p} results in voltage levels equal to $\pm 0.5V_{p-p}$. Assuming the initial charging voltage is $V_{0+} = 0.5V_{p-p}$ and the final value of the voltage is $V_{\infty} = 0$, we get the following

$$\Delta V = 0.5V_{p-p}(1 - e^{-\frac{t}{\tau}})$$

where ΔV is the voltage droop at time t and τ is the time constant. Assuming that the degradation due to this voltage droop is 0.25dB, then the maximum $\Delta V/V_{p-p} = 6\%$:

$$6\% = 0.5(1 - e^{-t/\tau}) \quad \text{or, } \tau = 7.8t$$

If we let T_b represent the bit period and N_{CID} represent the maximum tolerated consecutive identical digits, then the total discharge time is $t = N_{CID} \cdot T_b$. If C is the AC-coupling capacitor and R is total resistance as seen from the capacitor, then the time constant of the RC circuit is $\tau = RC$. Combining these equations yields the closed form solution of C :

$$C = 7.8N_{CID}T_b / R$$

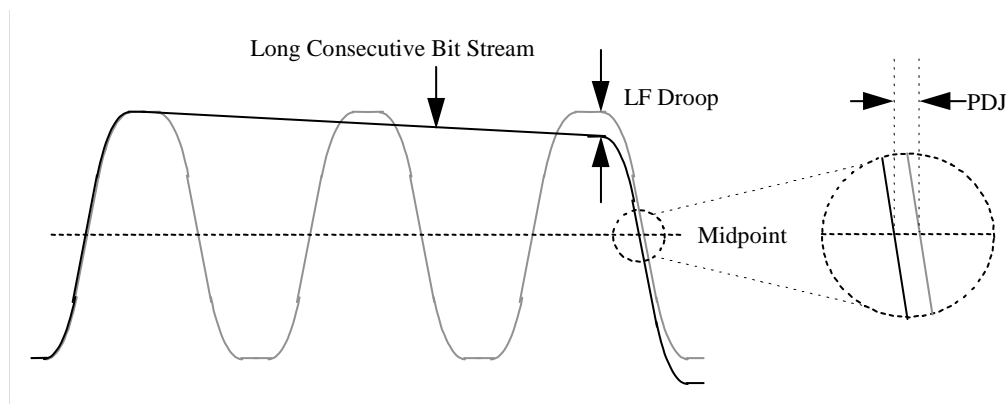


Figure 1. Low-frequency pattern-dependent jitter caused by AC-coupling

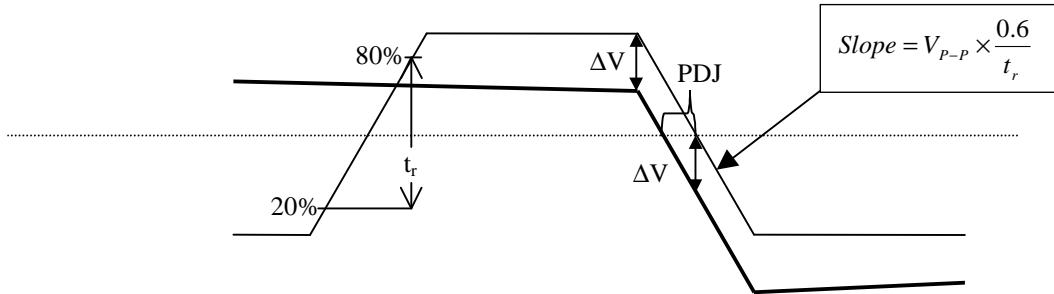


Figure 2. Estimation of PDJ caused by low-frequency droop

From Figure 2, PDJ can be estimated by:

$$PDJ = \frac{\Delta V}{slope} = \frac{0.5V_{p-p}(1 - e^{-t_r/\tau})}{0.6V_{p-p}/t_r} = \frac{0.5t_r(1 - e^{-T_b \cdot N_{CID}/R \cdot C})}{0.6}$$

where t_r is the (20% to 80%) rise time of the NRZ data. For a first-order system, the rise time can be estimated as:

$$t_r = 0.22 / BW$$

For fiber optic communications, the typical bandwidth is normally 0.6 to 1.0 times the data rate. For a 2.488Gbps receiver, $T_b = 402\text{ps}$. If $N_{CID} = 72\text{bits}$ and $R = 100\Omega$, the calculated C is 2.25nF . If $t_r = 120\text{ps}$ and $C = 2.25\text{nF}$, the calculated PDJ is 12ps . If we increase C to 100nF , the resulting PDJ will be reduced to $<1\text{ps}$.