Application Note:

HFAN-1.1

Rev 0; 9/00

Choosing AC-Coupling Capacitors

[Some parts of this application note first appeared in
Electronic Engineering Times on July 3, 2000, Issue 1120.]

MAXIM High-Frequency/Fiber Communications Group

MAXIM

Maxim Integrated Products

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 $V_{p\text{-}p}$ results in voltage levels equal to $\pm 0.5V_{p\text{-}p}$. Assuming the initial charging voltage is $V_{0+} = 0.5V_{p\text{-}p}$ 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 $\Delta V/V_{p\text{-}p} = 6\%$:

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

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:

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

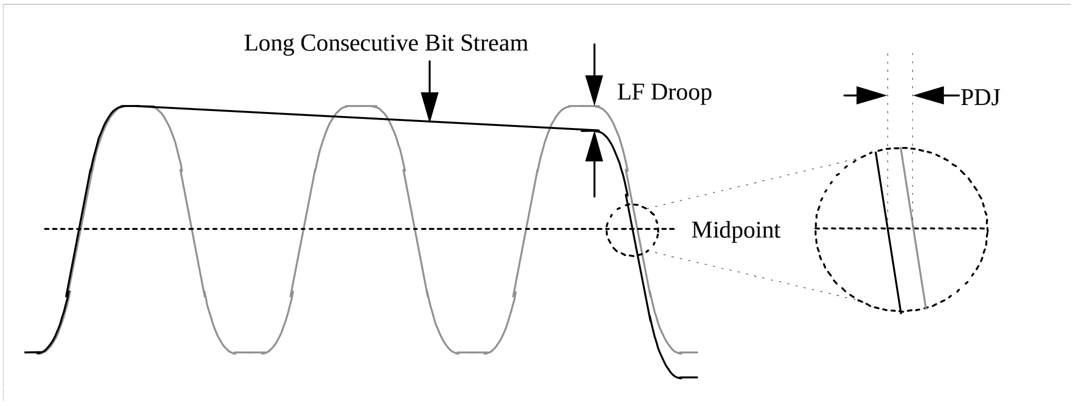

Figure 1. Low-frequency pattern-dependent jitter caused by AC-coupling

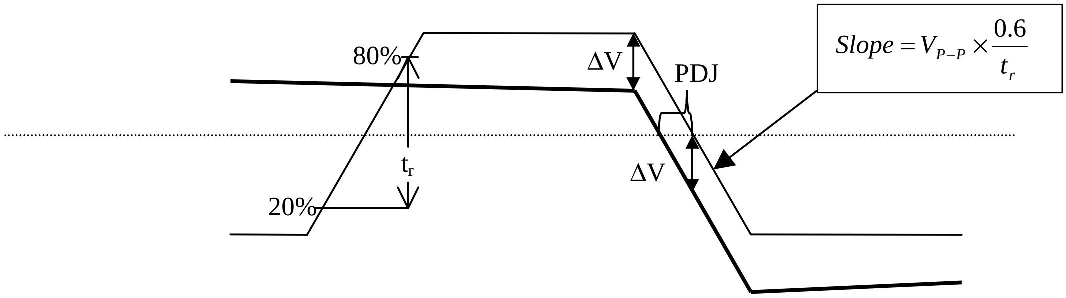

Figure 2. Estimation of PDJ caused by low-frequency droop

From Figure 2, PDJ can be estimated by:

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

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 = 402ps. If N_{CID} = 72bits and R = 100Ω, the calculated C is 2.25nF. If t_r = 120ps and C = 2.25nF, the calculated PDJ is 12ps. If we increase C to 100nF, the resulting PDJ will be reduced to <1ps.