From June 2011 *High Frequency Electronics*

DESIGN NOTES

Sensitivity of an Optical Receiver

The interface between an optical signal input and the detected electronc signal output is an essential part of an optical data link. Figure 1 is a simplified block diagram of an optical receiver, where the first two stages—the photodiode detector and the transimpedance amplifier—determine overall sensitivity. This is the same process as in an RF/microwave receiver front end, but is described using different terminology. The key terms are:

Optical modulation amplitude (*OMA*)—The difference between the power levels representing a logic one (P_1) and logic zero (P_0), in watts (peak-to-peak).

Extinction ratio (r_e)—Ratio of P_1 to P_0 expressed as:

$$r_e = \frac{P_1}{P_0} \quad \text{or} \quad r_e = 10\log\left(\frac{P_1}{P_0}\right) \text{ (dB)}$$

Average optical power (P_{AVG})—The mean power level in dBm.

Responsivity (ρ)—Conversion efficiency of the photodetector, in amperes per watt (A/W).

Input-referred noise (i_n)—The noise floor of the transimpedance amplifier. May be specified as either RMS current (A_{RMS}) or as noise density ($A_{RMS}/\sqrt{\text{Hz}}$).

Signal-to-noise ratio (*SNR*)—The peak-to-peak signal to RMS noise ratio, usually with the minimum value required to obtain acceptable bit-error rate (BER).

$$SNR = \frac{Signal_{(pp)}}{Noise_{(RMS)}}$$

The relationship of the extinction ratio r_e and OMA to average optical power P_{AVG} is:

$$P_{AVG} = \frac{OMA(r_e+1)}{2(r_e-1)} \text{ (watts)}$$

or expressed in dBm:

$$P_{AVG} = 10\log\left[1000\frac{OMA(r_e+1)}{2(r_e-1)}\right] \text{ (dBm)}$$

Computing the Sensitivity

The photodetector converts the lightwave signal into electrical current, which is converted to a voltage and amplified by the transimpedance amplifier. The sensitivity of the combined photodetector and transimpedance amplifier is computed according to the following equation:

$$\text{Sensitivity} = 10\log\left[1000\frac{i_n SNR(r_e+1)}{\rho(r_e-1)}\right] \text{ (dBm)}$$

The result of the above equation is useful when comparing the sensitivity of different devices.

To determine the minimum peak-to-peak optical signal, the designer must first select the *SNR* for the desired BER, then identifies ρ and i_n from device data sheets. The minimum *OMA* is then:

$$OMA_{MIN} = (i_n\, SNR)/\rho$$

This can be converted into P_{AVG} using the relationship to r_e and *OMA* noted above.

The Limiting Amplifier

This note is adapted from Ref. [1], which cautions that many references for optical front end sensitivity do not include the performance of the limiting amplifier. This device also has a noise floor (decision threshold), below which the logic zero to one transition becomes ambiguous. When this specification is included in sensitivity analysis, the designer will have a more accurate estimate when selecting devices.

Reference

"Accurately Estimating Optical Receiver Sensitivity," Application Note HFAN-3.0.0, Maxim Integrated Products, www.maxim-ic.com

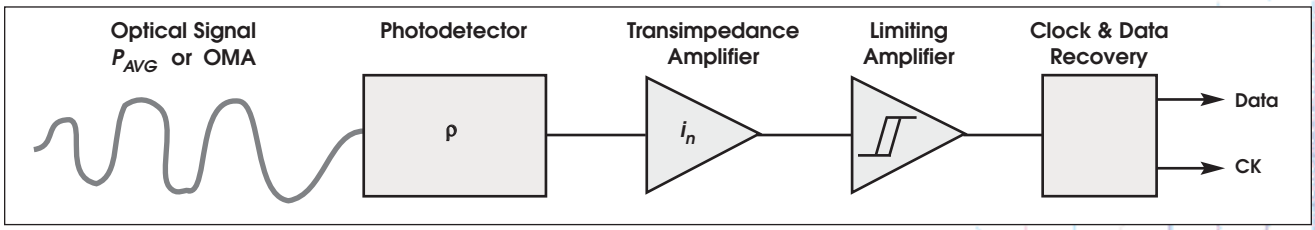

Figure 1 · Basic block diagram of an optical receiver.