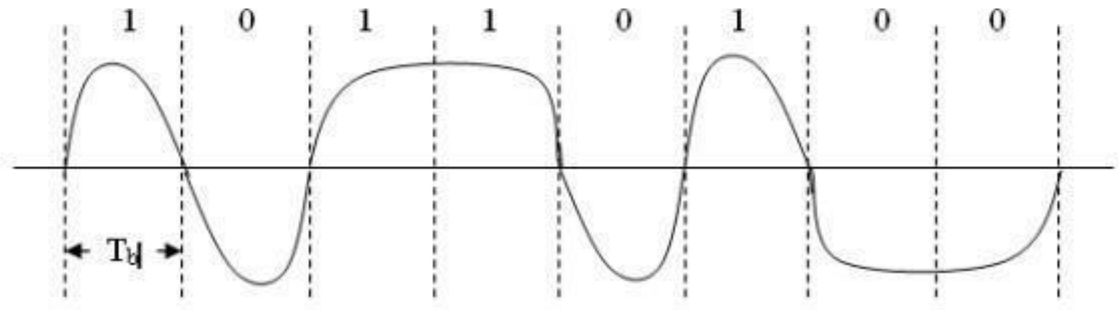
EYE PATTERN

The quality of digital transmission systems are evaluated using the bit error rate. Degradation of quality occurs in each process modulation, transmission, and detection. The eye pattern is experimental method that contains all the information concerning the degradation of quality. Therefore, careful analysis of the eye pattern is important in analyzing the degradation mechanism.

- Eye patterns can be observed using an oscilloscope. The received wave is applied to the vertical deflection plates of an oscilloscope and the saw tooth wave at a rate equal to transmitted symbol rate is applied to the horizontal deflection plates, resulting display is eye pattern as it resembles human eye.

- The eye pattern, also referred to as the eye diagram, is produced by the synchronized superposition of (as many as possible) successive symbol intervals of the distorted waveform appearing at the output of the receive filter prior to thresholding. As an illustrative example, consider the distorted, but noise-free, waveform shown in part a of Figure 8.12. Part b of the figure displays the corresponding synchronized superposition of the waveform’s eight binary symbol intervals. The resulting display is called an “eye pattern” because of its resemblance to a human eye. By the same token, the interior of the eye pattern is called the eye opening

- The interior region of eye pattern is called eye opening



(Source:Brainkart)

We get superposition of successive symbol intervals to produce eye pattern as shown below.

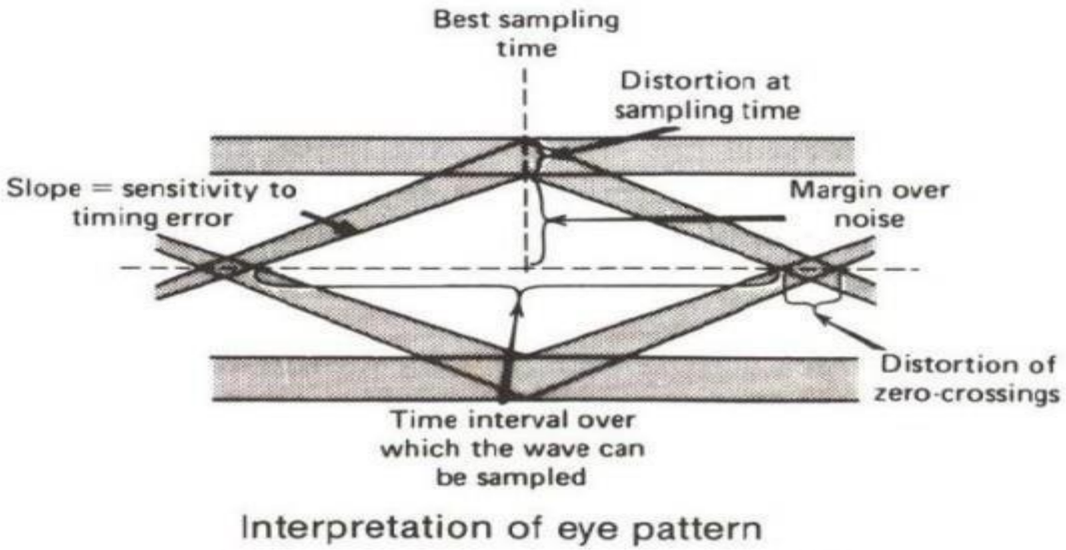


Fig 3.1Eye pattern (Source:Brainkart)

- The width of the eye opening defines the time interval over which the received wave can be sampled without error from ISI
- The optimum sampling time corresponds to the maximum eye opening

- The height of the eye opening at a specified sampling time is a measure of the margin over channel noise.

The sensitivity of the system to timing error is determined by the rate of closure of the eye as the sampling time is varied. Any non linear transmission distortion would reveal itself in an asymmetric or squinted eye. When the effected of ISI is excessive, traces from the upper portion of the eye pattern cross traces from lower portion with the result that the eye is completely closed.

As long as the additive channel noise is not large, then the eye pattern is well defined and may, therefore, be studied experimentally on an oscilloscope. The waveform under study is applied to the deflection plates of the oscilloscope with its time-base circuit operating in a synchronized condition. From an experimental perspective, the eye pattern offers two compelling virtues:

- The simplicity of eye-pattern generation.
- The provision of a great deal of insightful information about the characteristics of the data transmission system. Hence, the wide use of eye patterns as a visual indicator of how well or poorly a data transmission system performs the task of transporting a data sequence across a physical channel.

Timing Features

A generic eye pattern for distorted but noise-free binary data. The horizontal axis, representing time, spans the symbol interval from $-T_b$ □ 2 to T_b □ 2, where T_b is the bit duration. From this diagram, we may infer three timing features pertaining to a binary data transmission system, exemplified by a PAM system:

Optimum sampling time. The width of the eye opening defines the time interval over which the distorted binary waveform appearing at the output of the receive filter in the PAM system can be uniformly sampled without decision errors. Clearly, the *optimum sampling time* is the time at which the eye opening is at its widest.

Zero-crossing jitter. In practice, the timing signal (for synchronizing the receiver to the transmitter) is extracted from the *zero-crossings* of the waveform that appears at the receive-filter output. In such a form of synchronization, there will always be irregularities in the zero-crossings, which, in turn, give rise to *jitter* and, therefore, nonoptimum sampling times.

Timing sensitivity. Another timing-related feature is the sensitivity of the PAM system to *timing errors*. This sensitivity is determined by the rate at which the eye pattern is closed as the sampling time is varied.

The Peak Distortion for Intersymbol Interference

Hereafter, we assume that the ideal signal amplitude is scaled to occupy the range from –1 to +1. We then find that, in the absence of channel noise, the eye opening assumes two extreme values:

An eye opening of unity, which corresponds to zero ISI.

An eye opening of zero, which corresponds to a completely closed eye pattern; this second extreme case occurs when the effect of intersymbol interference is severe enough for some upper traces in the eye pattern to cross with its lower traces.

It is indeed possible for the receiver to make decision errors even when the channel is noise free. Typically, *an eye opening of 0.5 or better is considered to yield reliable data transmission*.

In a noisy environment, the extent of eye opening at the optimum sampling time provides a measure of the operating margin over additive channel noise. This measure, as illustrated in Figure 8.13, is referred to as the *noise margin*.

From this discussion, it is apparent that the eye opening plays an important role in assessing system performance; hence the need for a formal definition of the eye opening. To this end, we offer the following definition:

$$\text{Eye opening} = 1 - D_{\text{peak}}$$

where D_{peak} denotes a new criterion called the *peak distortion*. The point to note here is that peak distortion is a *worst-case* criterion for assessing the effect of ISI on the performance (i.e., error rate) of a data transmission system. The relationship between the eye opening and peak distortion is illustrated in Figure 8.14. With the eye opening being dimensionless, the peak distortion is dimensionless too. To emphasize this statement, the two extreme values of the eye opening translate as follows:

Zero peak distortion, which occurs when the eye opening is unity.

Unity peak distortion, which occurs when the eye pattern is completely closed.

Example of eye pattern:

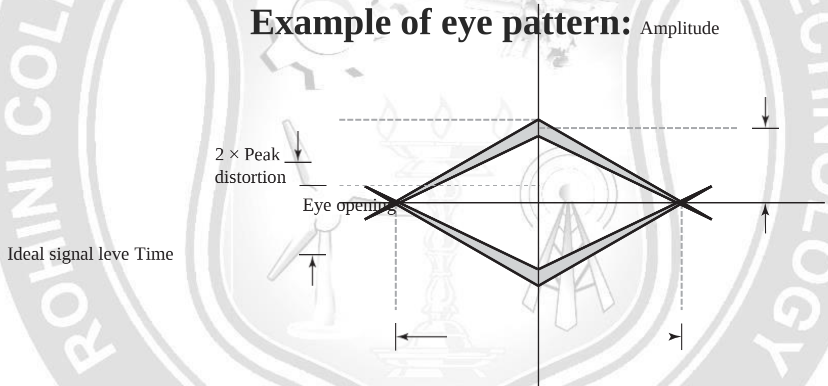


Figure 8.14 Illustrating the relationship between peak distortion and eye opening.

Note: the ideal signal level is scaled to lie inside the range –1 to +1.

(Source: S. Haykin, ―Digital Communications‖, John Wiley, 2005- Page- 465)

Eye Patterns for *M*-ary Transmission

By definition, an *M*-ary data transmission system uses *M* encoded symbols in the transmitter and $M - 1$ thresholds in the receiver. Correspondingly, the eye pattern for an *M*-ary data transmission system contains $M - 1$ eye openings stacked vertically one on top of the other. The thresholds are defined by the amplitude-transition levels as we move up from one eye opening to the adjacent eye opening. When the encoded symbols are all equiprobable, the thresholds will be equidistant from each other. In a strictly linear data transmission system with truly transmitted random data sequences, all the $M - 1$ eye openings would be identical. In practice, however, it is often possible to find asymmetries in the eye pattern of an M-ary data transmission system, which are caused by nonlinearities in the communication channel or other distortion- sensitive parts of the system.

Binary-PAM Perfect channel (no noise and no ISI)

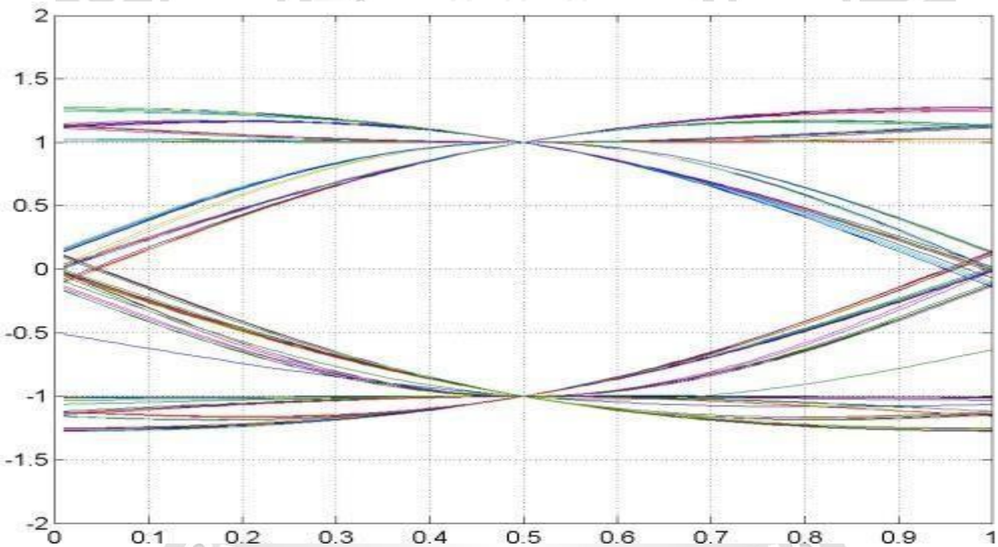


Fig 3.2 Example of eye pattern: Binary-PAM with noise no ISI (Source:Brainkart