Application Brief: Metastability Characteristics for Philips CPLDs - PZ3032

Introduction

When using a latch or flip-flop in normal circumstances (i.e., when the devices set-up and hold times are not being violated) the outputs will respond to a latch enable or clock pulse within some specified time. These are the propagation delays found in the data sheets. If, however, the set-up and hold times are violated so that the data input is not a clear one or zero, there is a finite chance that the flip-flop will not immediately latch a high or low but get caught half way in between. This is the metastable state and it is manifested in a bistable device by the outputs glitching, going into an undefined state somewhere between a high and low, oscillating, or by the output transition being delayed for an indeterminable time.

Once the flip-flop has entered the metastable state, the probability that it will still be metastable some time later has been shown to be an exponentially decreasing function. Because of this property, a designer can simply wait for some added time after the specified propagation delay before sampling the flip-flop output so that he can be assured that the likelihood of metastable failure is remote enough to be tolerable. On the other hand, one consequence of this is that there is some probability (albeit vanishingly small) that the device will remain in a metastable state forever. The designer needs to know the characteristics of metastability so that he can determine how long he must wait to achieve his design goals. The following information on the PZ3032 is provided to fill this basic need to know how the device operates in situations where metastability may be a problem. It is important in evaluating the reliability of your system that you obtain and evaluate this information from any programmable logic supplier you may be using. Also note that metastable characteristics are different at operating corners of supply voltage and temperature ranges - be wary of data that is presented only at room temperature and nominal Vcc. For more detailed background information on metastability, refer to application note AN219, ‘A Metastability Primer’. For applications where metastability is a critical concern, the designer may want to investigate Philips ABT22V10-7, which employs patented ‘metastable-immune’ flip-flops.

PZ3032 Metastable Characteristics

The following table presents the metastability data for Philips PZ3032 CoolRunner CPLD:

<table>
<thead>
<tr>
<th></th>
<th>0°C</th>
<th>25°C</th>
<th>70°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>τ</td>
<td>T₀</td>
<td>τ</td>
</tr>
<tr>
<td>3.0V</td>
<td>95.00ps</td>
<td>1.43E+13</td>
<td>101.0ps</td>
</tr>
<tr>
<td>3.3V</td>
<td>86.70ps</td>
<td>1.53E+13</td>
<td>90.30ps</td>
</tr>
<tr>
<td>3.6V</td>
<td>80.70ps</td>
<td>2.50E+17</td>
<td>84.10ps</td>
</tr>
</tbody>
</table>

As shown, Philips provides complete data on the PZ3032’s metastable characteristics. While the PZ3032 does not employ Philips patented metastable immune flip-flops, its metastable
characteristics are still quite favorable relative to competitive devices. For information on metastable immune PLDs, refer to the datasheet for the ABT22V10-7.

**Design Example**

Suppose a designer wants to use the PZ3032 for synchronizing asynchronous data that is arriving at 10MHz (as measured by a frequency counter), in a 3.3V system that has a clock frequency of 50MHz, at an ambient temperature of 25°C. The next device in the system samples the output of the PZ3032 8ns after the clock edge to ensure that any metastable conditions that occur have time to resolve to the correct state. The MTBF for this situation can be calculated by using equation below:

\[
MTBF = e^{(t' / \tau)} / (T_0 F_c F_1)
\]

In this formula, \(F_c\) is the frequency of the clock, \(F_1\) is the average input event frequency, and \(t'\) is the time after the clock pulse that the output is sampled \((t' > T_{co})\). \(T_0\) and \(\tau\) are device parameters provided by the semiconductor manufacturer (refer to the previous table for the PZ3032 metastability specifications). \(T_0\) and \(\tau\) are derived from tests and can be most nearly defined as follows: \(\tau\) is a function of the rate at which a latch in a metastable state resolves that condition. \(T_0\) is a function of the measurement of the propensity of a latch to enter a metastable state. \(T_0\) is also a normalization constant which is a very strong function of the normal propagation delay of the device.

In this situation the \(F_1\) will be twice the data frequency, or 20 MHz, because input events consist of both low and high transitions. Thus in this case \(F_c\) is 50MHz, \(F_1\) is 20Mhz, \(\tau\) is 90.3ps, \(t'\) is 8ns, and \(T_0\) is 1.98x10^{13} seconds. Using the above formula the actual MTBF for this situation is 1.51 \times 10^{10} seconds or 478.6 years for the PZ3032.