

Note that different authors and manufacturers may specify metastability parameters differently. For example, author Chaney and manufacturer Texas Instruments measure the metastability resolution time t_r from the triggering clock edge, as in our previous subsection. On the other hand, manufacturers Cypress and Xilinx define t_r as the *additional* delay beyond a normal clock-to-output delay time t_{pd} .

The last column in the table gives a somewhat arbitrarily chosen figure of merit for each device. It is the metastability resolution time t_r required to obtain an MTBF of 1000 years when operating a synchronizer with a clock frequency of 25 MHz and with 100,000 asynchronous input changes per second. For the Cypress and Xilinx devices, their parameter values yield a value of t_r , marked with an asterisk, consistent with their own definition as introduced above.

As you can see, the 74LS74 is one of the worst devices in the table. If we replace FF1 in the 16-MHz microprocessor system of the preceding subsection with a 74ALS74, we get

$$\text{MTBF}(42.5 \text{ ns}) = \frac{\exp(42.5/1.00)}{8.7 \cdot 10^{-6} \cdot 1.6 \cdot 10^7 \cdot 10^5} = 2.06 \cdot 10^{11} \text{ s}$$

If you're satisfied with a synchronizer MTBF of about 65 centuries per system shipped, you can stop here. However, if FF2 is also replaced with a 74ALS74, the MTBF gets better, since the 'ALS74 has a shorter setup time than the 'LS74, only 10 ns. With the 'ALS74, the MTBF is over 20,000 times better:

$$\text{MTBF}(52.5 \text{ ns}) = \frac{\exp(52.5/1.00)}{8.7 \cdot 10^{-6} \cdot 1.6 \cdot 10^7 \cdot 10^5} = 4.54 \cdot 10^{15} \text{ s}$$

Even if we ship a million systems containing this circuit, we (or our heirs) will see a synchronizer failure only once in 144 years. Now that's job security!

Actually, the margins above aren't as large as they might seem. (How large does 144 years seem *to you*?) Most of the numbers given in Table 8-35 are *averages* and are seldom specified, let alone guaranteed, by the device manufacturer. Furthermore, calculated MTBFs are extremely sensitive to the value of τ , which in turn may depend on temperature, voltage, and the phase of the moon. So the operation of a given flip-flop in an actual system may be much worse (or much better) than predicted by our table.

For example, consider what happens if we increase the clock in our 16-MHz system by just 25%, to 20 MHz. Your natural inclination might be to think that metastability will get 25% worse, or maybe 250% worse, just to be conservative. But, if you run the numbers, you'll find that the MTBF using 'ALS74s for both FF1 and FF2 goes down from $4.54 \cdot 10^{15}$ s to just $3.7 \cdot 10^9$ s, over a million times worse! The new MTBF of about 429 years is fine for one system, but if you ship a million of them, one will fail every four hours. You've just gone from generations of job security to corporate goat!