Why did the latencies calculated manually and simulation differ?

Analytical formulas are based on simplified or approximate models, so their results may not exactly match those from simulations. One key reason for this mismatch is the reliance on small-signal approximations, which fail to fully reflect the nonlinear and time-dependent behavior of real transistors during switching. For a single inverter, this difference is likely to be minimal. However, when multiple stages are connected in sequence, the small inaccuracies from each stage can build up, resulting in a significant overall deviation from theoretical predictions. SPICE simulations are realizing the circuit more preciesly.

Brief conclusion

Cascading inverters helps achieve faster signal transitions by amplifying small voltage variations and supplying enough drive capability to handle large capacitive loads. This performance boost is due to the progressively stronger drive provided by each stage. Although the design approach is based on idealized models and numerical methods but still it is a practical and commonly used solution in real-world circuits. However, this increase in speed comes at the cost of greater area and power usage, as larger transistors take up more space on the chip and consume more dynamic power.

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