Lecture 03.03 Digital signals

A *digital signal* is a continuous signal transmitted with the assumption that the receiver will interpret it as representing a finite number of values. Typically, only two values are represented: binary `1` or `0`, also called *Boolean true* ($\top$) and *false* ($\bot$). Digital signals are the signals of digital circuits, of which CPUs, memory reading/writing devices, and I/O devices are made.

digital signal

Boolean true

Boolean false

Why would one want to discard the potentially infinite amount of information resolution in a continuous signal? Primarily because (1) often our transmission (TX) has a limited number of potential values, especially when dealing with data stored as computer memory bits, and (2) *noise*: offsets (biases) and random signals added to the transmitted signal through a number of mechanisms. With noise, we lose significant resolution, and a tradeoff emerges between voltage resolution and fidelity. Throughout the history of digital electronics, the tendency has been to sacrifice voltage resolution—settling for binary encoding—for time resolution: digital electronics can send and receive digital signals that switch between `0` and `1` at blazing speeds.

noise

A number of digital signal standards have been developed,[1] with the *complementary metal-oxide-semiconductor* (CMOS) standard being the most popular, but several others remain in use, including the *transistor-transistor logic* (TTL) standard, which is now described. All these standards are similar, so describing one is sufficient for our purposes.

CMOS

TTL

With reference to Figure 03.3, the TTL standard defines interpretations for voltage level ranges for both transmission output and reception input. Note that the output ranges are *stricter* than the input ranges. This accounts for noise added to a signal between transmission and reception, and is called the *noise margin*. From the figure, what is the noise margin for a TTL signal?

noise margin

Most digital circuits can function properly with signals greater than their maximum defined voltage and those less than their minimum (typically `0` V). Most TTL circuits will "interpret" signals greater than 5 V as `1` and those less than `0` V as `0`.

In addition to voltage specifications, the TTL standard includes current output and input ranges. Furthermore, it specifies the maximum time for a TTL-compliant device to switch between `0` and `1`.

In Lecture 05.03, some building blocks of digital circuits are described. How analog signals are converted to digital and *vice versa* are explored in

[1] For a thorough description and history of standards, see Horowitz and Hill (2015).

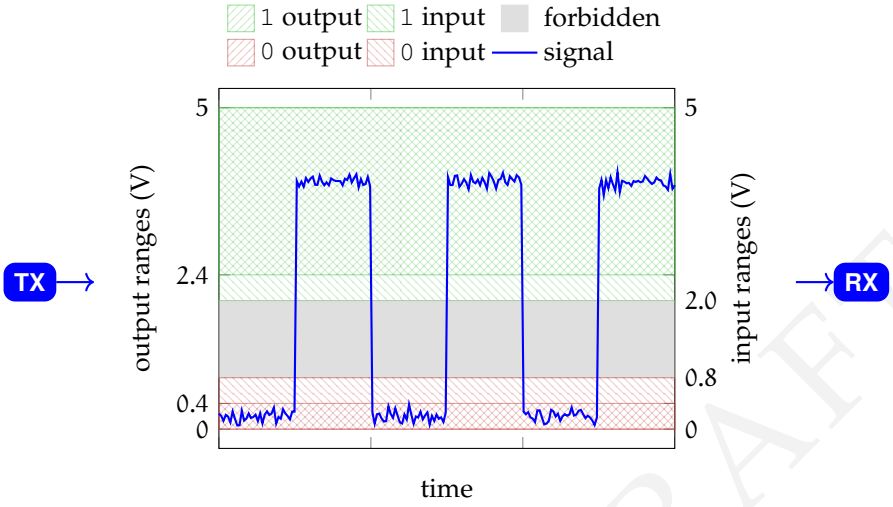

Figure 03.3: standard TTL signal transmission (TX) and reception (RX) voltage levels. Note the 0.4 V noise margin. Typically, values greater than 5 V can be received as 1 and values less than 0 V as 0.

Lecture 06.01.