[Rule of Thumb #2: Signal bandwidth from clock frequency]

[Eric Bogatin] - December 05, 2013

Here's a quick way to determine the bandwidth of a signal when all you know is the clock frequency.

$$BW[GHz] = 5 \times F_{clock}[GHz]$$

Where:
BW = the bandwidth of the signal, in GHz
F_{clock} = clock frequency in GHz

This rule of thumb relates the bandwidth of a signal when all you know is the clock frequency of the signal.

Remember: before you start using rules of thumb, be sure to read the [Rule of Thumb #0: Use rules of thumb wisely]. And, perhaps, the previous Rule of Thumb: RoT #1, [Bandwidth of a signal from its rise time].

Of course, the bandwidth of a signal is about the rise time of the signal, not the clock frequency. We can have exactly the same clock frequency of different signals, but with very different rise times, and each signal will have a very different bandwidth. Figure 1 shows three different signals, each with exactly the same clock frequency but very different rise times and very different bandwidths.

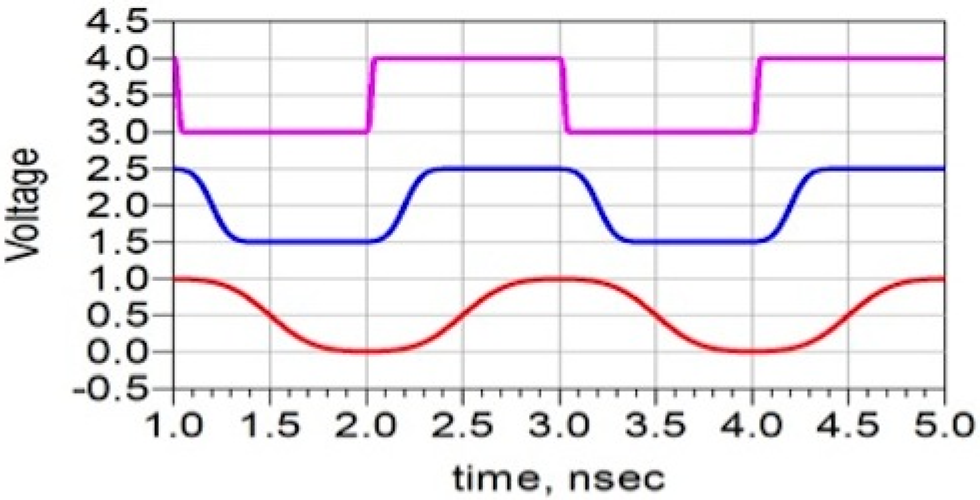

Figure 1. Three different signals with the same clock frequency, but very different bandwidths.

Clearly, just knowing the clock frequency of a signal is not enough to know the highest sine wave frequency in the signal. We have to know the rise time of the signal.

But, “sometimes an OK answer NOW! is better than a good answer late.” Sometimes, we just don’t have all the information we need to get a good answer and rather than wait around until we can get all the information we need, we have to make do with what we have.

In order to estimate the bandwidth of a signal, we have to know what its rise time is. If we only know the clock frequency, we have to “guess” the rise time. If we want to sound like we have put some more thought into it, we can say, “estimate” or if we want to sound like we really know what we are doing, we can say, “extrapolate” the rise time.

The question is, what percent of the period is the rise time? It may be 1% the period if we have a leading edge ASIC driving a legacy bus. It may be 25% if we are driving the TX as fast as its little heart will go.

We always use as much information as we can about the specific signal to “estimate” its rise time. If we don’t know anything then a good starting place is to assume the rise time is

RT = 7% x Period

This is usually a little conservative a guess. This rise time is a little shorter than we might normally find, so would give us a little higher estimate on the bandwidth of the signal. But, it is a good starting place.

Knowing the rise time, we can estimate the bandwidth of the signal:

$$BW = \frac{0.35}{RT} = \frac{0.35}{0.07 \times T} = \frac{0.35}{0.07} \times F_{clock} = 5 \times F_{clock}$$

Based on this assumption of the rise time being 7% the period, we can estimate the bandwidth of the signal as 5 times the clock frequency. This really says the bandwidth is the 5th harmonic of the clock.

Of course the bandwidth depends on the rise time, but if we don’t know the rise time this is a good starting place estimate.

For example, if the clock frequency is 1 GHz, the bandwidth is 5 GHz. If the clock frequency is 2.5 GHz, the bandwidth is 12.5 GHz.

If we have a USB 2.0 signal, the data rate is 400 Mbps. What is the bandwidth? Since most serial links are NRZ (non return to zero) and with 2 bits per cycle, the underlying clock frequency, the Nyquist, is ½ the bit rate. For a 400 Mbps signal, the clock is 200 MHz, and the bandwidth is 1 GHz.

You try it:

1. What is the bandwidth of a 33 MHz PCI bus?

2. What is the bandwidth of a PCIe I bus, at the TX?

3. What is the bandwidth of a PCIe III bus at the TX?

Leave your answers and your own examples in the comments section.

Next rule of thumb, RoT #3: The speed of a signal.

Also See:

- Build a UWB pulse generator on an FPGA
- Problems and solutions for clocks and clocking