

CW 19 summary

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1 Understanding RF Specifications

1.1 Basic Terminology

digitizer amplitude error

The following formula provides the dampening or attenuation factor E of the digitizer:

$$E = 1 - \frac{R}{\sqrt{1 + R^2}} \quad (1)$$

A X -Hz digitizer is defined to have $E = \frac{1}{\sqrt{2}}$ at the frequency X , which implies $R = 1$ for the frequency X . X is called bandwidth of the digitizer in this context, and R is the ratio of the digitizer bandwidth and the maximum frequency of interest $\frac{f_d}{f_i}$.

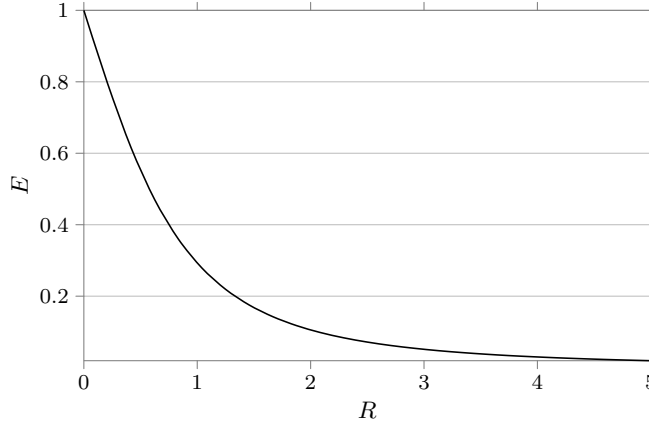


Figure 1: Digitization error versus bandwidth ratio

It is recommended by NI to have X be 3 to 5 times higher than the frequency of interest. This corresponds to errors or dampening between 1.94% and 5.13%

rise time

Rise time is defined as the time a signal needs to rise from 10% to 90% of its steady-state or periodic maximum.

- The rise time of a simple RC-circuit is about $\frac{0.35}{RC}$.
- The formula to calculate the total rise time of a digitized signal is:

$$T_{r_t} = \sqrt{T_{r_s}^2 + T_{r_d}^2}$$

- In order to minimize rise time errors NI recommends to have T_{r_d} be around $\frac{1}{3}$ and $\frac{1}{5}$ of T_{r_s} .

Nyquist Theorem

The bandwidth of the digitizer must be at least 2 times the maximum frequency of the signal to avoid aliasing.

\Leftrightarrow To extinguish aliasing in the passband one either has to make sure the Nyquist Theorem is matched or apply a lowpass filter to limit the signal's bandwidth.

phase noise

Phase noise is the frequency domain representation of time domain jitter. Jitter in turn is the first derivative of a delay. Phase noise is usually close to the carrier and thus measured in dBc (decibels relative to the carrier).

spectral density

Measures the power per frequency in a frequency domain [W/Hz].

resolution bandwidth

The resolution bandwidth equals the FFT bin size and is smallest resolvable frequency. It is inversely proportional to the number of samples.

noise density

Noise level below which signal cannot be detected. One has to distinguish between broadband noise density of a sinusoidal and random (perhaps AWGN) noise. In the latter case one can use a narrow band filter to improve our signal.

dynamic range

Ratio between the highest and lowest signal level a circuit can take. Spurious dynamic range is the ratio between the highest and lowest signal level, without any unwanted sinusoidal frequencies. It is usually expressed in dB.

voltage standing wave ratio (VSWR)

The VSWR is the reflected-to-transmitted wave ratio. Self-evidently, the smaller, the better.

$$VSWR = \frac{1 + p}{1 - p}$$

where p is the reflection coefficient.

Note that is also possible to represent reflections as return loss (in dB):

$$\begin{aligned}
RL &= 10 \log \left(\frac{P_{\text{in}}}{P_{\text{reflected}}} \right) \\
&= 20 \log \left(\frac{V_{\text{in}}}{V_{\text{reflected}}} \right) \\
&= -20 \log \left(\frac{V_{\text{reflected}}}{V_{\text{in}}} \right) \\
&= -20 \log (|p|)
\end{aligned}$$

frequency response

Just as a reminder: the frequency response is the fourier transform of the impulse response $h(t)$.

$$H(f) = \int_{-\infty}^{\infty} h(\tau) \cdot \exp(-j2\pi f t) d\tau$$

modulation error ratio (MER)

A measure of SNR for digitally modulated signals, also expressed in dB.

$$MER = \frac{\sum_{j=1}^N \tilde{I}_j^2 + \tilde{Q}_j^2}{\sum_{j=1}^N (\tilde{I}_j - I_j)^2 + (\tilde{Q}_j - Q_j)^2}$$

Where the components with \sim are the ideal and those without are the actually received components of the N symbols of the signal.

IQ procedure

In-phase and quadrature demodulation procedure.

error vector magnitude (EVM)

Quantifies demodulation performance under the influence of noise. The EVM is the normalized root-mean-square of the difference of ideal and measured location over all symbols. It is normalized by the maximum length of an ideal symbol to make the EVM's value comparable under different system gain conditions.

$$EVM = \frac{\sqrt{\frac{1}{N} \sum_{j=1}^N (\tilde{I}_j - I_j)^2 + (\tilde{Q}_j - Q_j)^2}}{|v_{\text{max}}|}$$

third-order intercept (TOI)

Theoretical number. TOI is the power level when the third-order harmonic distortion has the same power level as the fundamental tone. The bigger the TOI, the better since it is a measure for the maximum RF-circuit power.

2 Physical Layer Challenge

2.1 Basic Terminology

2.1.1 FIR Filters

passband, transitionband, stopband

The passband is the frequency band that is not attenuated band of a filter, i.e. that band of allowed frequencies. The stopband is the band that a filter stops, or attenuates strong enough, so that the signal amplitude for those frequencies is below the stopband threshold. The transitionband is an attenuated band between passband and stopband.

filter tap

A filter tap is a (coefficient, delay) pair. The number of taps is often denoted as N. This number is a good measure for the amount of filtering, the required space and the amount of calculation required by the filter.

2.1.2 Frame Synchronization

frame preamble and start frame delimiter (SFD)

Aliases: syncword or sync sequence framing.

Repetitive pattern of all the same nibbles (and thus bytes). Marks an Ethernet frame beginning. After the preamble the one-byte *start frame delimiter* is located to mark the beginning of real data. This mechanism is employed to achieve a self-clocking protocol. The preamble is needed to resynchronize the receiver once a bit slip occurs.

CRC-based framing

[question] CRC-based framing is used in ATM protocols by reusing the header CRC. How exactly does this work? Also, I wondered since 802.11 and Ethernet both also have a FCS (CRC) at the end of their frames, do they use some kind of CRC-based / syncword-based framing at the same time? As of now I think it is as follows: 802.11 and Ethernet frame synchronization is syncword-based and CRC is employed for error correction only.

self-clocking signal

Signal that is synchronized without a separate clock signal. Receiver synchronization information is contained in the signal (preamble+SFD).

bit slip

A lost bit or an extra bit in the signal.

2.2 FIR Filters vs. IIR Filters

2.3 iNets PHY Layer

3 GNU Radio Techniques

3.1 Creating a hierarchical block directly in GRC

3.2 Read and Write Stream Tags

4 Good to Know...

4.1 Python

4.2 L^AT_EX

I learned...

- ... when to use input or include
- ... some tikz basics