Formatting (2A)

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This document was produced by using OpenOffice and Octave.

Formatting and Source Coding

Formatting

Make the source signal compatible with digital processing

Transmit Formatting

A transformation from source information to digital symbols

Source Coding

Formatting + Data Compression

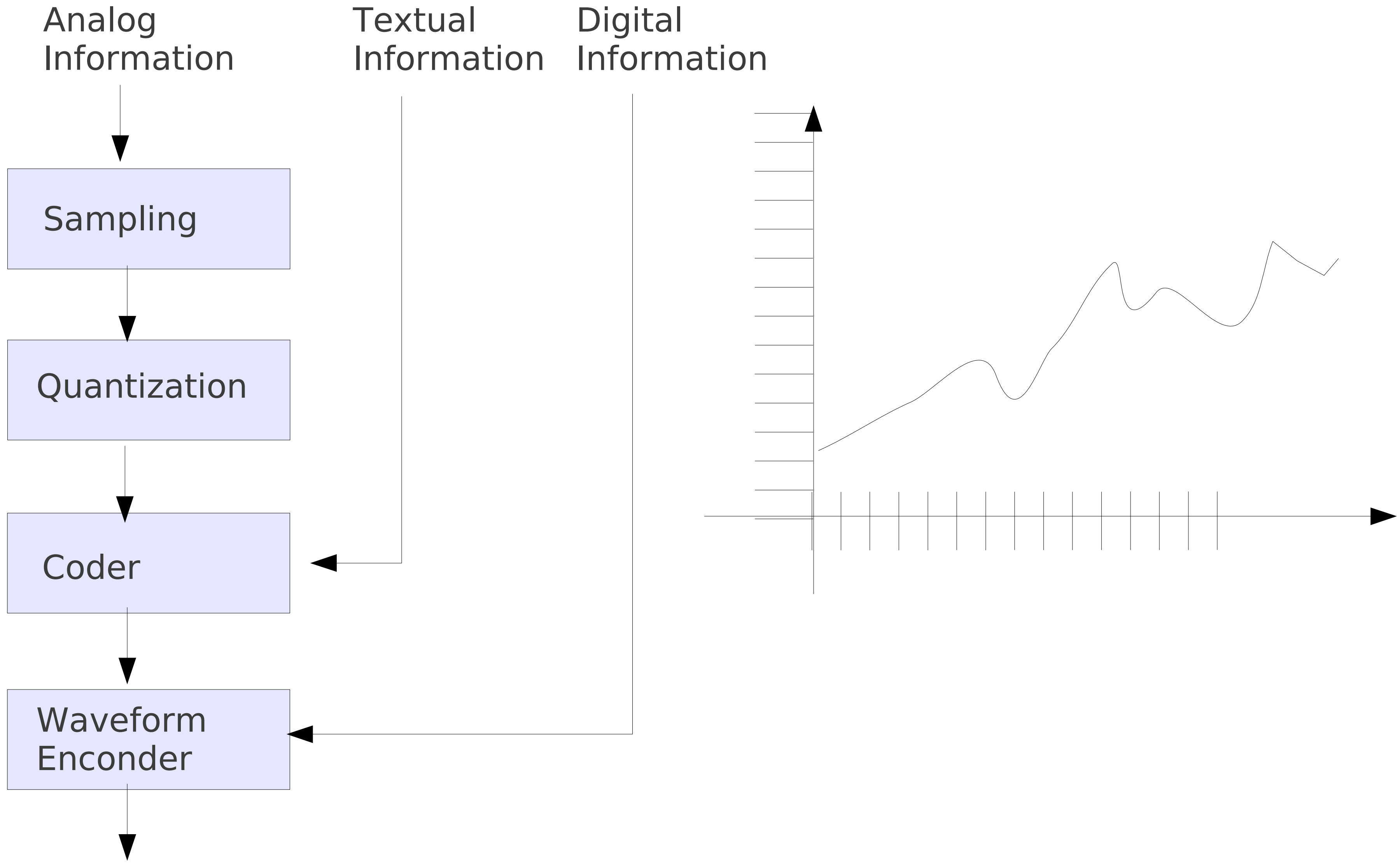
Baseband Signal

From DC up to some finite frequency (< a few MHz)
Transmitted over the cable
Not appropriate to transmit over long distance → Bandpass Mod

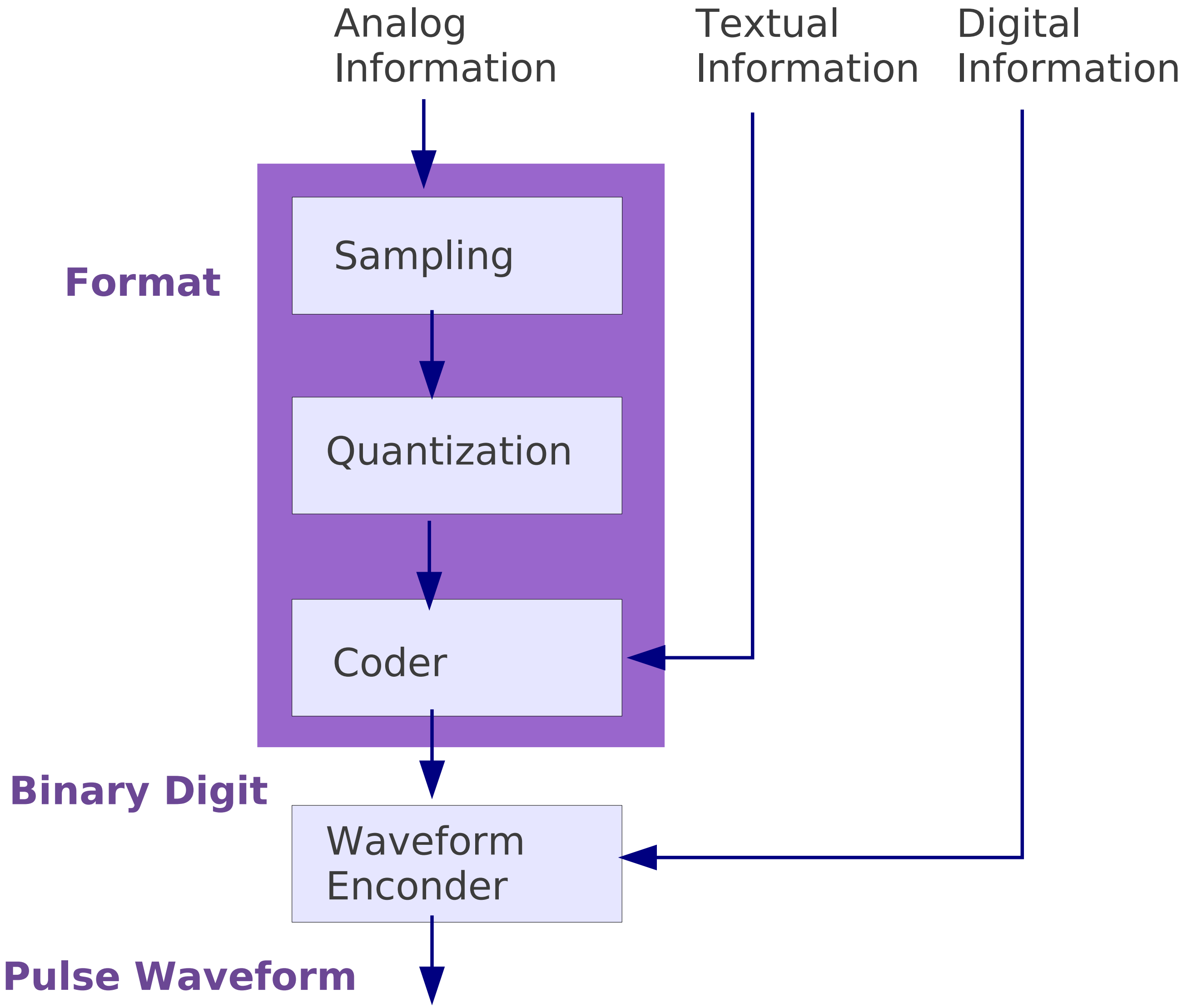
Pulse (Baseband) Modulation

Pulse waveforms are assigned that represent formatted symbols

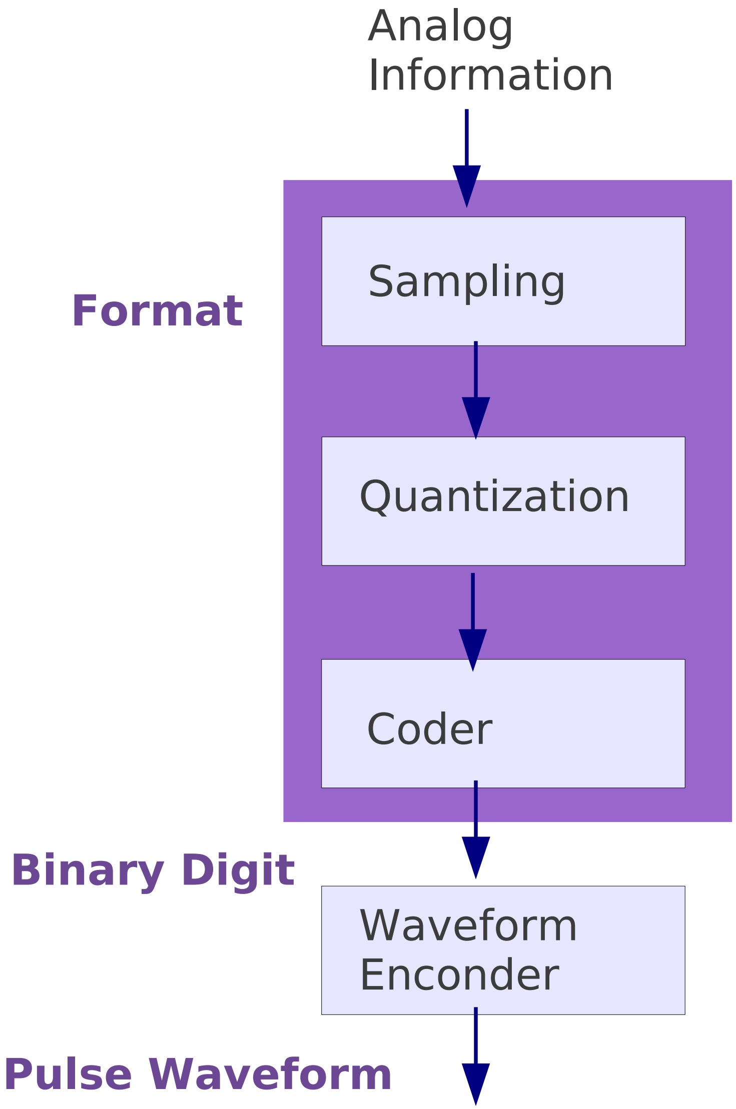
Energy and Power Spectral Densities (2)

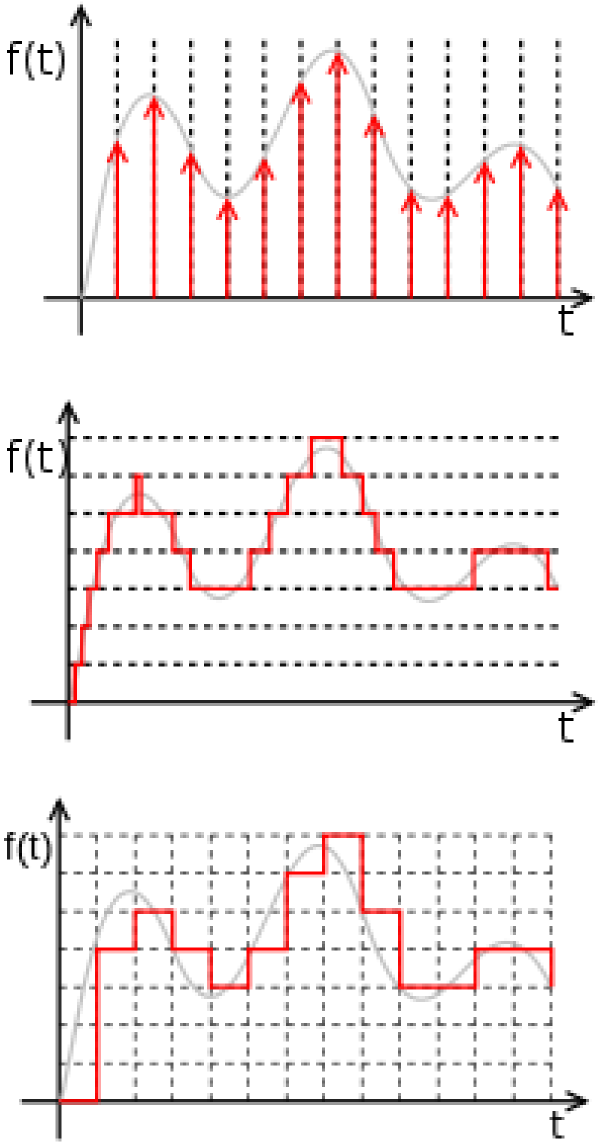


Baseband Signal

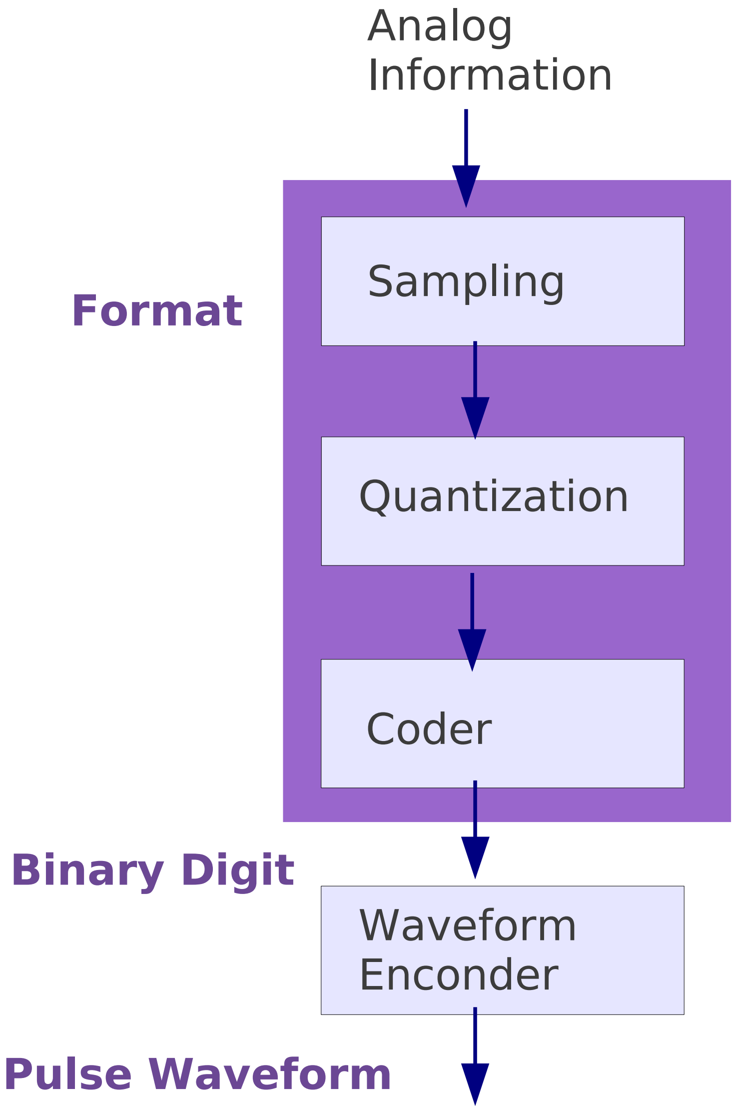


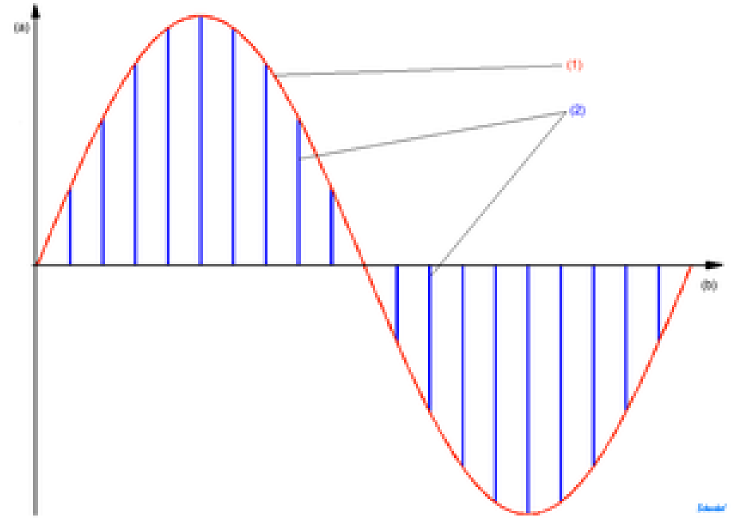
Sampling and Quantization

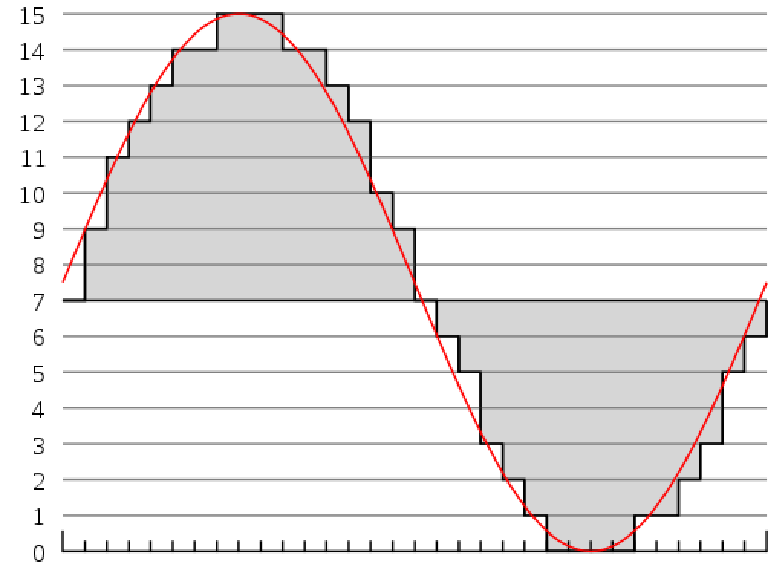




PAM and PCM


Analog
Information
Format
Sampling
Quantization
Coder
Binary Digit
Waveform
Enconder
Pulse Waveform




15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

8-ary Symbol

T H I N K **Message**

001010 000100 100100 011100 110100 **6-bit ASCII**

001 010 000 100 100 100 011 100 110 100

1 2 0 4 4 4 3 4 6 4 8-ary digits `(symbols)

$s_1(t)$ $s_2(t)$ $s_0(t)$ $s_4(t)$ $s_4(t)$ $s_4(t)$ $s_3(t)$ $s_4(t)$ $s_6(t)$ $s_4(t)$ 8-ary waveform

Binary Symbol

T	H	I	N	K	**Message**
001010	000100	100100	011100	110100	**6-bit ASCII**

0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 1 1 0 1 0 0

0 0 1 0 1 0 0 0 0 1 0 0 1 0 0 1 0 0 0 1 1 1 0 0 1 1

binary digits (symbols)

$s_0(t)$ $s_0(t)$ $s_1(t)$ $s_0(t)$ $s_1(t)$ $s_0(t)$ $s_0(t)$ $s_0(t)$ $s_0(t)$ $s_0(t)$ $s_1(t)$ $s_0(t)$ $s_0(t)$

binary waveform

Impulse Sampling

Impulse train

$$x_\delta(t) = \sum_{n=-\infty}^{+\infty} \delta(t - nT_s) \quad \Longleftrightarrow \quad X_\delta(f) = \frac{1}{T_s} \sum_{n=-\infty}^{+\infty} \delta(f - nf_s)$$

Shifting property

$$x(t)\delta(t-t_0) = x(t_0)\delta(t-t_0)$$

$$x_s(t) = x(t)x_\delta(t) \quad \Longleftrightarrow \quad X_s(f) = X(f) * X_\delta(f)$$

$$= \sum_{n=-\infty}^{+\infty} x(t)\delta(t - nT_s) \qquad = X(f) * \left[\frac{1}{T_s} \sum_{n=-\infty}^{+\infty} \delta(f - nf_s)\right]$$

$$= \sum_{n=-\infty}^{+\infty} x(nT_s)\delta(t - nT_s) \qquad = \frac{1}{T_s} \sum_{n=-\infty}^{+\infty} X(f - nf_s)$$

Natural Sampling

Pulse train

$$x_p(t) = \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi n f_s t} \quad \Leftrightarrow \quad c_n = \frac{1}{T_s} sinc\left(\frac{nT}{T_s}\right)$$

$$x_s(t) = x(t) x_p(t) \quad \Leftrightarrow \quad X_s(f) = X(f) * X_p(f)$$

$$= x(t) \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi f_s t}$$

$$= \sum_{n=-\infty}^{+\infty} c_n \left[x(t) e^{j2\pi f_s t} \right] \quad \Leftrightarrow \quad = \sum_{n=-\infty}^{+\infty} c_n X(f - n f_s)$$

Sample and Hold

Sampled Pulse train

$$x_p(t) = \sum_{n=-\infty}^{+\infty} c_n e^{j2\pi n f_s t} \quad \Longleftrightarrow \quad c_n = \frac{1}{T_s} sinc(\frac{nT}{T_s})$$

$$x_s(t) = p(t) * [x(t) x_\delta(t)] \quad \Longleftrightarrow \quad X_s(f) = X(f) * X_p(f)$$

$$= p(t) * \left[x(t) \sum_{n=-\infty}^{+\infty} \delta(t - nT_s) \right] \quad \Longleftrightarrow \quad = P(f) \left[X(f) * \left[\frac{1}{T_s} \sum_{n=-\infty}^{+\infty} \delta(f - nf_s) \right] \right]$$

$$= P(f) \left[\frac{1}{T_s} \sum_{n=-\infty}^{+\infty} X(f - nf_s) \right]$$

Uniform Sampling Theorem

A bandlimited signal having no spectral components above f_m Hz
can be determined uniquely
by values sampled at *uniform intervals* of T_s seconds

$$T_s \le \frac{1}{2 f_m} \qquad f_s = \frac{1}{T_s} \qquad f_s \ge 2 f_m$$

Upper limit of T_s

Lower limit of f_s

Nyquist Criterion

Nyquist Rate $f_s = 2 f_m$

Autocorrelation of Energy and Power Signals

Ensemble Average

WSS (Wide Sense Stationary)

Autocorrelation of Random and Power Signals

Time Averaging and Ergodicity

Autocorrelation of Random and Power Signals

Time Averaging and Ergodicity

References

[1] http://en.wikipedia.org/
[2] http://planetmath.org/
[3] B. Sklar, "Digital Communications: Fundamentals and Applications"