EITF25 Internet--Techniques and Applications

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L2 Physical layer (part 1)

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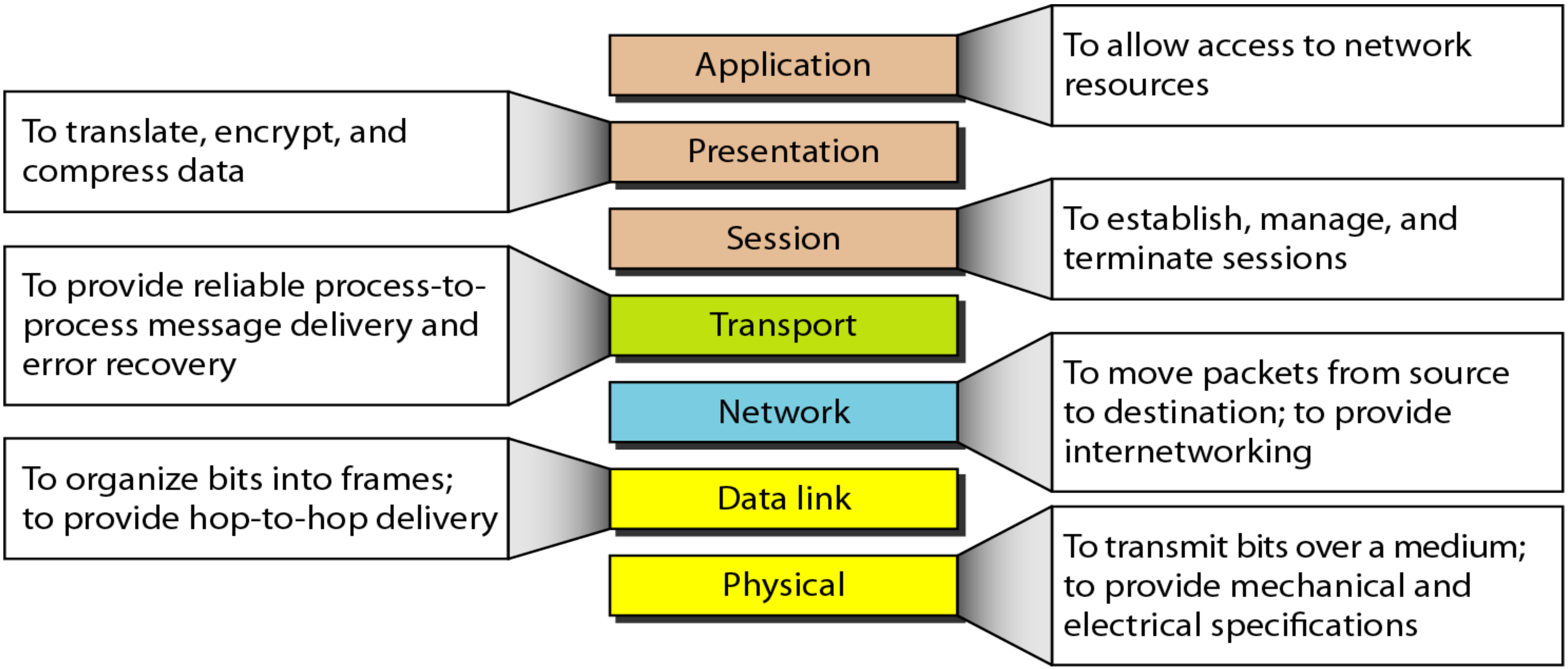
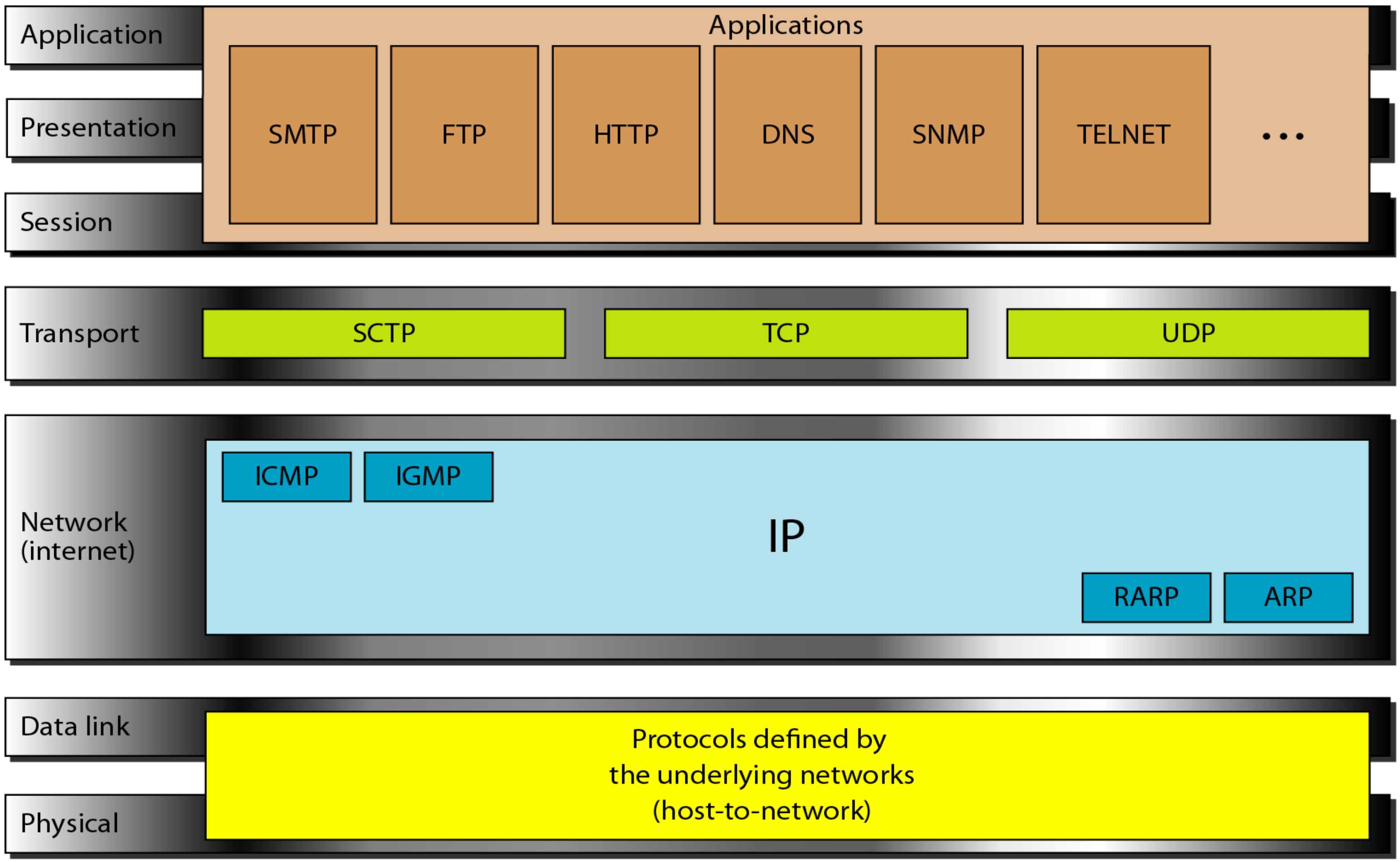
OSI model
Open Systems Interconnection

- Developed by ISO, 1970~



TCP/IP model

- Developed by DARPA, 1970~

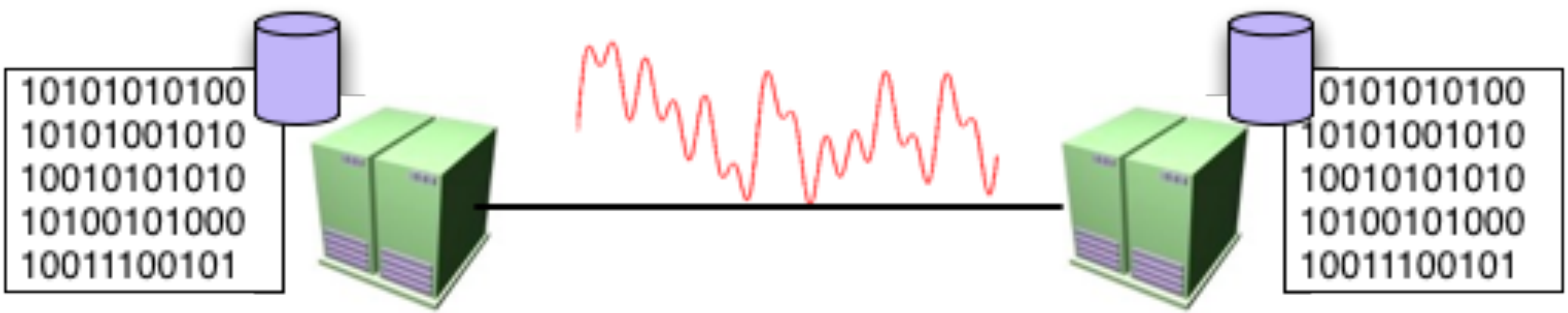


Physical layer

- Analog vs digital signals
  - Sampling, quantisation
- Modulation
  - Represent digital data in a continuous world
- Transmission media
  - Cables and such
- Disturbances
  - Noise and distortion

Data vs Signal

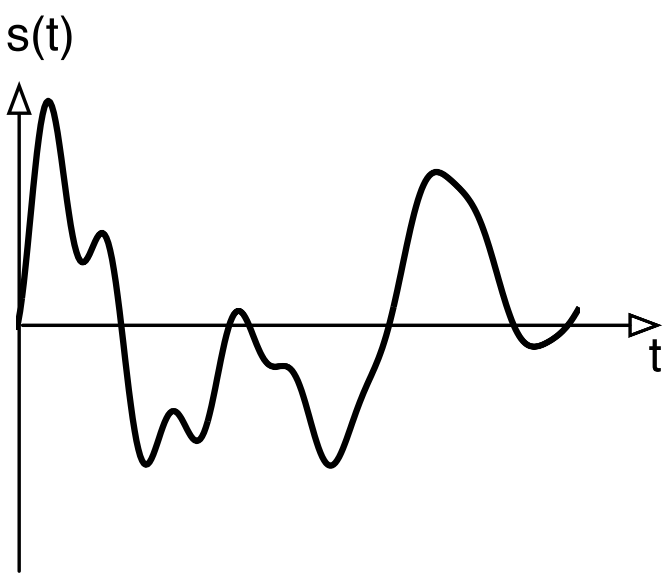
- Data: Static representation of information
  - For storage (often digital)
- Signal: Dynamic representation of information
  - For transmission (often analog)



Analog vs digital

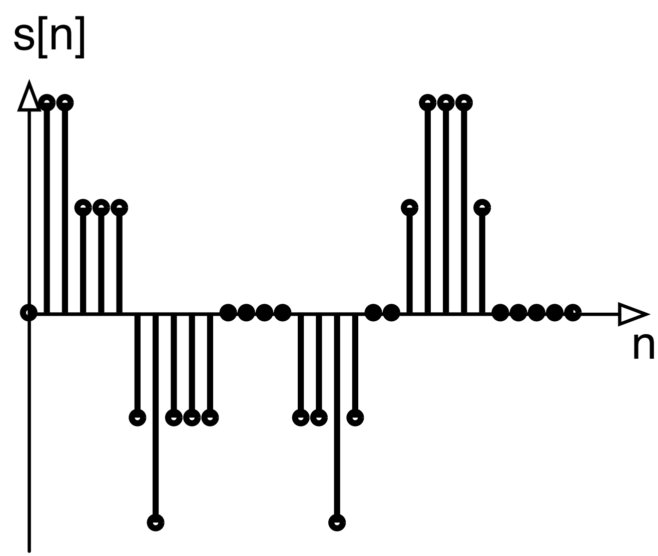
Analog

- Continuous time and amplitude signal
- Electrical/optical domain



Digital

- Discrete time and amplitude
- Binary representation



Digitalization of analog signals

Performed in three steps:

1. Sampling

   Discretization in time

2. Quantization

   Discretization in amplitude

3. Encoding

   Binary representation of amplitude levels

Sampling

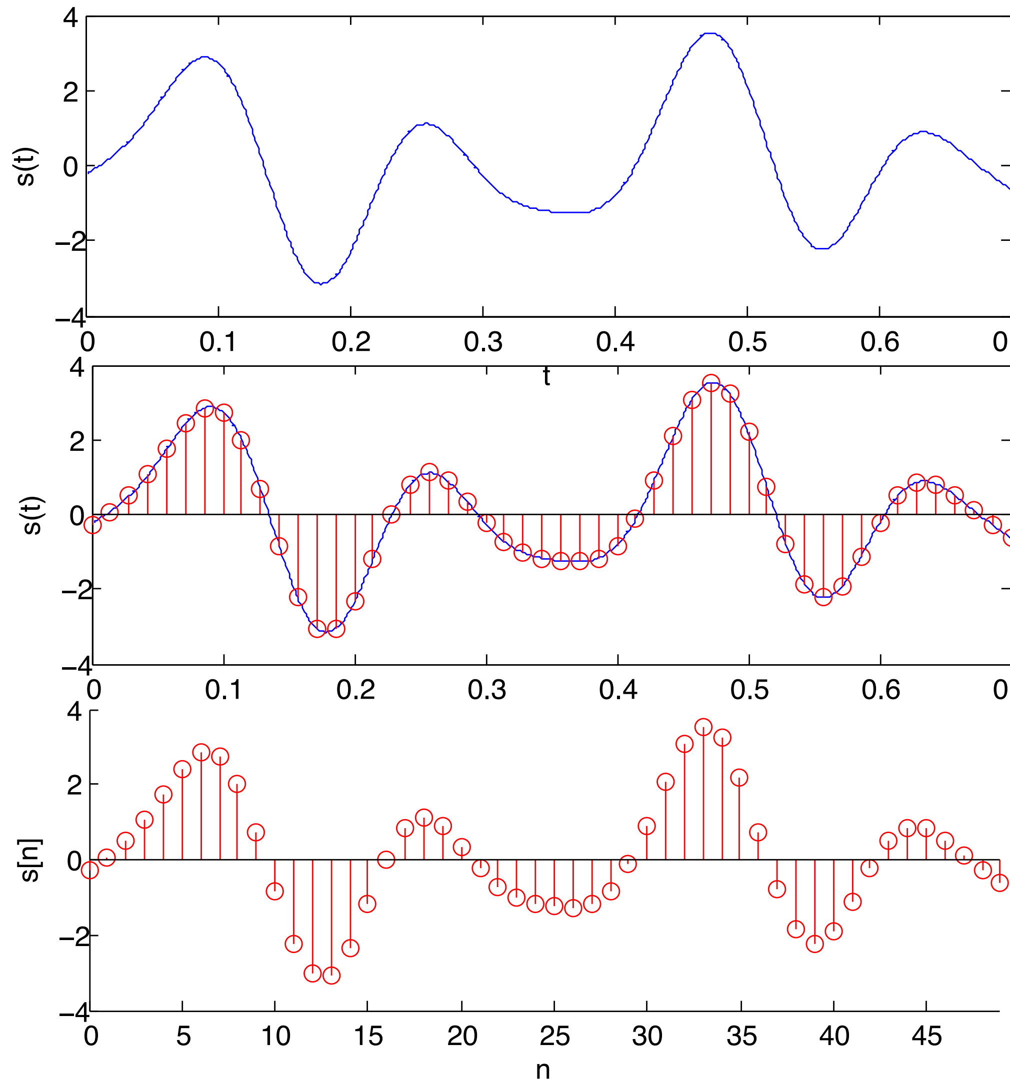
- The process of discretizing time of a continuous signal.

$$s[n] = s(nT_s)$$

- Sampling time: T_s
- Sampling frequnecy:

$$F_s = 1/T_s$$

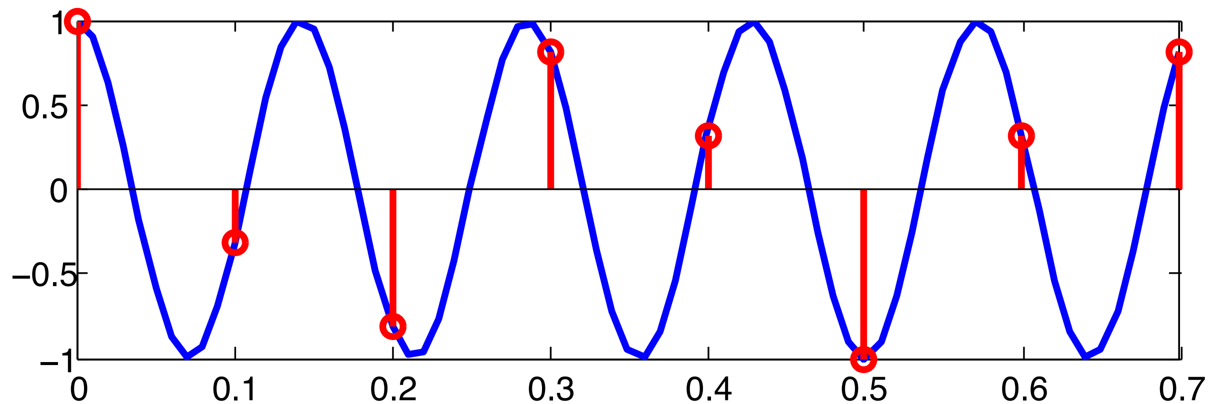
- Loose iformation about time



Aliasing

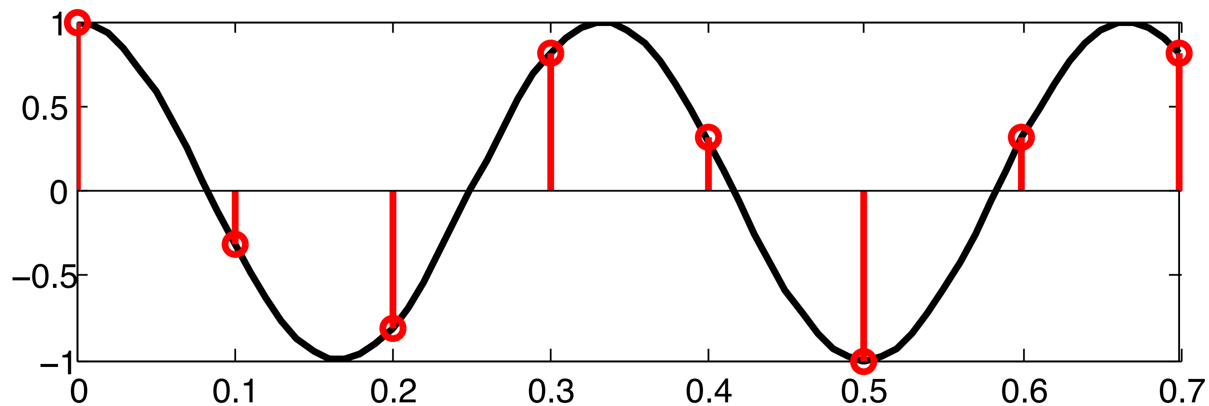
$y(t)=\cos(14\pi t)$

$F_s=10$ Hz



Reconstruction to lowest possible frequency

$y(t)=\cos(6\pi t)$



Shannon-Nyquist Sampling Theorem

If *s(t)* is a band limited signal with highest frequency component F_{max}, then *s(t)* is uniquely determined by the samples $s[n] = s(nT)$ if and only if

$$F_s = \frac{1}{T} \geq 2F_{\max}$$

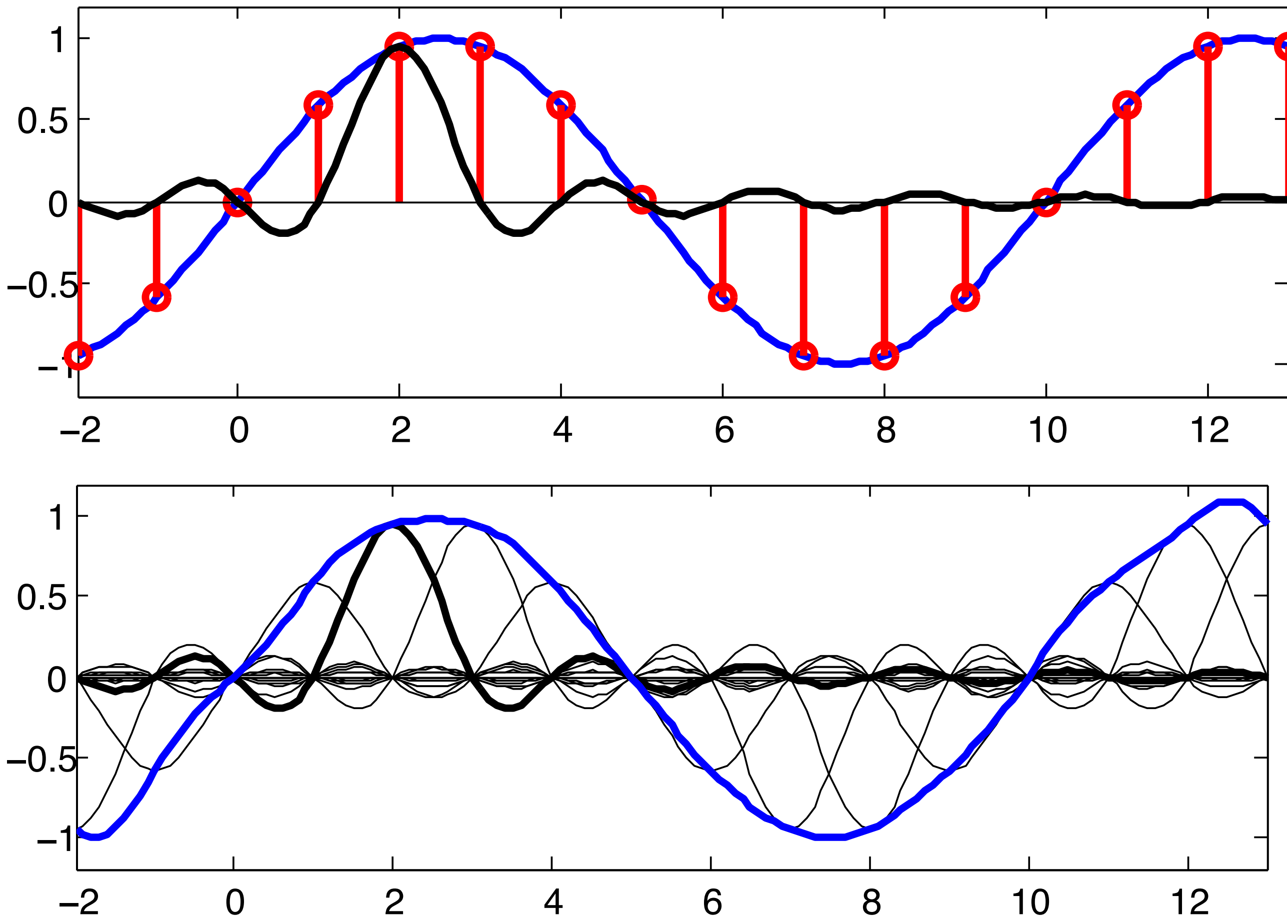
The signal can be reconstructed with

$$s(t) = \sum_{n=-\infty}^{\infty} s[n] \operatorname{sinc}\left(\frac{t - nT_s}{T_s}\right)$$

$F_s/2$ is the Nyquist frequency and $2F_{max}$ the Nyquist rate

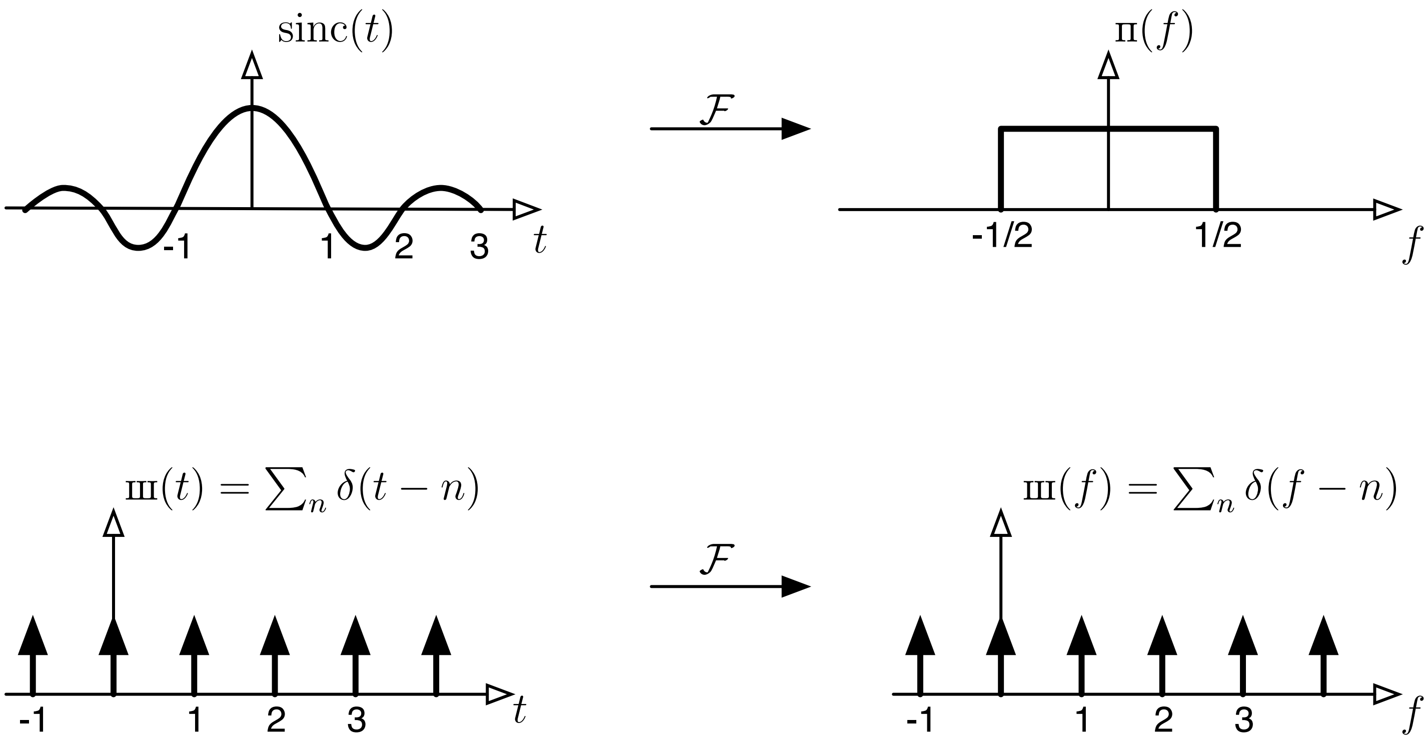
Reconstruction Example

$y(t)=\sin(2/7\pi t)$, $F_s=1\text{Hz}$



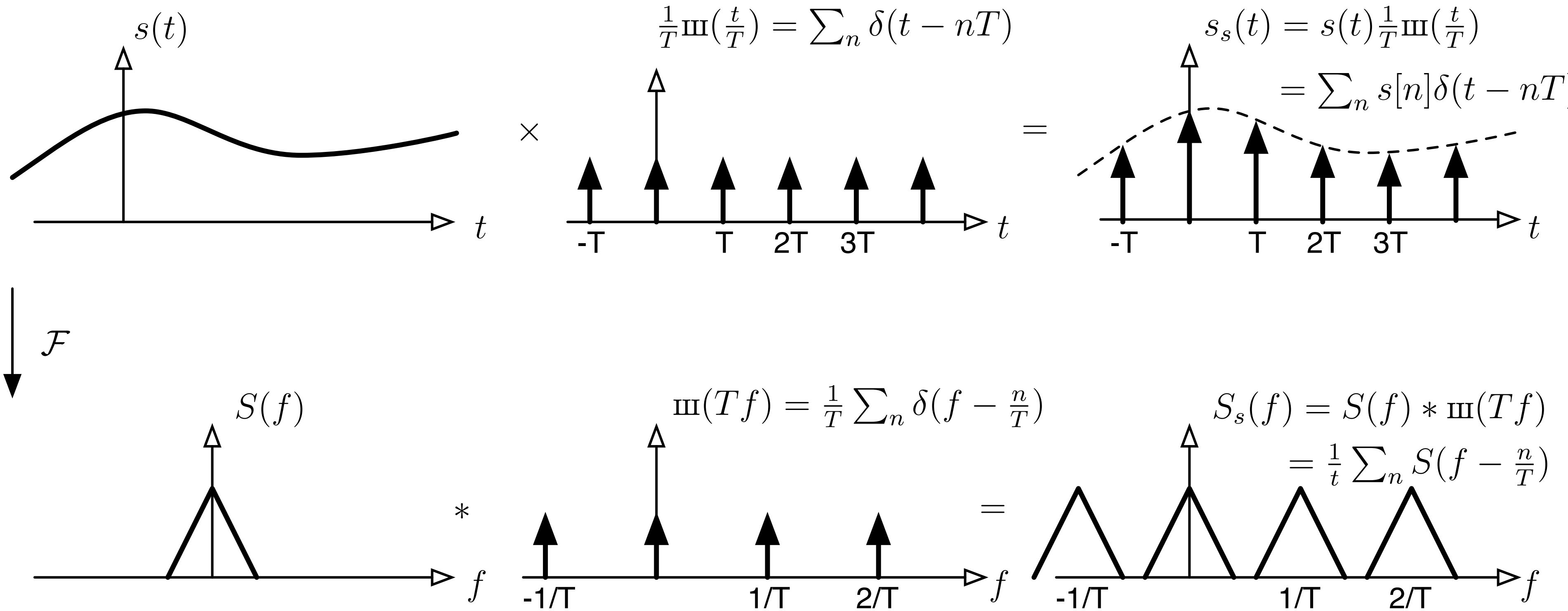
Sampling theorem proof

Two important transforms



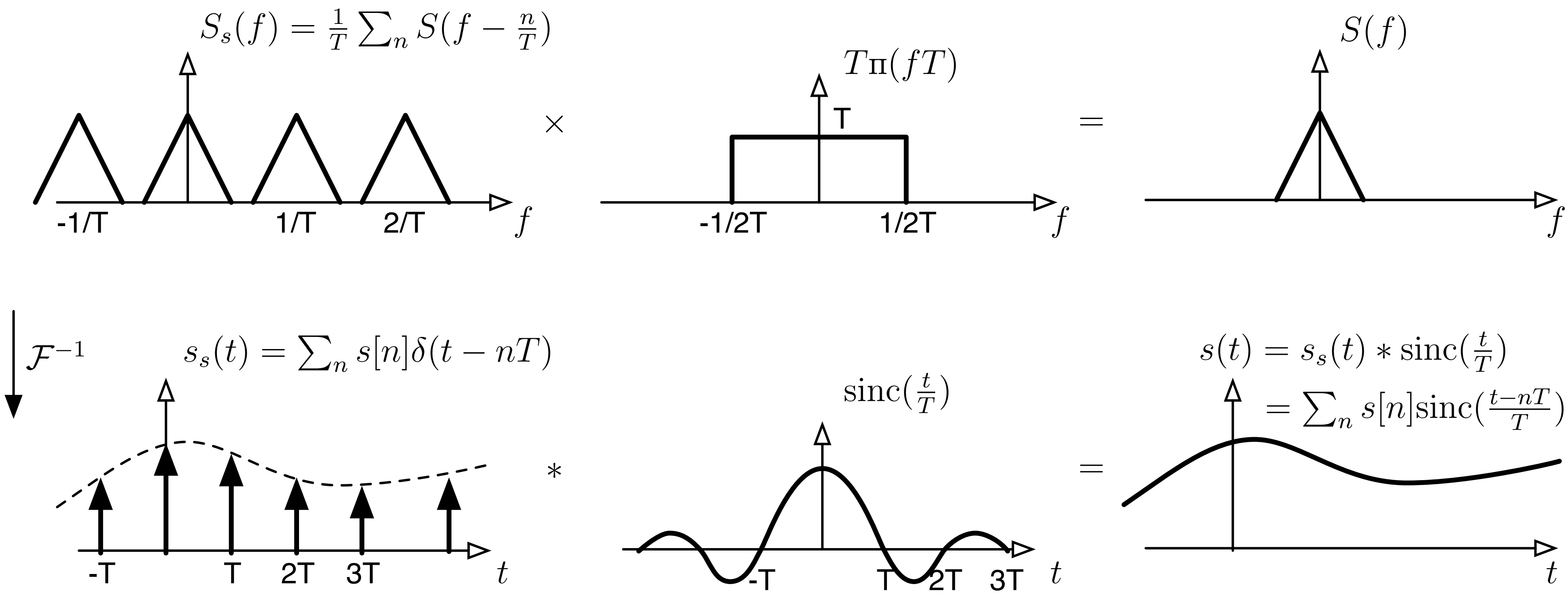
Sampling theorem proof

Mathematical description of sampling



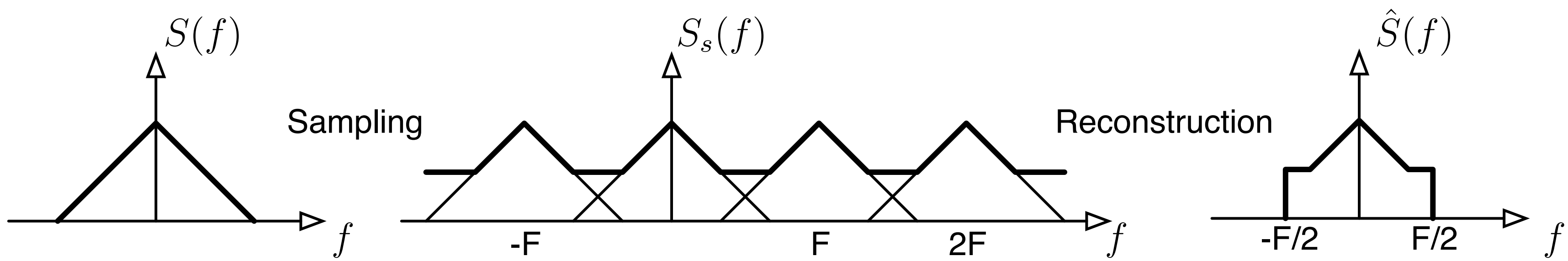
Sampling theorem proof

Reconstruction



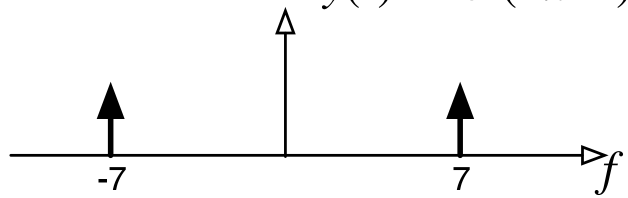
Sampling theorem
Aliasing

Let $F_s < 2F_{max}$

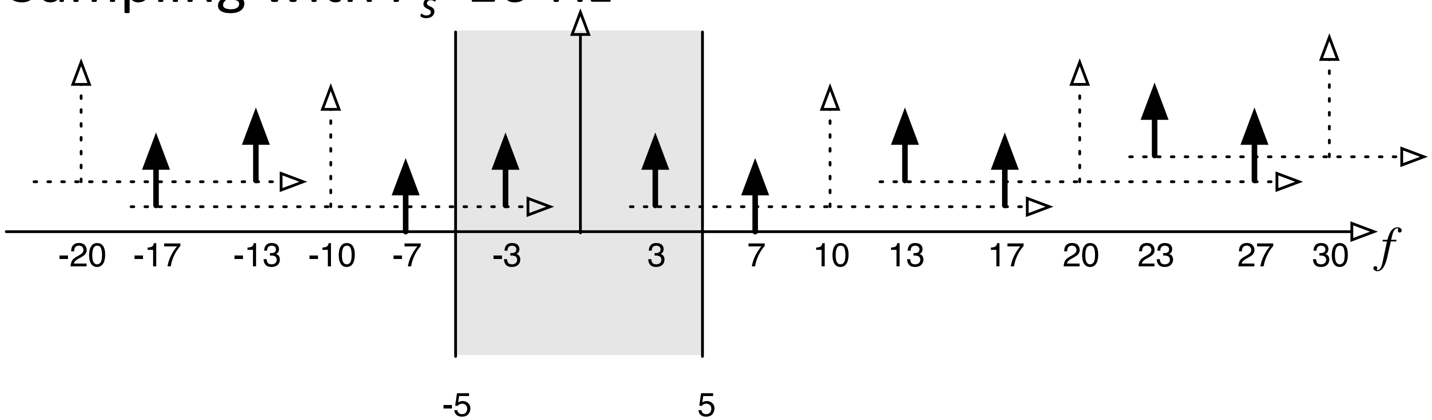


Example

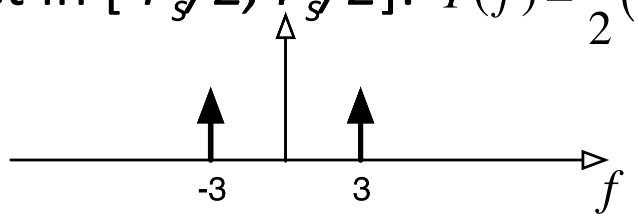
$$y(t)=\cos(2\pi 7t)\rightarrow Y(f)=\frac{1}{2}\big(\delta(f+7)+\delta(f-7)\big)$$



Sampling with $F_s=10$ Hz



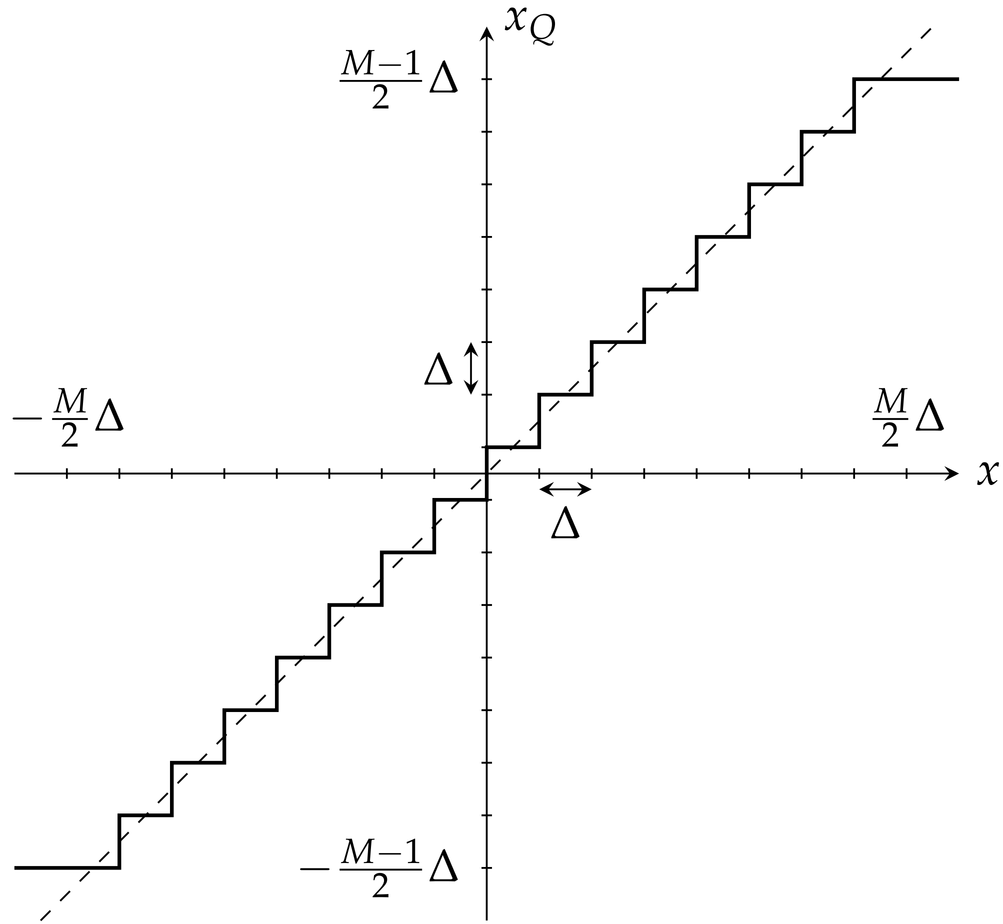
Reconstruct in $[-F_s/2, F_s/2]$: $\hat{Y}(f)=\frac{1}{2}\big(\delta(f+3)+\delta(f-3)\big)\rightarrow \hat{y}(t)=\cos(2\pi 3t)$



Quantization

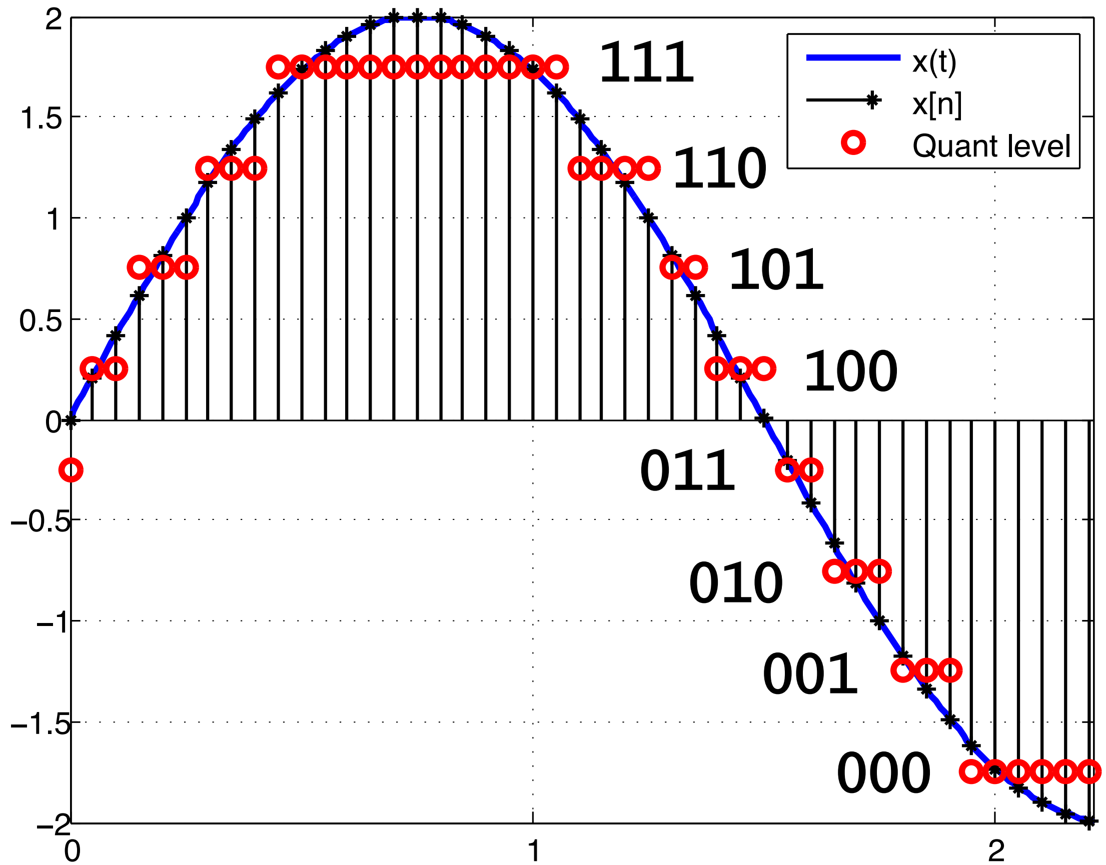
Linear Quantization for k bits

- $M=2^k$ equidistant levels
- Represent sample with *k* bits



Encoding

Representation of quantized samples in bits



x=011100100101101101111111111...

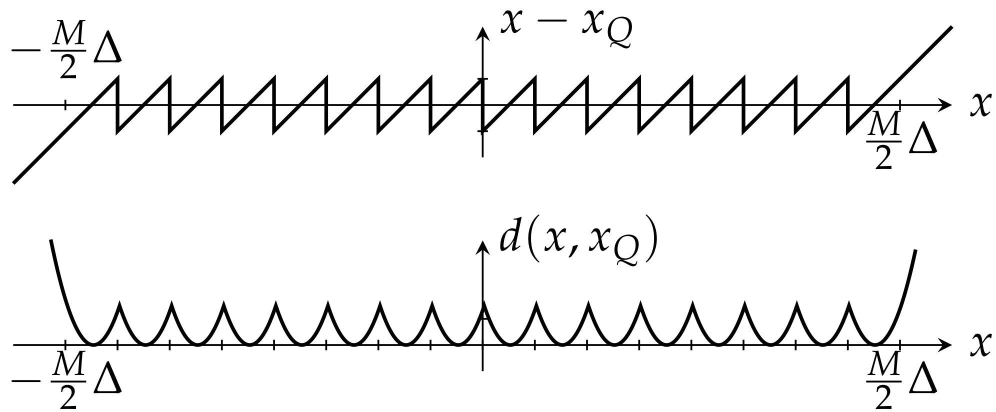
Quantisation distortion

Distortion:

$$d(x, x_Q) = (x - x_Q)^2$$

Average distortion for uniform input:

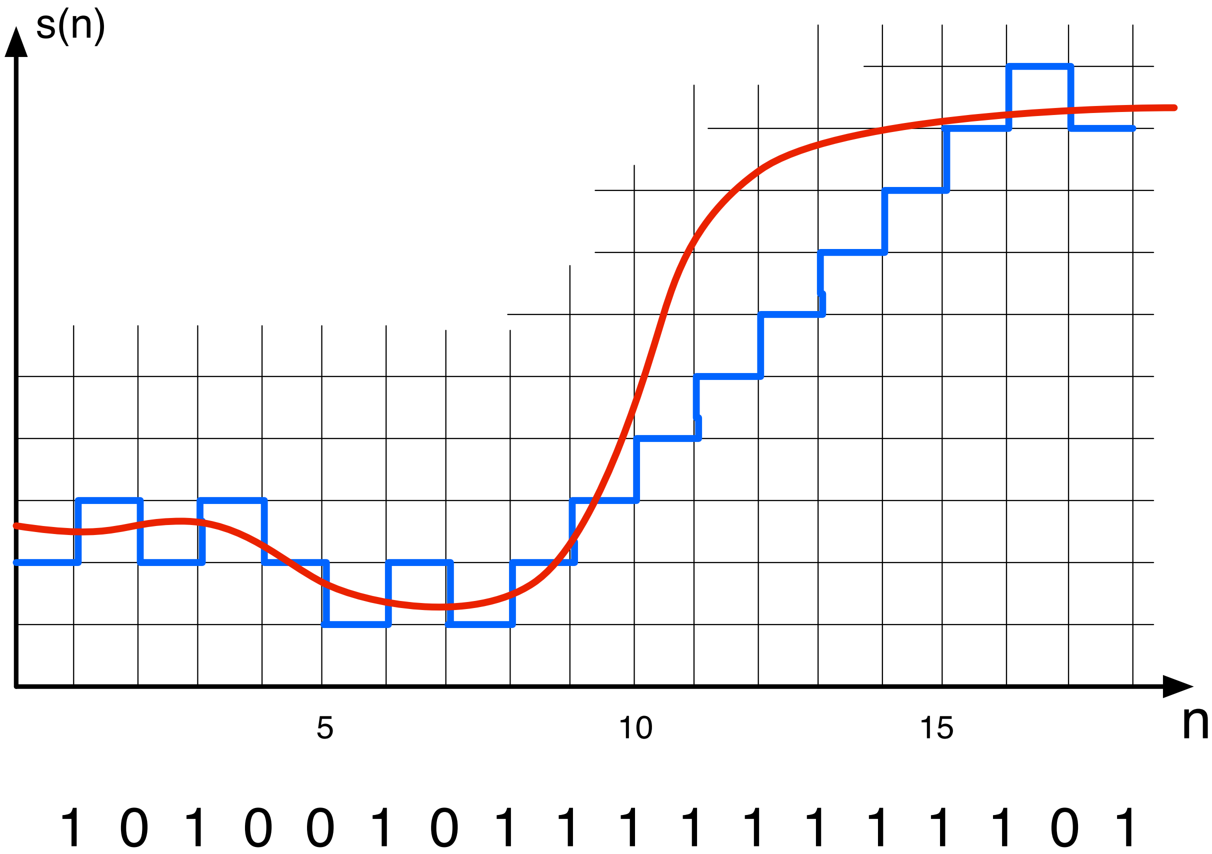
$$E\left[\left(X - X_Q\right)^2\right] = \int_{-\Delta/2}^{\Delta/2} x^2 \frac{1}{\Delta} dx = \frac{\Delta^2}{12}$$



Quantization

Delta modulation

- Represent change in amplitude with 1 bit
  - 1: +1
  - 0: −1
- Must be faster sampling



Examples

Telephony

F_{max}= 4 kHz

F_s= 8 kHz (samples per sec)

8 bit/sample => 64 kb/s

CD

F_{max}= 20 kHz

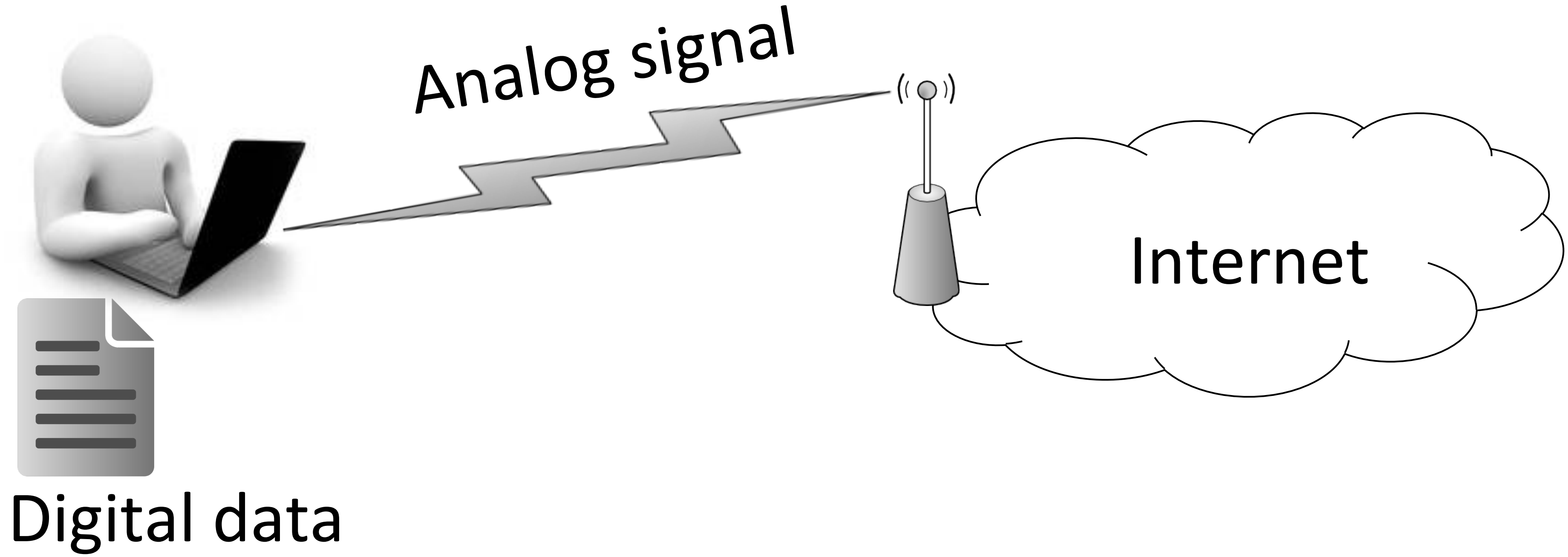
F_s= 44.1 kHz (samples per sec)

16 bit/sample => 705.6 kb/s

2 channels (stereo)
=> 1.4 Mb/s

From bits to signals

Principles of digital communications

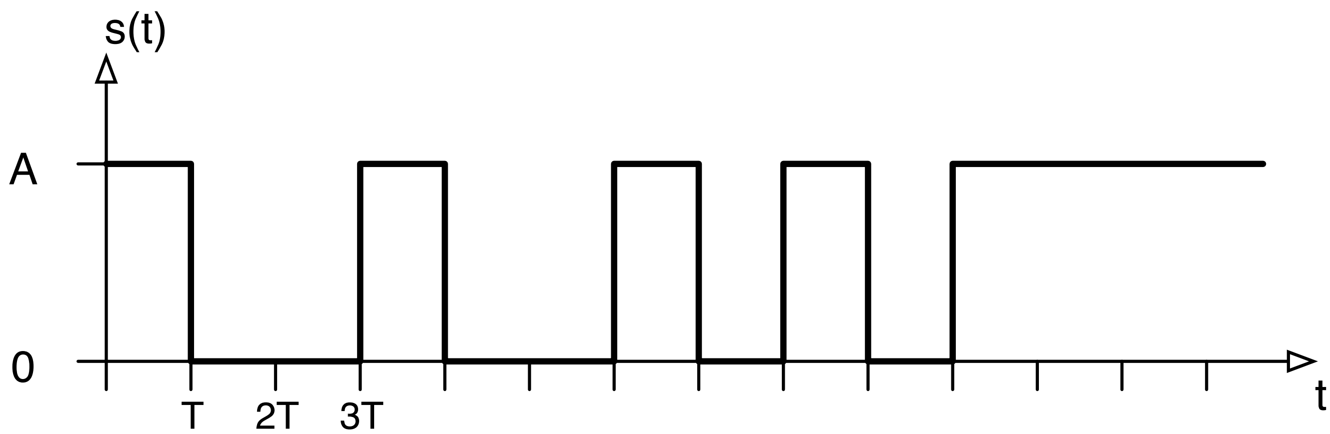


On-off keying

- Send one bit during T_b seconds and use two signal levels, “on” and “off”, for 1 and 0.

Ex.

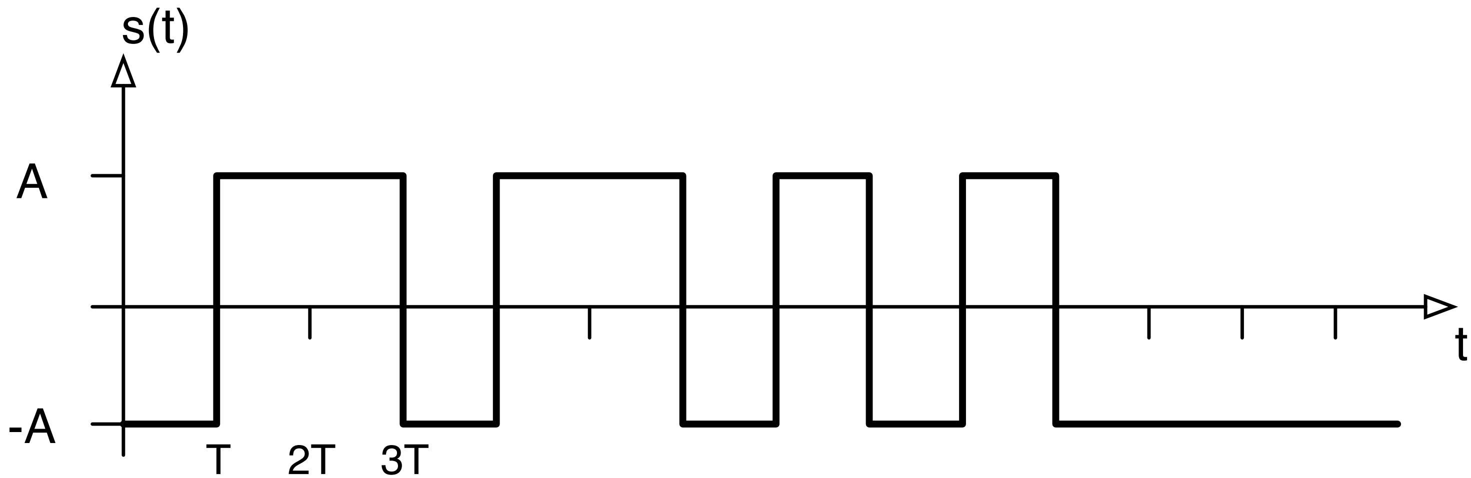
x=10010010101111100



Non-return to zero (NRZ)

- Send one bit during T_b seconds and use two signal levels, +A and -A, for 0 and 1.

Ex. x=1001001010111100



Mathematical description

With g(t)=A, $0<t<T$, the signals can be described as

$$s(t) = \sum_n a_n g(t - nT)$$

- On-off

$$a_n = x_n$$

- NRZ

$$a_n = (-1)^{x_n}$$

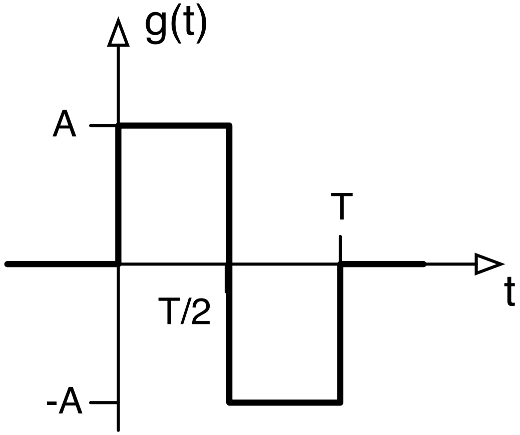
Two signal alternatives

- $s_0(t)=0$ and $s_1(t)=g(t)$
- $s_0(t)=g(t)$ and $s_1(t)=-g(t)$

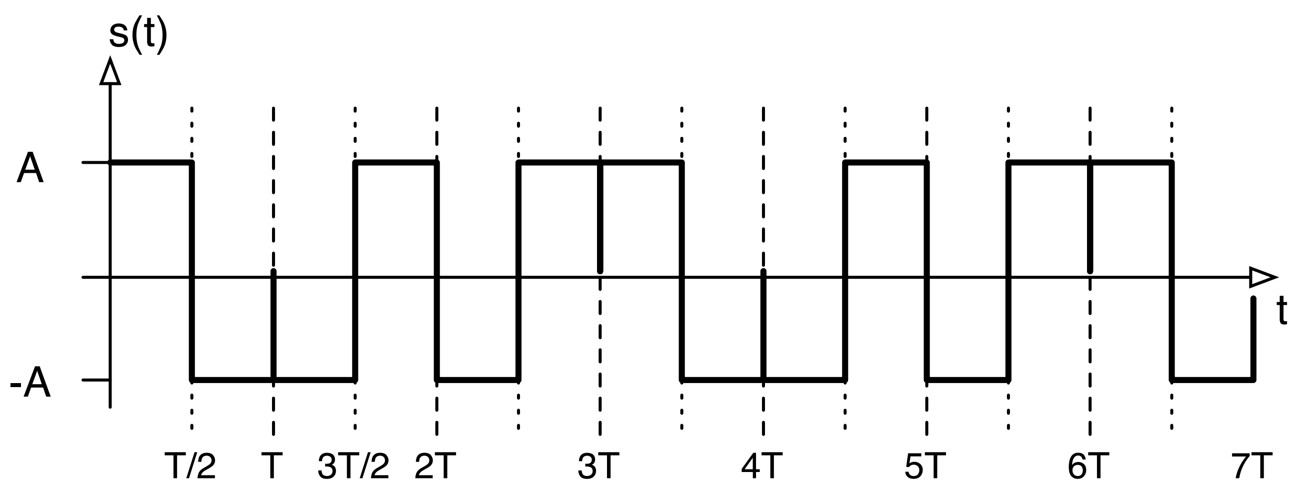
Manchester coding

- To get a zero passing in each signal time, split the pulse shape *g(t)* in two parts and use +/- as amplitude.

Ex.



x=10010010101111100



Multi level modulation

- To transmit k bits in one signal alternative of duration T_s, use $M=2^k$ levels.

Ex. Two bits per signal

x=10 01 00 10 10 11 11 10 00