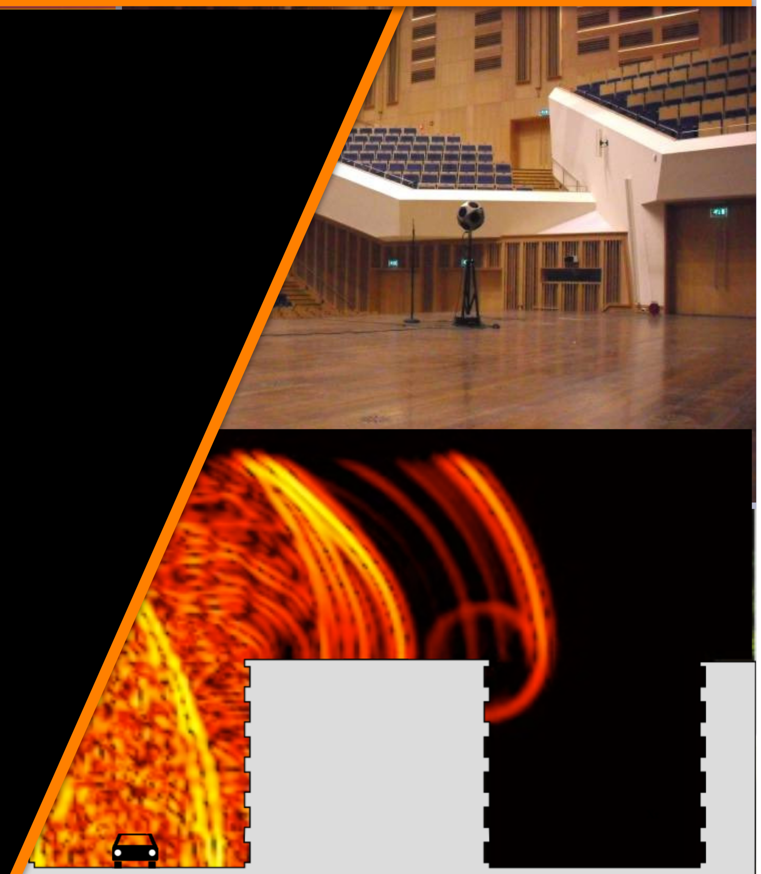
Architectural Acoustics

Week 1: Fundamentals of Acoustics
Lecture F.2

prof.dr.ir. Maarten Hornikx



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Contents

- Wave function (Harmonic motion)
- Complex numbers
- Impedance
- Resonance

- Acoustic Power
- Fourier Transform
- Impulse response and Transfer function

http://metaist.com

Acoustic power

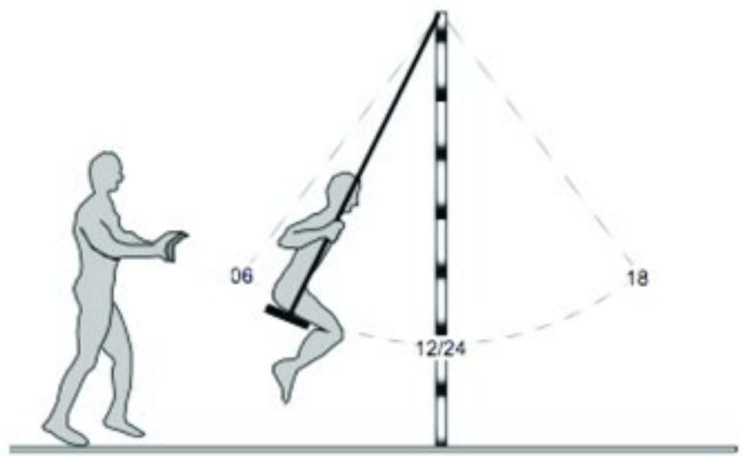
Acoustic power: amount of acoustic energy
Examples:

- Acoustic power radiated by a sound source (loudspeaker)
- Vibration energy injected into floor (while walking on it)

$$P \quad = \quad F \cdot v$$

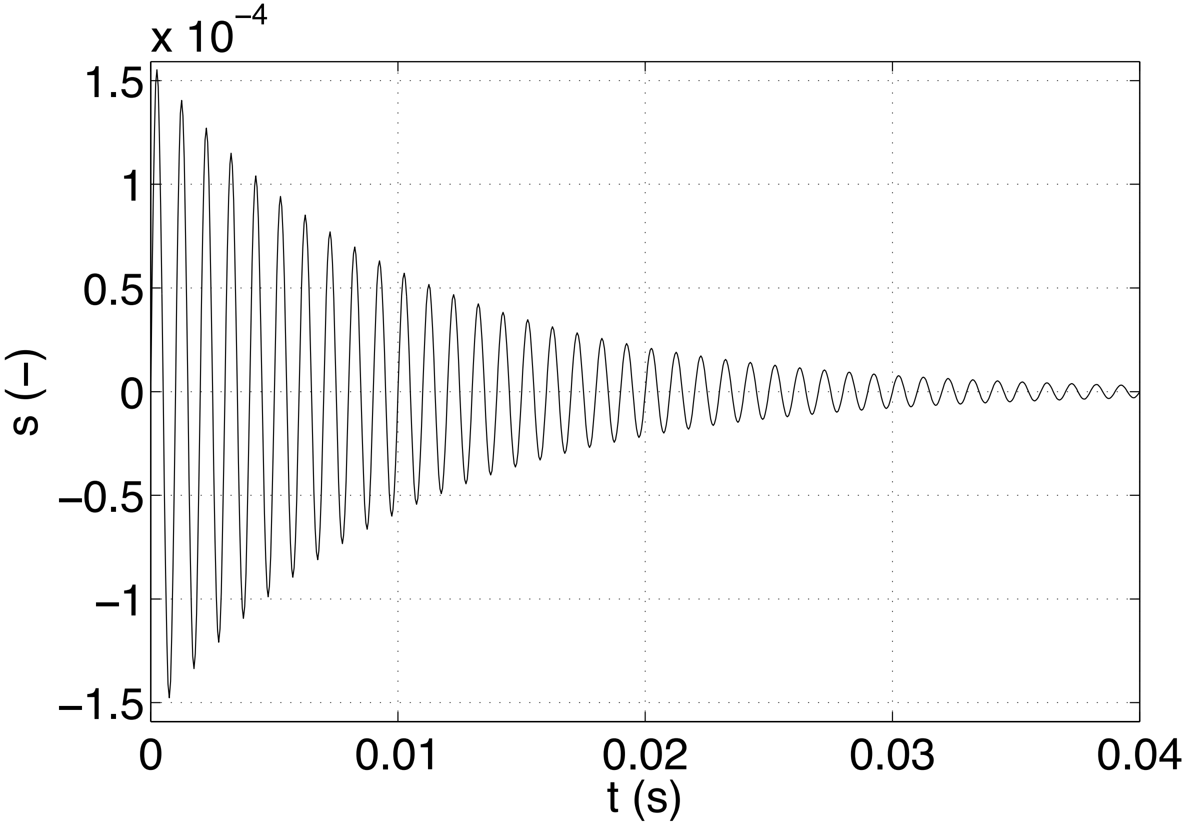
Tot total power is the time-independent part of the (time-average of the oscillating part of P is zero)

$$P_a \quad = \quad \frac{1}{2}\hat{v}^2 Re\{Z\}$$



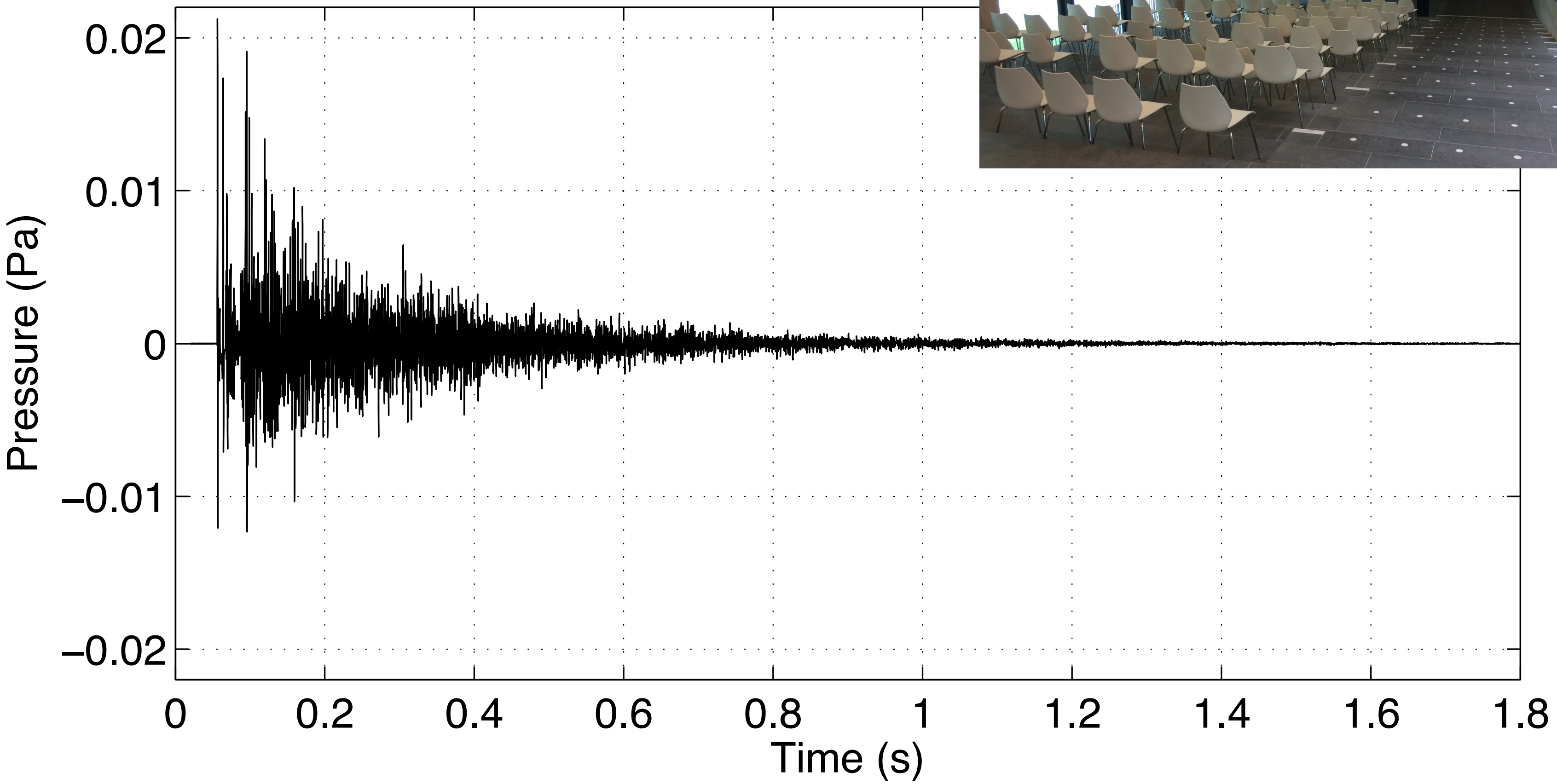
https://www.researchgate.net/publication/267942854_Clocks_in_Action_Exploring_the_impact_of_internal_time_in_real_life

Transient response

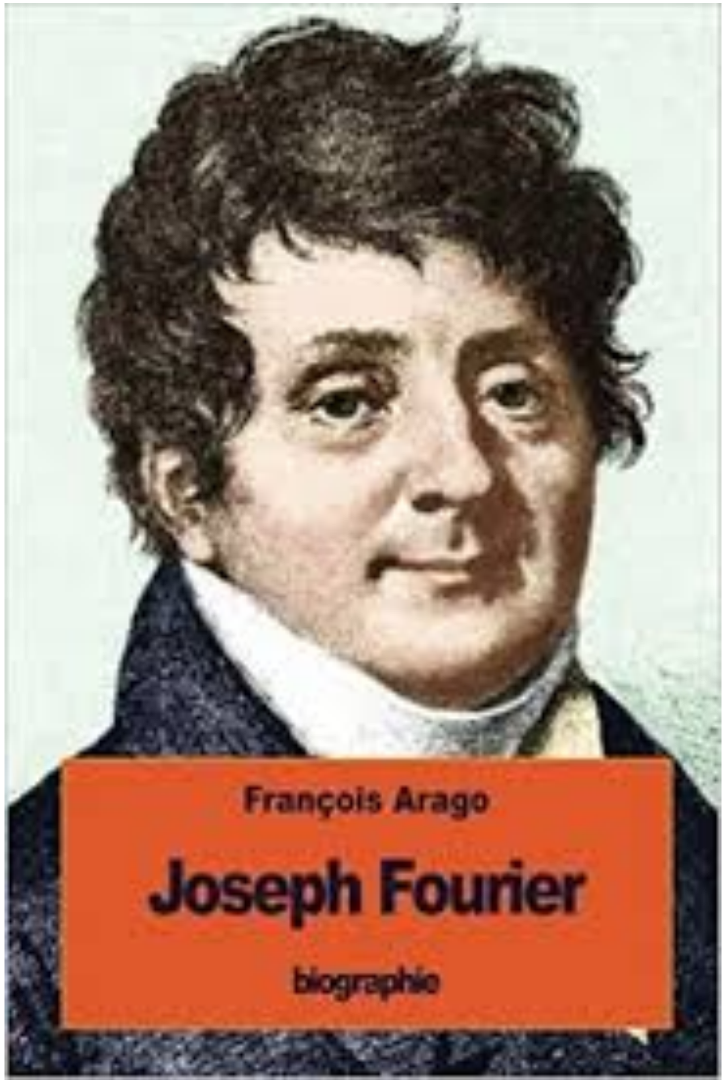


$$s(t) \quad = \quad \hat{s}e^{\delta t}e^{j(\omega t+\phi)}$$

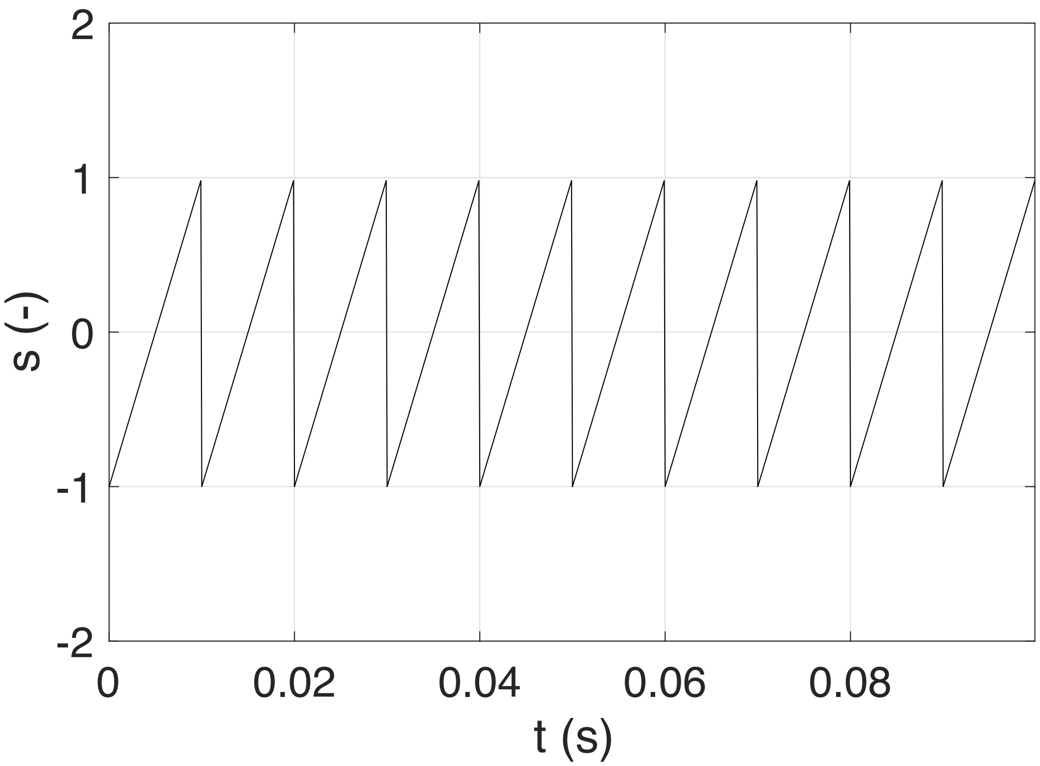
Transient response



Fourier Transform



Periodic signals

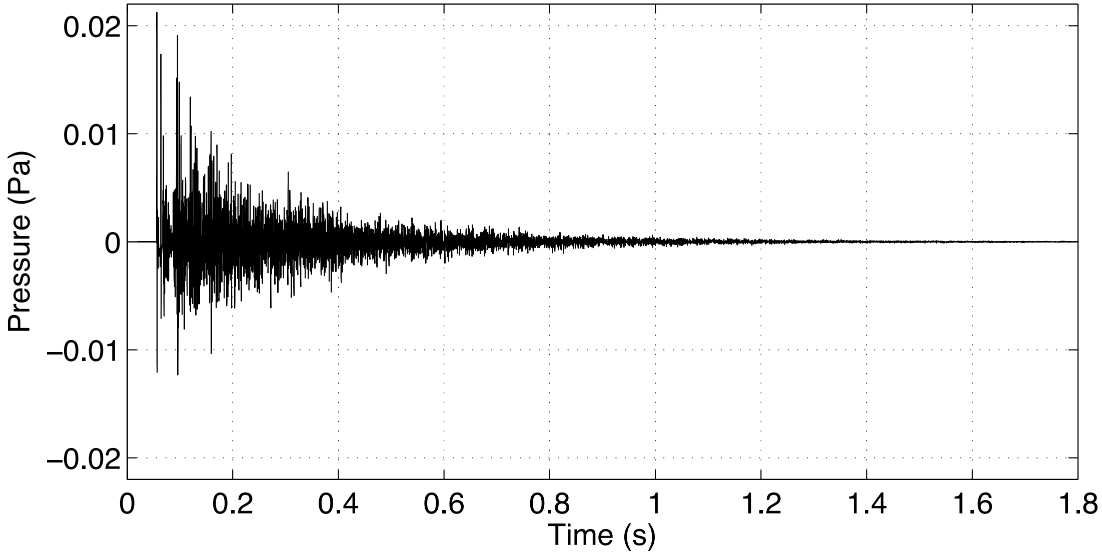


$$s(t) = \sum_{n=-\infty}^{\infty} C_n e^{j\omega_0 n t}$$

$$\omega_0 = \frac{2\pi}{T}$$

C_n = Fourier coefficients

Non-periodic signals

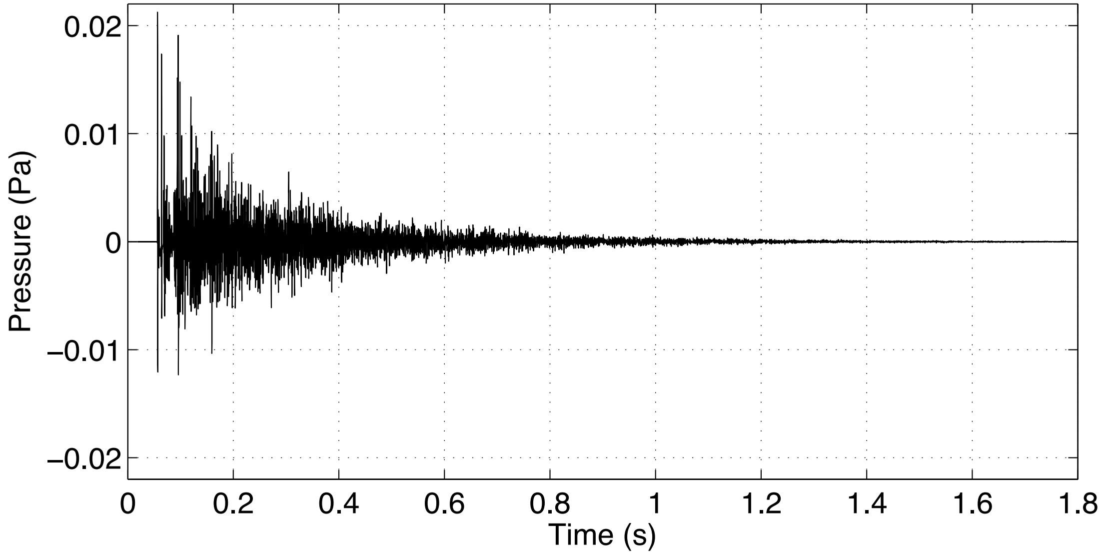


$$s(t) = \int_{-\infty}^{\infty} C(\omega) e^{j\omega t} d\omega$$

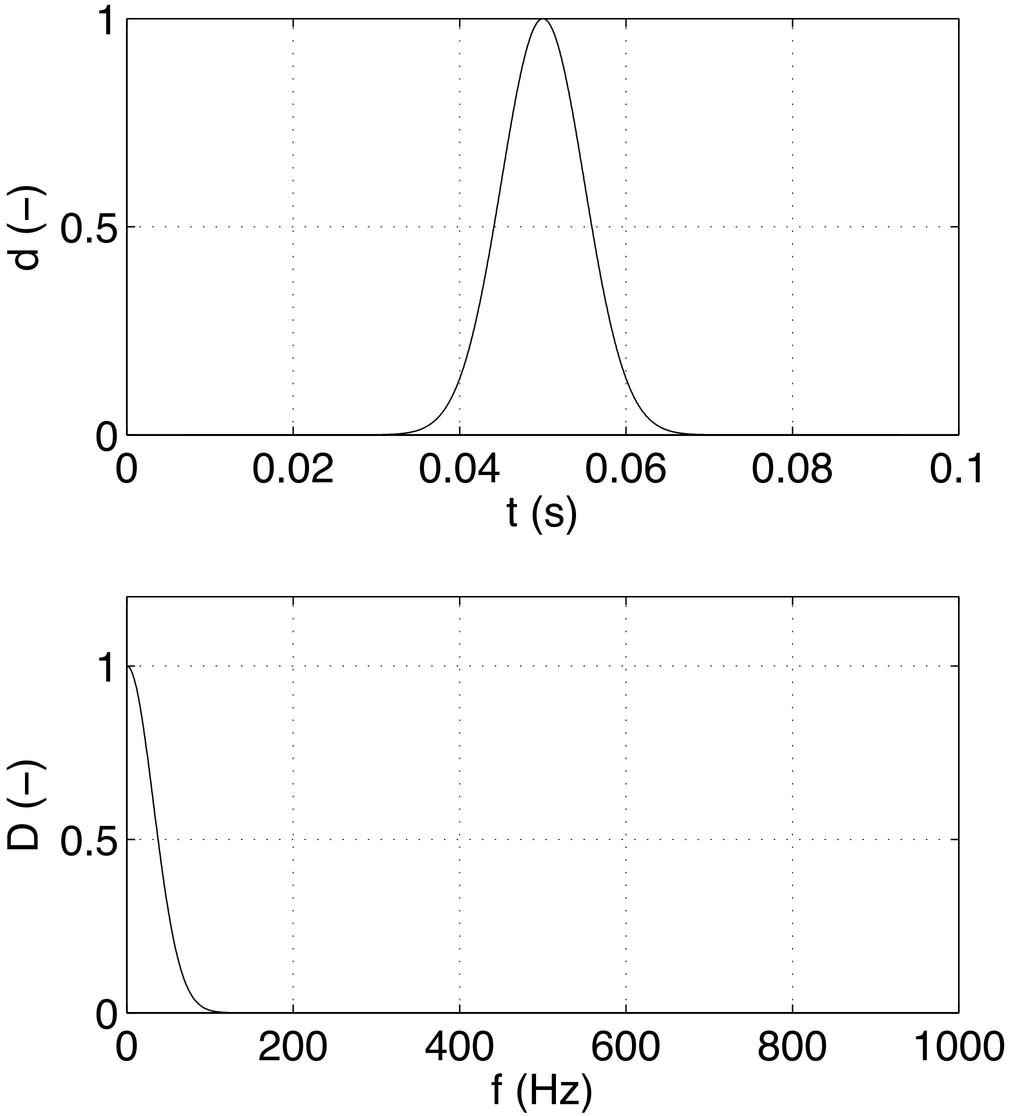
$$C(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} s(t) e^{-j\omega t} dt$$

Fourier Transform

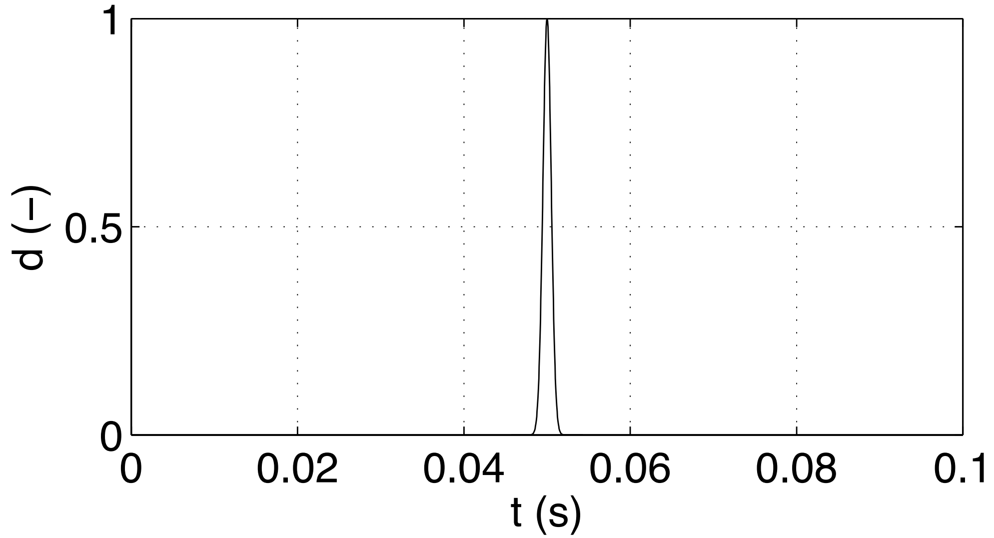
Non-periodic signals

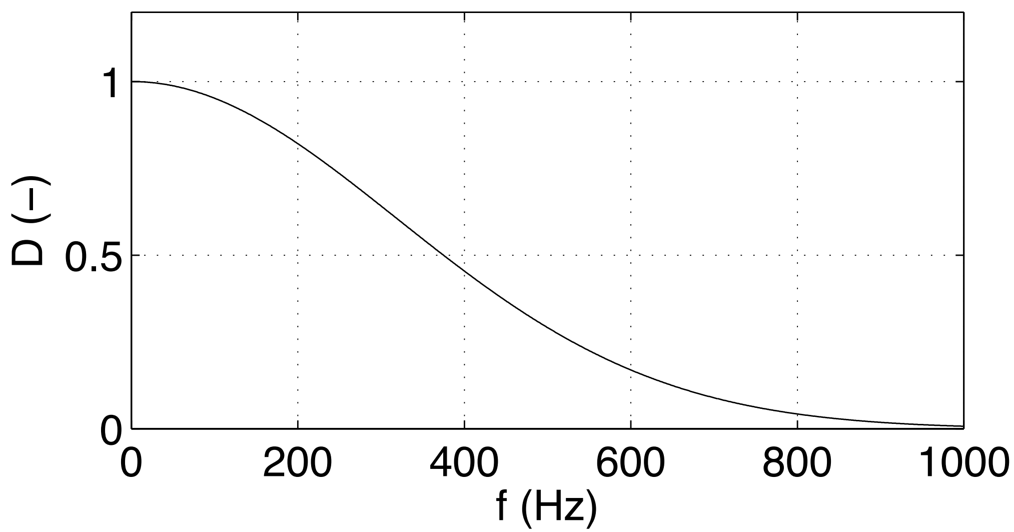


Delta function

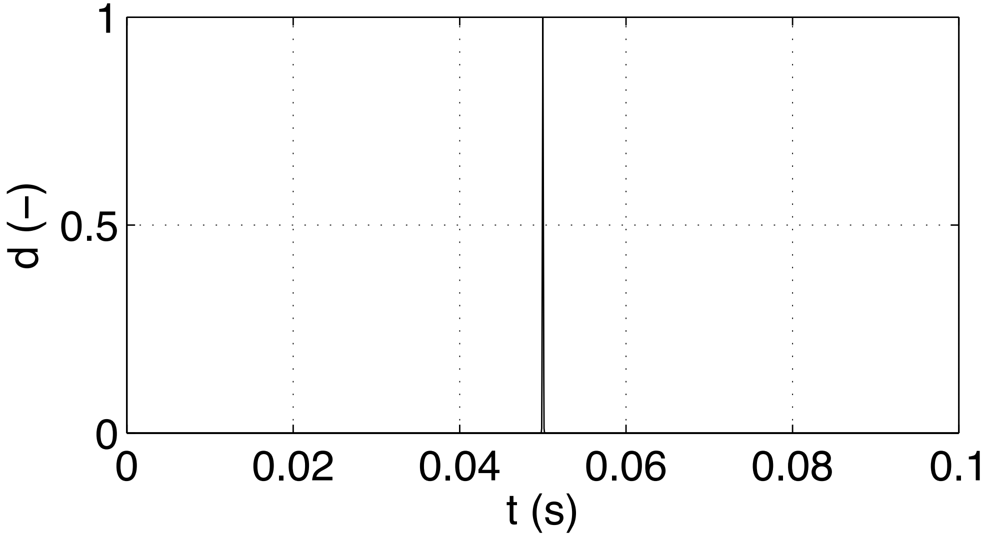


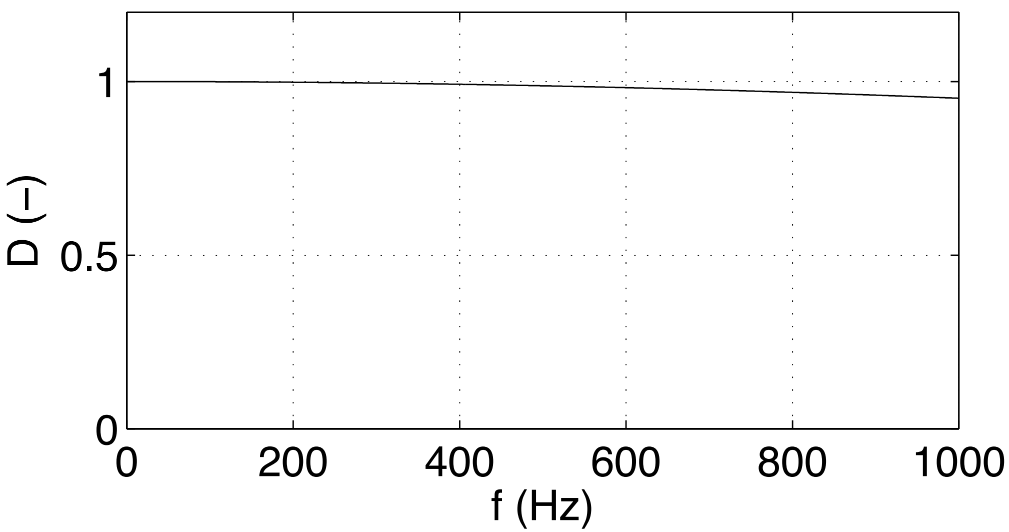
Delta function



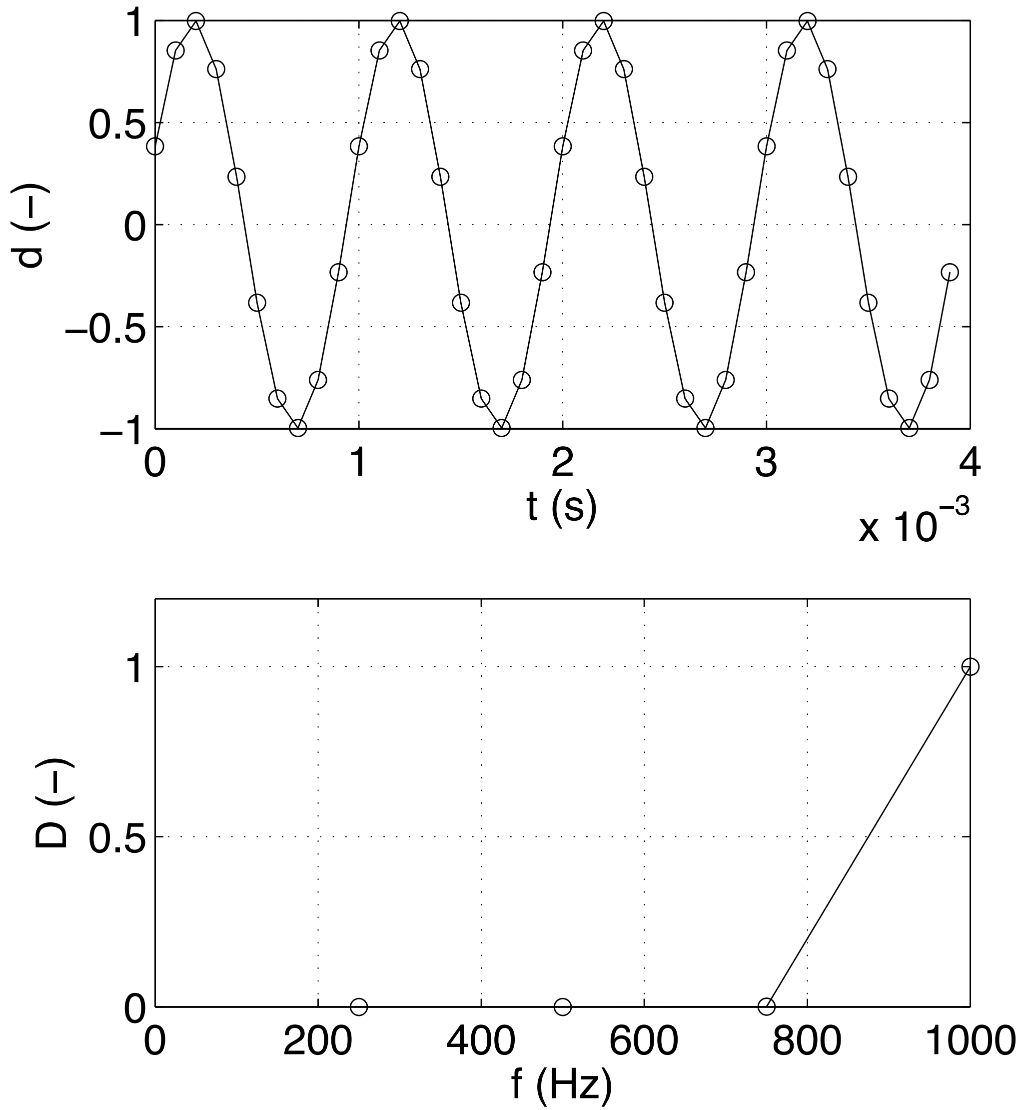


Delta function

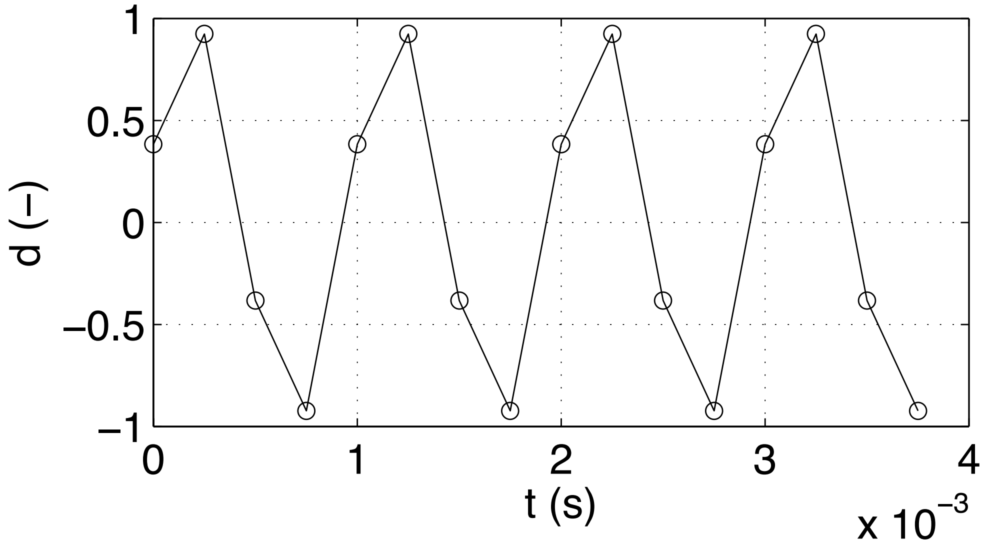


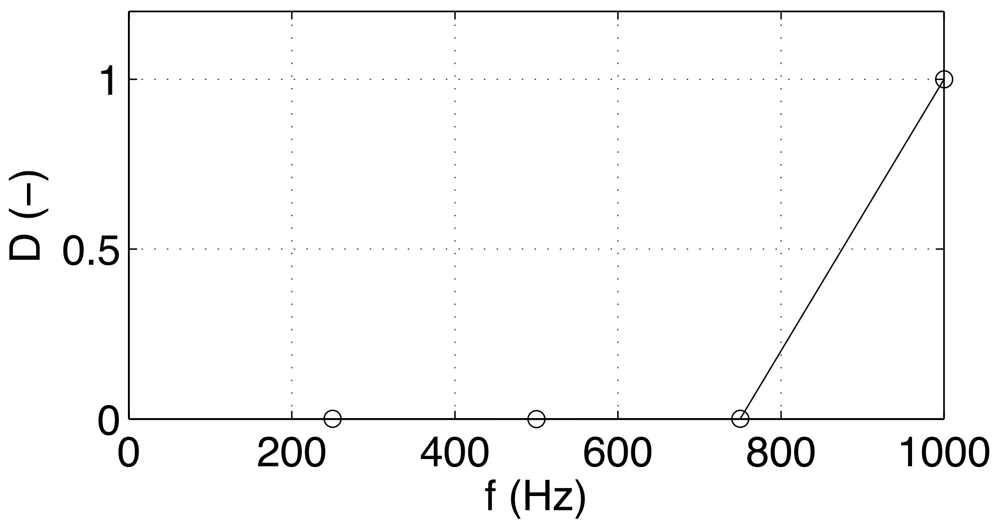


Discrete Fourier Transform

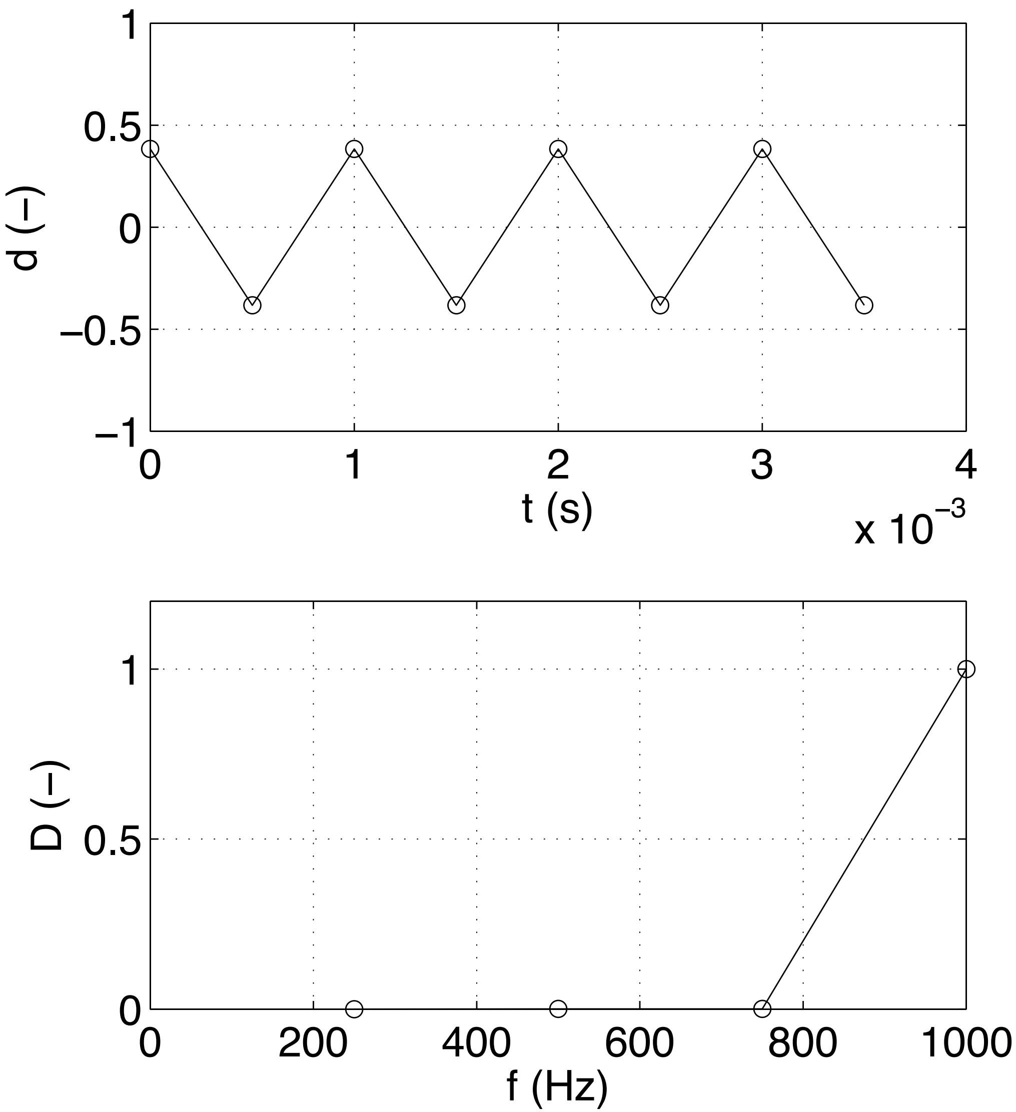


Discrete Fourier Transform

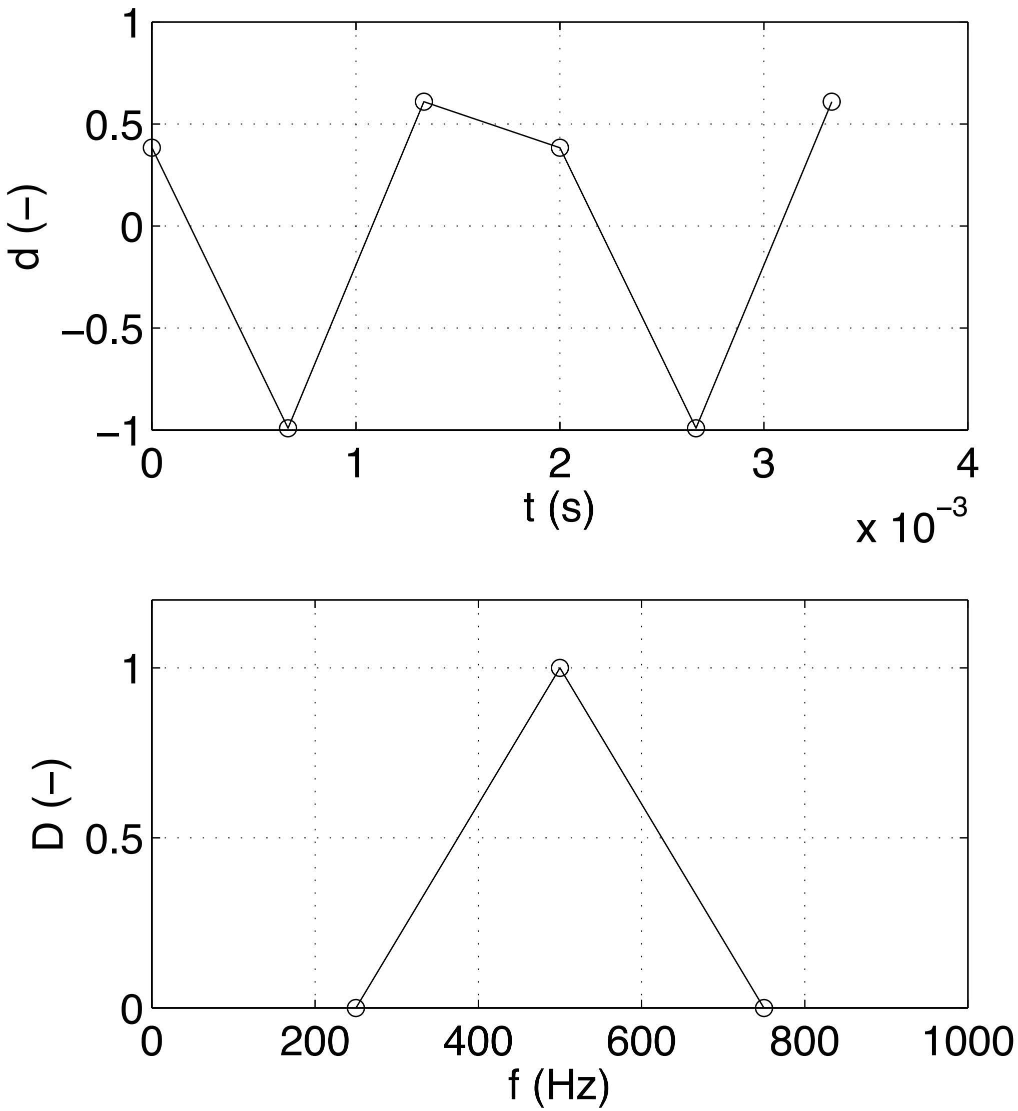




Discrete Fourier Transform



Discrete Fourier Transform



Impulse response g(t)

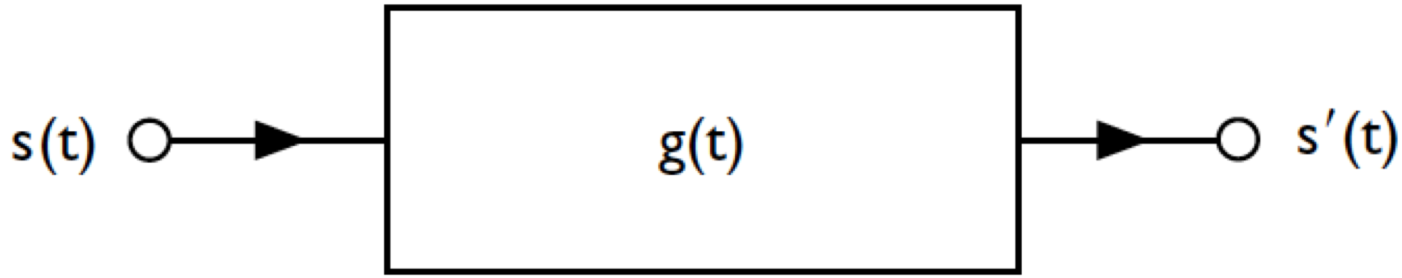


Figure 2.13 Transmission system.

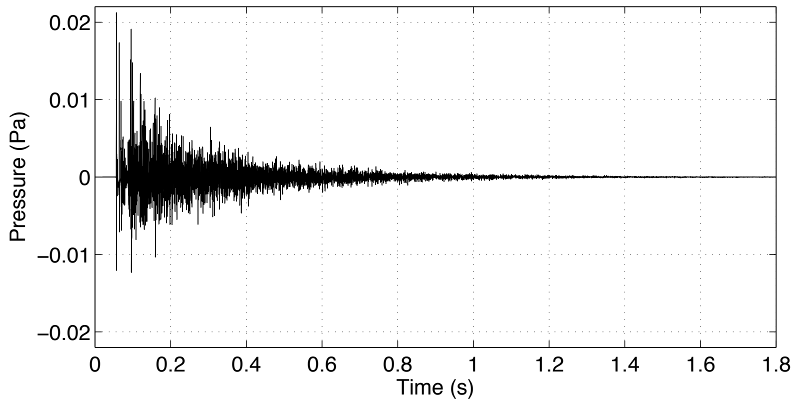
Kuttruff, H. (2007). *Acoustics: an introduction*. CRC Press.

Convolution operation

$$s'(t) = \int_{-\infty}^{\infty} s(\tau)g(t-\tau)d\tau = \int_{-\infty}^{\infty} g(\tau)s(t-\tau)d\tau$$

$$s'(t) = g(t) * s(t)$$

Impulse response g(t)



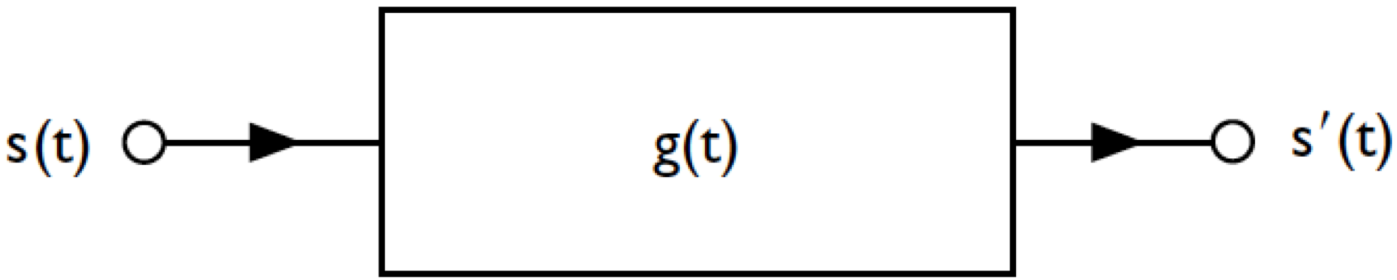
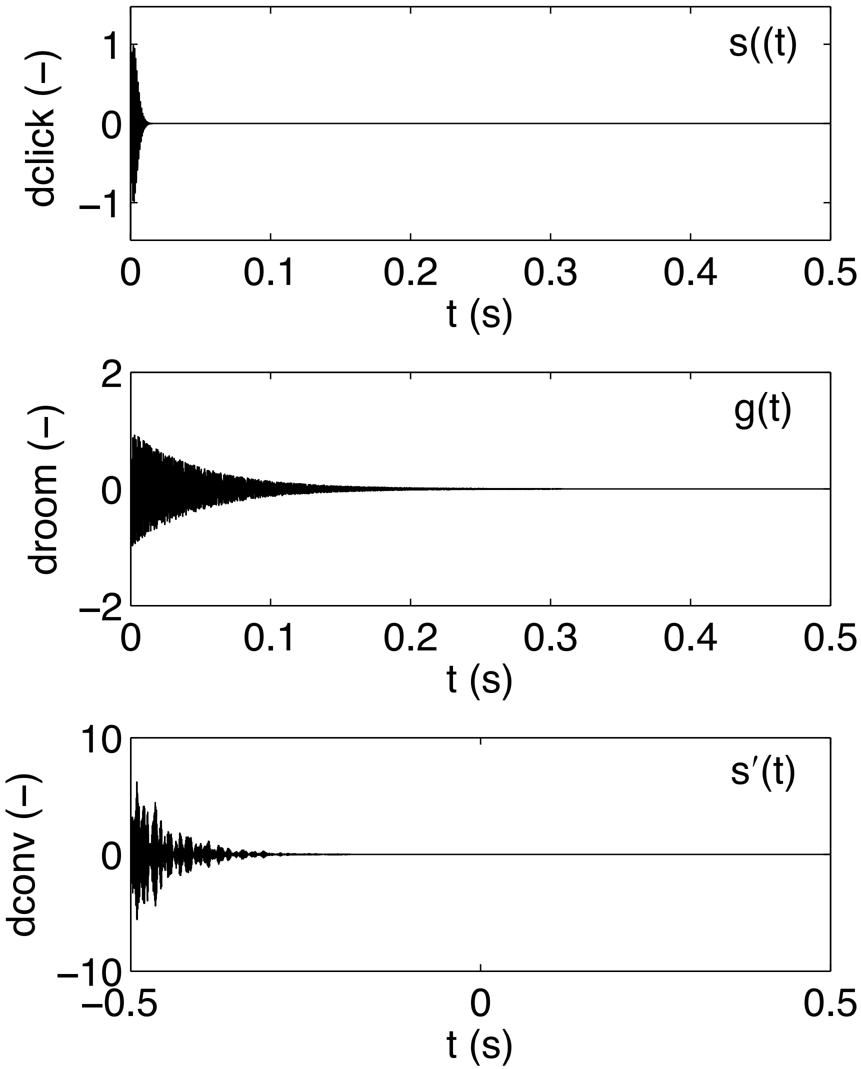


Figure 2.13 Transmission system.

Impulse response g(t)



Formulas week 1

Mechanical vibrations (chapter 2)

$$
\begin{aligned}
f &= \frac{\omega}{2\pi} = \frac{1}{T} && (1)\\
\langle s^2 \rangle &= \frac{1}{t_0}\int_0^{t_0} [s(t)]^2 dt = \tilde{s}^2 \qquad \text{Effective value} && (2)\\
\tilde{s} &= \hat{s}/\sqrt{2} \qquad \text{For harmonic signals s(t)} &&\\
e^{jz} &= \cos(z) + j\sin(z) \qquad \text{z real} && (3)\\
s(t) &= Re\{\hat{s}e^{j(\omega t+\phi)}\} &&\\
s(t) &= \hat{s}e^{j(\omega t+\phi)} &&\\
\omega &= 2\pi f &&\\
|s(t)| &= \sqrt{Re\{s(t)\}^2 + Im\{s(t)\})^2} &&\\
&= \sqrt{Re\{\cos(\omega t+\phi)\}^2 + Im\{\sin(\omega t+\phi)\})^2} &&\\
\angle s &= \text{atan}\left(\frac{Im\{s(t)\}}{Re\{s(t)\}}\right) \qquad \text{for Im } \{s(t)\} > 0 &&\\
&= \pi + \text{atan}\left(\frac{Im\{s(t)\}}{Re\{s(t)\}}\right) \qquad \text{for Im } \{s(t)\} < 0,\ Re\{s(t)\} > 0 &&\\
&= -\pi + \text{atan}\left(\frac{Im\{s(t)\}}{Re\{s(t)\}}\right) \qquad \text{for Im } \{s(t)\} < 0,\ Re\{s(t)\} < 0 &&
\end{aligned}
$$

Formulas week 1

$$
\begin{aligned}
v(t) &= j\omega\hat{s}e^{j(\omega t+\phi)} \\
Z_{mass-spring} &= j\omega m + r + \frac{1}{j\omega n} \\
f_0 &= \frac{1}{2\pi\sqrt{mn}} \qquad \text{Mass-spring resonance frequency} \\
Z &= \frac{F}{v} = \frac{\hat{F}}{\hat{v}}e^{j\psi} \qquad (4) \\
P &= F \cdot v \qquad (5) \\
P_a &= \frac{1}{2}\hat{v}^2 Re\{Z\} = \frac{1}{2}\hat{F}^2 Re\{Y\} \qquad \text{Active part of the power} \\
P_a &= \tilde{v}^2 Re\{Z\} = \tilde{F}^2 Re\{Y\} \\
s(t) &= \int_{-\infty}^{\infty} C(\omega)e^{j\omega t}d\omega \qquad (6) \\
C(\omega) &= \frac{1}{2\pi}\int_{-\infty}^{\infty} s(t)e^{-j\omega t}dt \qquad (7) \\
s'(t) &= \int_{-\infty}^{\infty} s(\tau)g(t-\tau)d\tau = \int_{-\infty}^{\infty} g(\tau)s(t-\tau)d\tau \qquad \text{Convolution} \\
s'(t) &= g(t) * s(t)
\end{aligned}
$$