Signals and Systems

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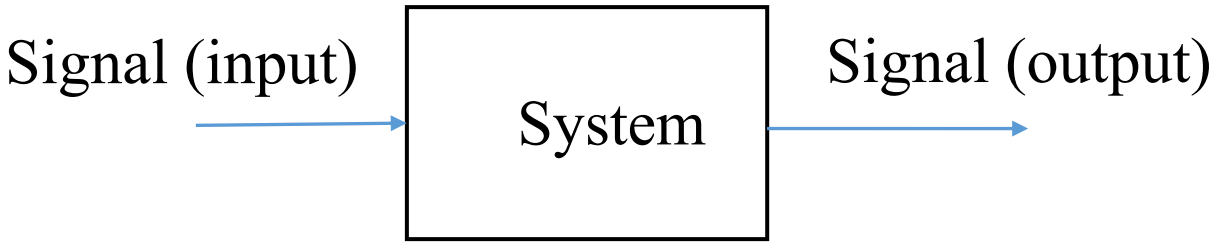
Course introduction

- Global content
- Exams and grades
- Text book and materials
- Organization
- Motivation
- Pre-knowledge

Global content

- Overview of Signals and Systems
- Linear-Time-Invariant Systems
- Fourier Series Representation of Periodic Signals
- The Continuous-Time Fourier Transform
- The Discrete-Time Fourier Transform
- Time and Frequency Characterization of Signals and Systems
- Sampling
- The Laplace Transform
- The Z-Transform

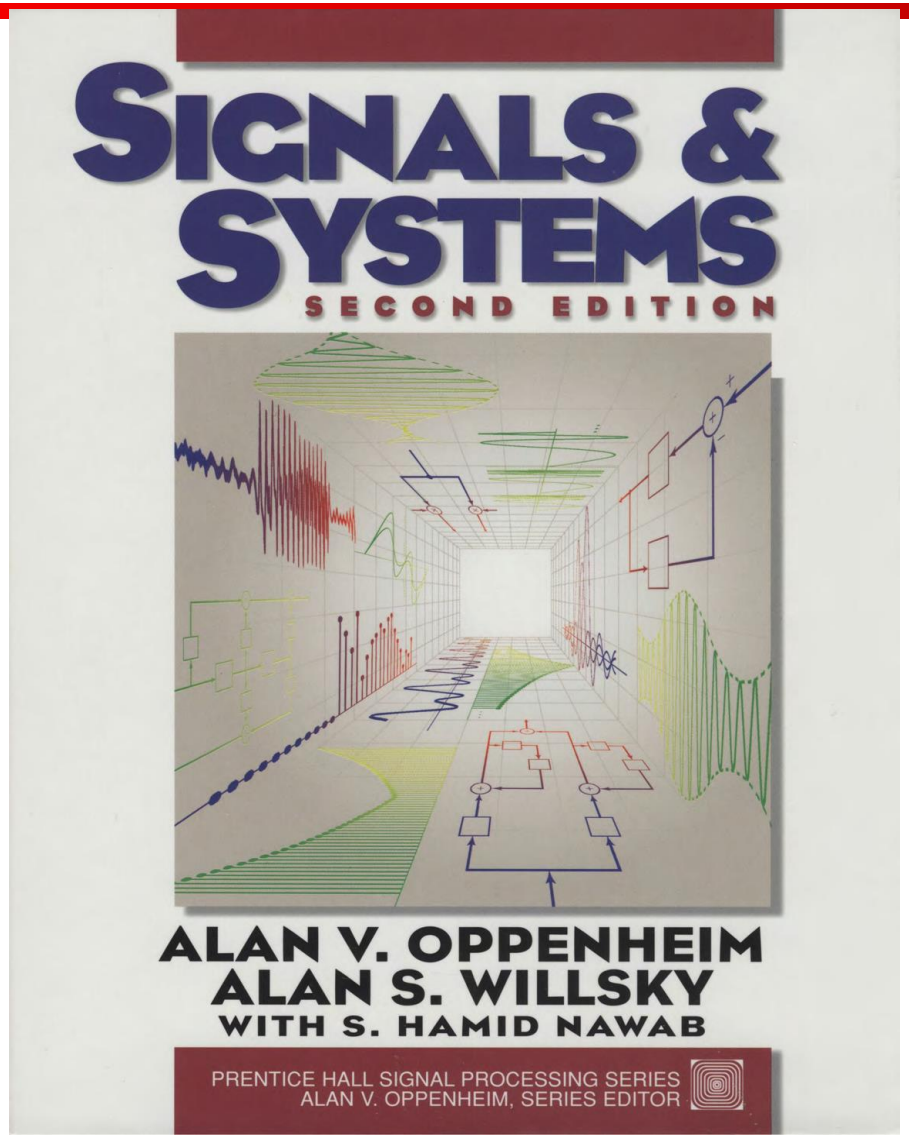


Exams and Grades

- Homework: 15% (Delay <=2 days, *0.8; >2 days, *0)
- Mid-term (written, close-book): 30%
- Final Exam (written, close-book): 50%
- Attendance: 5% (-1% point per absence, no late than 5 mins)
- All in English, otherwise *0.8
- Plagiarism:
  - one time: the assignment ZERO score
  - two times: the assignment ZERO score + course score * 0.8
  - three times: course ZERO score

Text book and materials

- Book
  - Signals and Systems (2nd Edition), by A. V. Oppenheim, A. S. Willsky, and S. Hamid. ISBN: 978-0138147570.
  - Signals and Systems using Matlab (2nd Edition), by Luis Chaparro. ISBN: 978-0123948120.
- These slides
- All materials will be available in the BB system



Organization

- **Lecture:** week 1-16; Teaching Center 301; Tue. and Thu. 08:15-9:55
- **Exercise:** once per week, time and location TBD
- **Office hour:** email us to find a suitable time slot
- **Experiment:** by Dr. Linyan Lu, start from the 2nd week
- **BB system**: Slides and text book, homework release
- **Gradescope:** homework submission and grading, entry code: already sent

Support team

- TAs:
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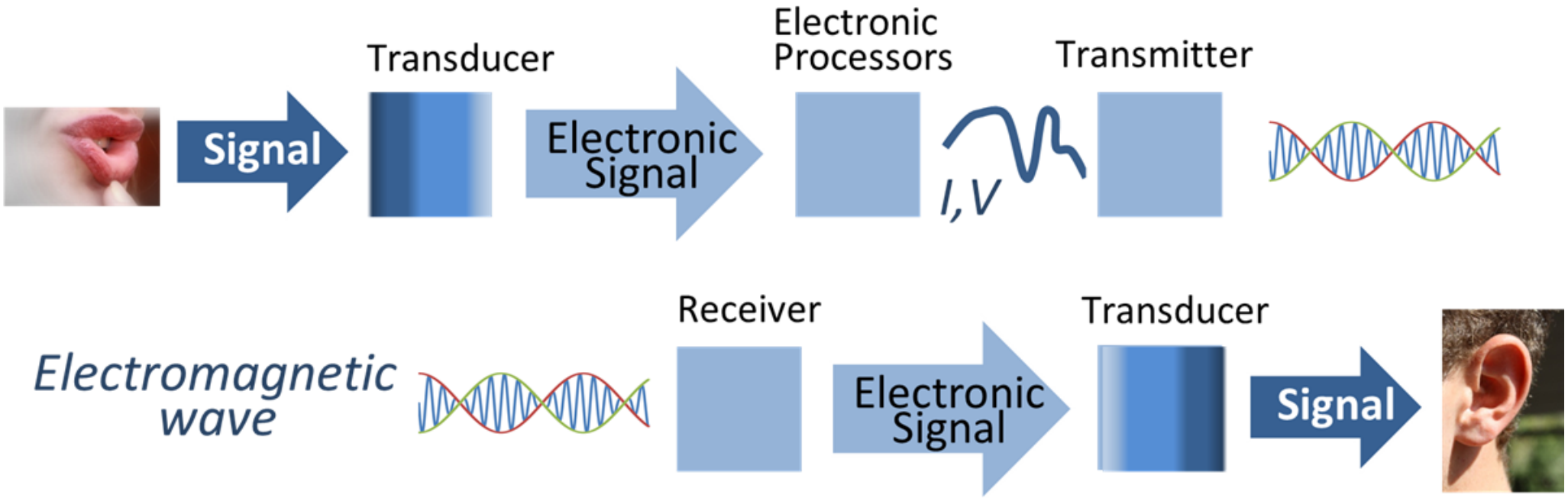
- QQ group:
  - QR code

Definition

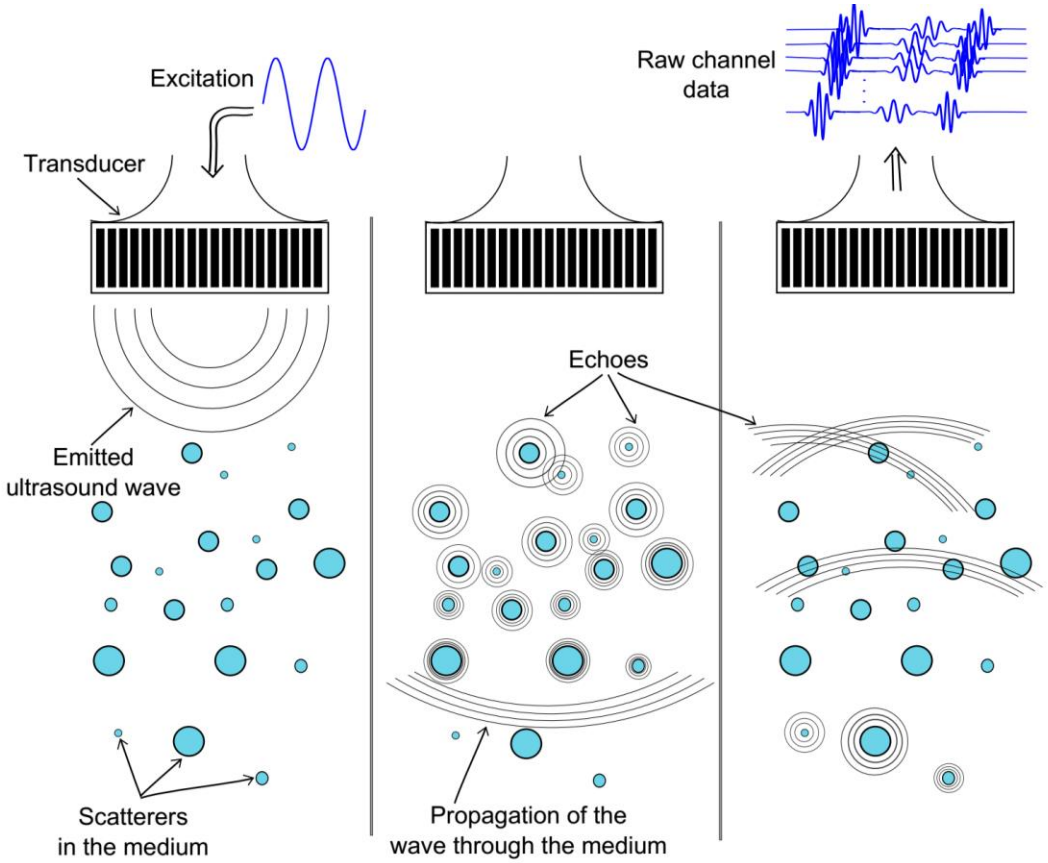
- **Signals**: functions containing information about the behavior or nature of some phenomenon.

- **Systems**: respond to particular signals by producing other signals or some desired behavior.

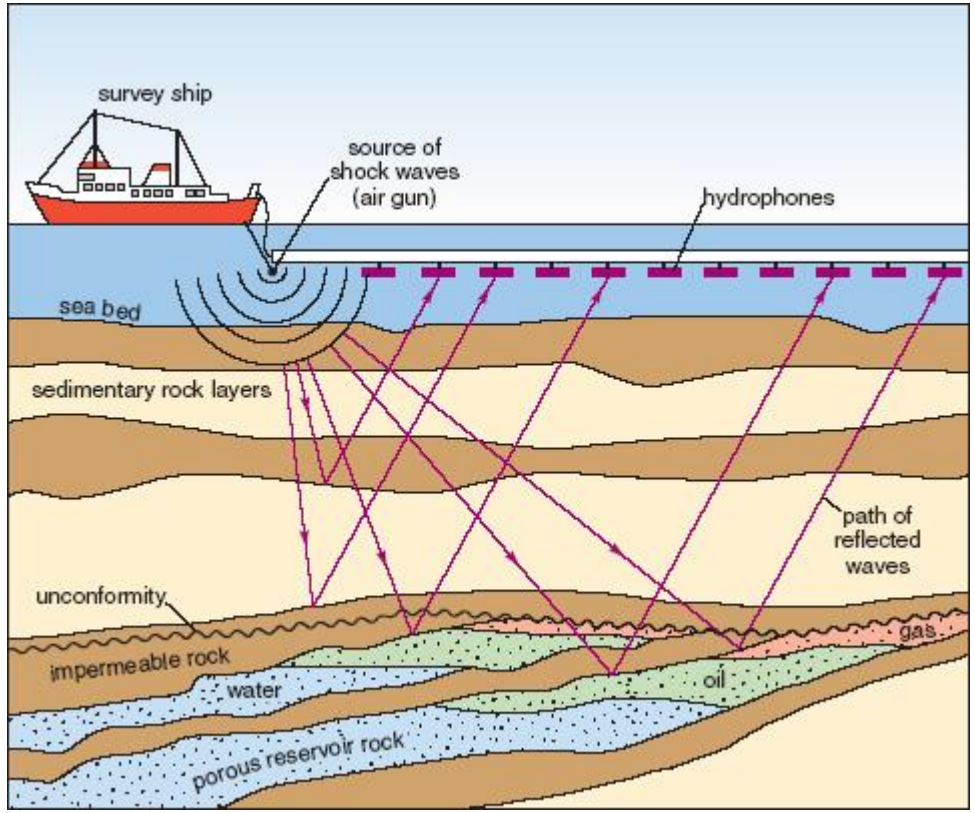
Communication systems

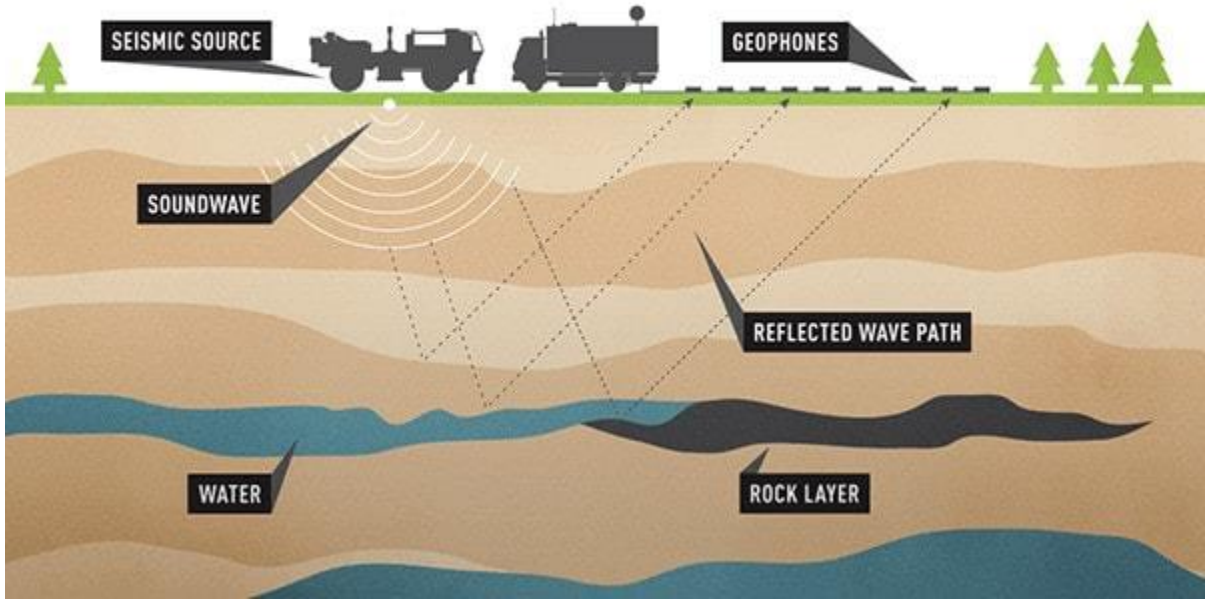


Medical imaging

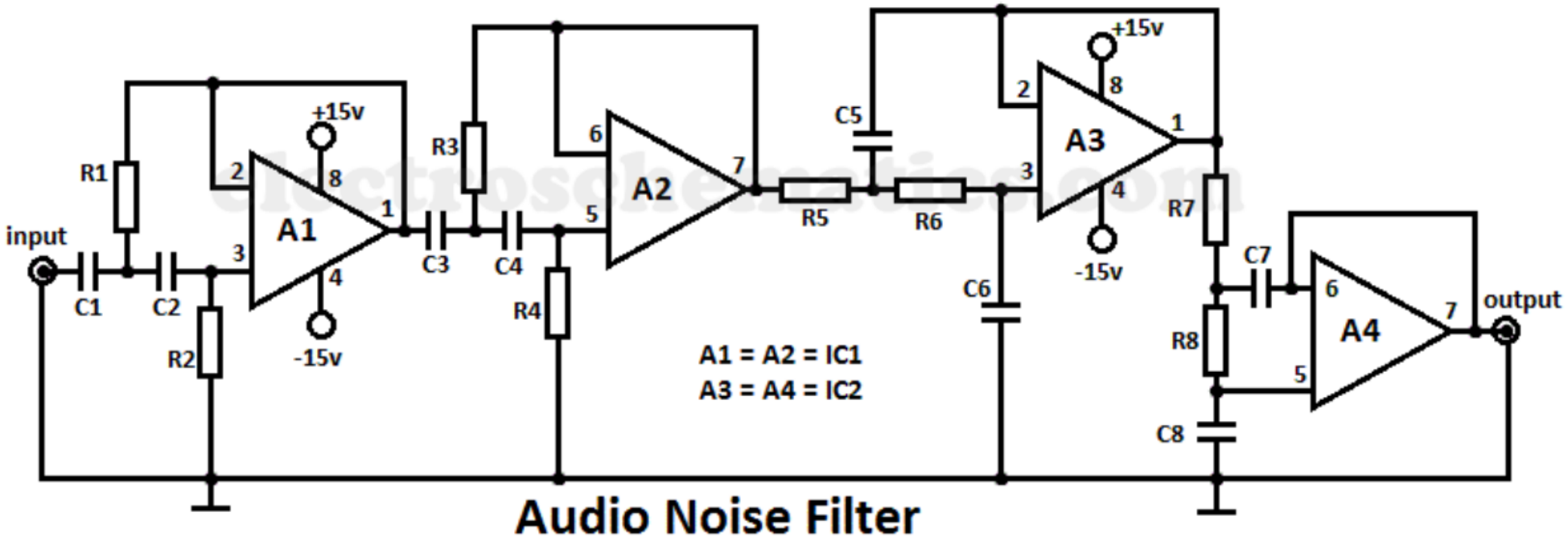


Geophysics



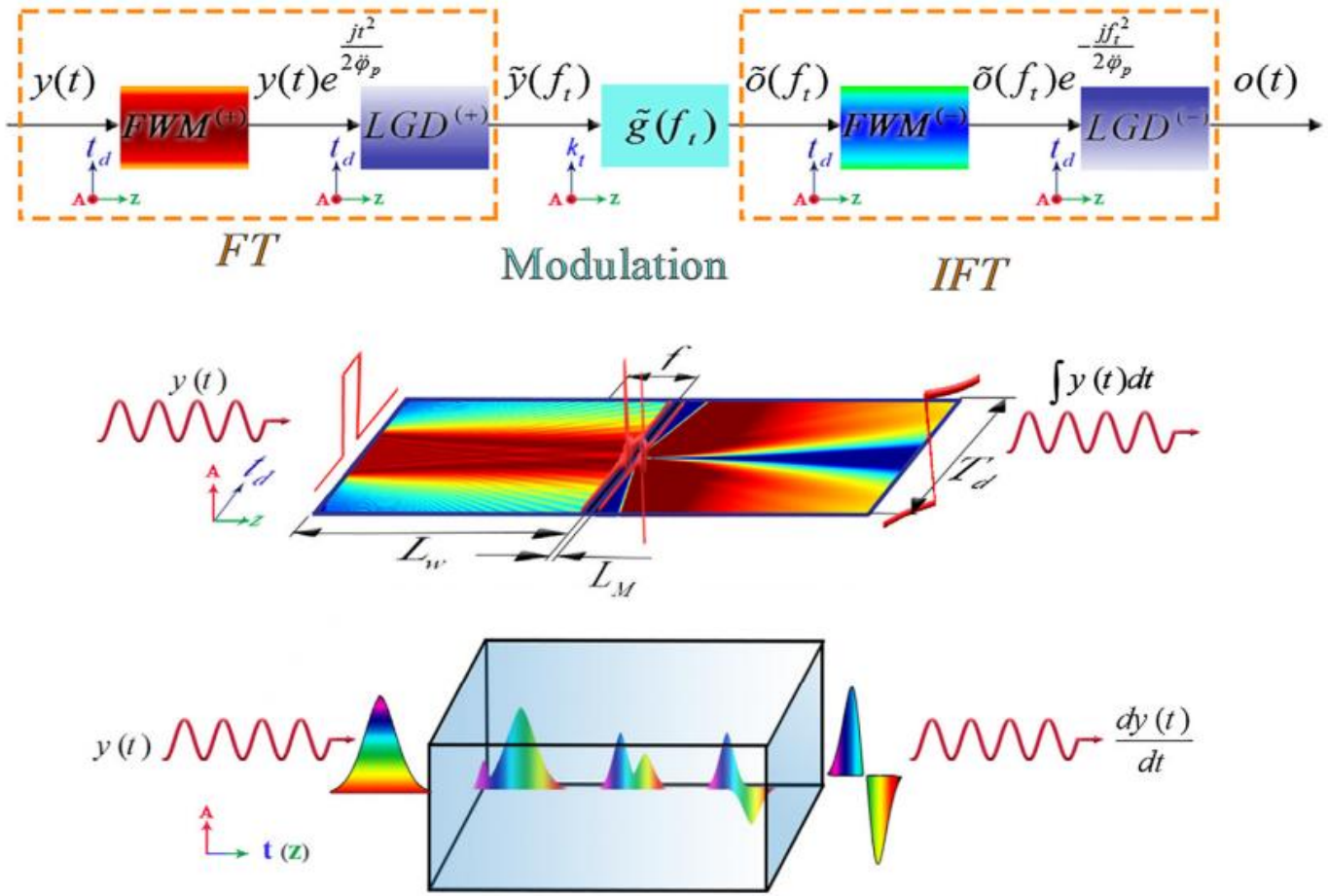


Signal processing



Audio Noise Filter

Optical computing



Babashah et. al., Optics and Laser Technology 111:66-74, 2019

Pre-knowledge

Complex numbers

Cartesian notation:

$$z = Re\{z\} + j \cdot Im\{z\}$$

Polar notation:

$$z = |z|e^{j\theta}$$

$\theta = \arctan \frac{Im[z]}{Re[z]}$

Complex conjugation: $j \Rightarrow -j$

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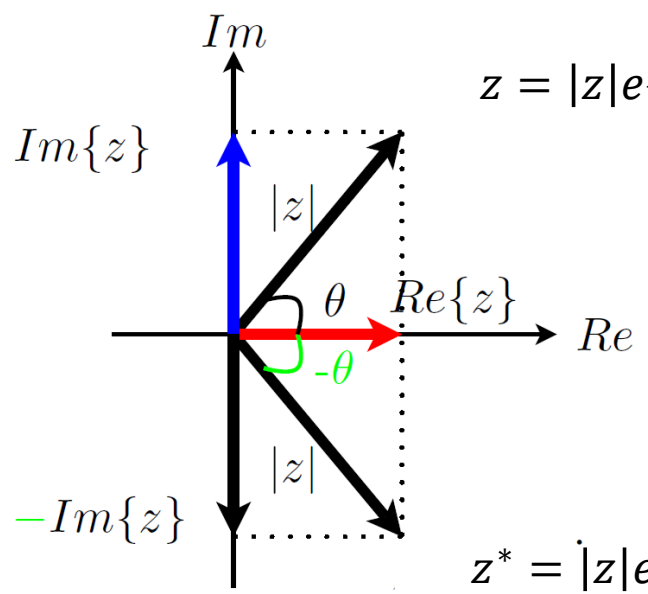
Euler: $e^{j\theta} = \cos(\theta) + j\sin(\theta)$



$$z = |z|e^{j\theta} = Re\{z\} + j \cdot Im\{z\}$$

$$z^* = |z|e^{-j\theta} = Re\{z\} - j \cdot Im\{z\}$$

$\tilde{z}$

$$\cos(\theta) = \frac{e^{j\theta} + e^{-j\theta}}{2}$$

$$\sin(\theta) = \frac{e^{j\theta} - e^{-j\theta}}{2j}$$

Pre-knowledge

Important geometric series

With z_0 some (possibly complex) number:

$$\boxed{\sum_{n=0}^{\infty}(z_0)^n = \frac{1}{1-z_0}} \quad \text{iff} \quad |z_0| < 1$$

$z = |z| e^{j\theta}$

$z^n = |z|^n e^{jn\theta}$

'Proof' via long tail division:

$$\frac{1}{1-z_0} = 1 + z_0 + (z_0)^2 + (z_0)^3 + \cdots = \sum_{n=0}^{\infty}(z_0)^n$$

$$\boxed{\sum_{n=0}^{M-1}(z_0)^n = \frac{1-z_0^M}{1-z_0}}$$

Pre-knowledge

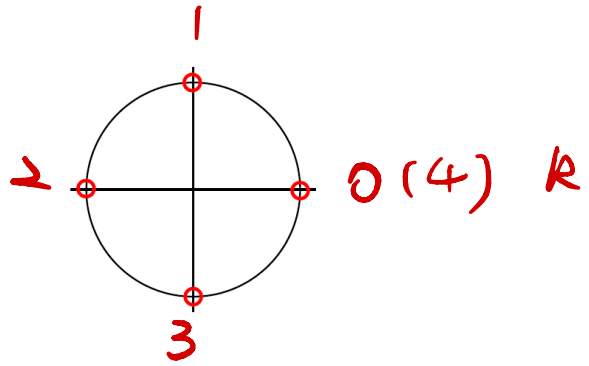
Zeros of a complex equation

With a some (complex) number, find zeros of: $\boxed{z^N - a = 0}$

$$z^N = a = a e^{j k \cdot 2\pi} \quad \Rightarrow \quad \boxed{z_k = a^{\frac{1}{N}} \cdot e^{j k \cdot \frac{2\pi}{N}}} \text{ for } k = 0, 1, \cdots, N-1$$

Example: $a = 1, N = 4$

$$\Rightarrow \quad z_k = e^{j k \cdot \frac{\pi}{2}}$$



Example: $a = -1, N = 3$

$$\begin{aligned} \Rightarrow \quad z_k &= (-1)^{\frac{1}{3}} \cdot e^{j k \cdot \frac{2\pi}{3}} \\ &= (e^{j\pi})^{\frac{1}{3}} \cdot e^{j k \cdot \frac{2\pi}{3}} \\ &= e^{j \frac{\pi}{3} + k \cdot \frac{2\pi}{3}} \end{aligned}$$