Signal Processing

MIEET 1º ano

Peter Stallinga, UAlg 2011

MIEET. The levels of knowledge

Physics

Electronics

Sensors and Actuators

Systems

Control

Digital Electronics

Integrated Circuits

Micro Assembler

Machine Language

Macro Assembler

High Level Programming Languages

Object-oriented Programming

Distributed Programming

Information Processing

Optics / EM Waves

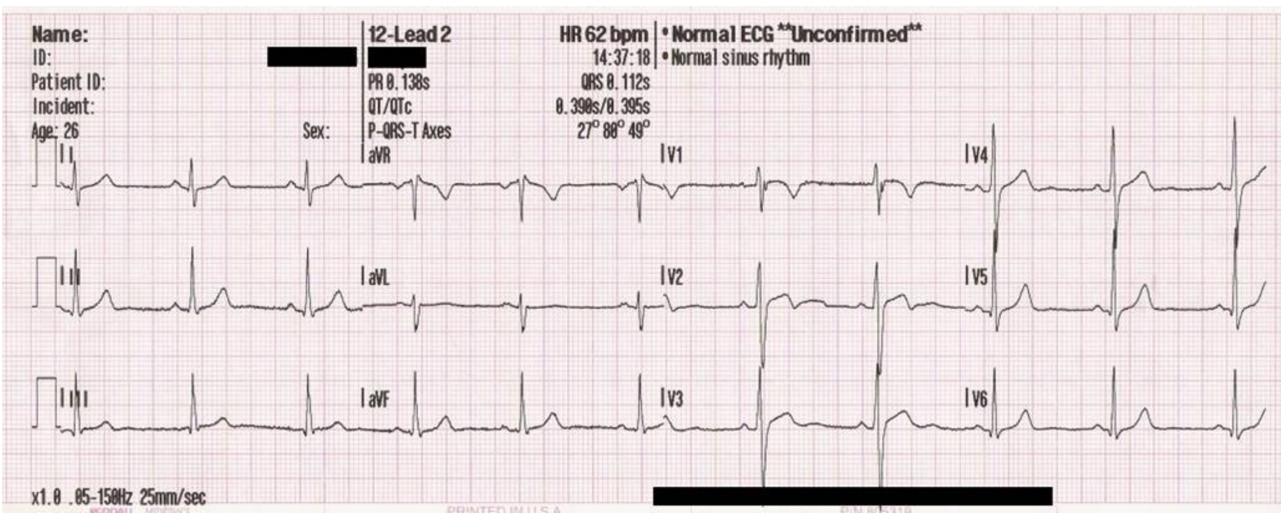
Telecommunications

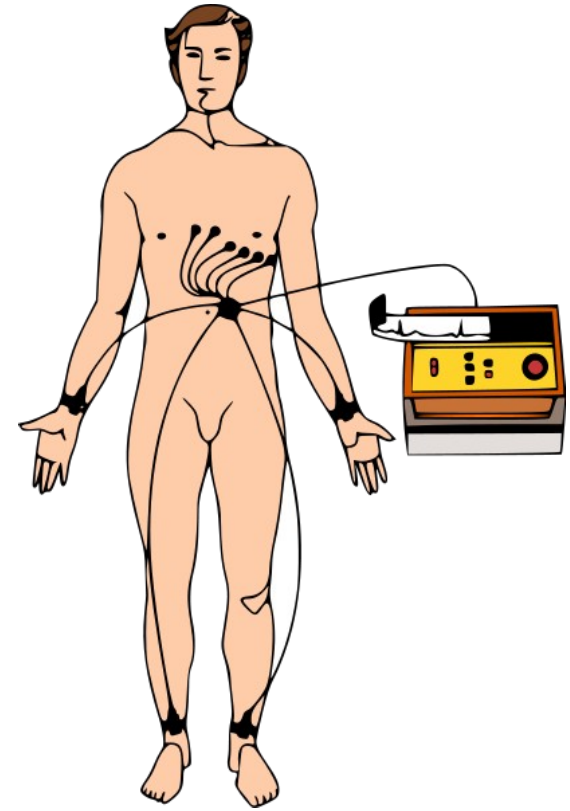
Internet

Today
IALP
MIEET

Signal processing. Example: cardiogram

Electrocardiography:





Is this person healthy?

The information is there somehow, but how to extract it?

Signal processing

Frequency analysis

Filtering

Noise

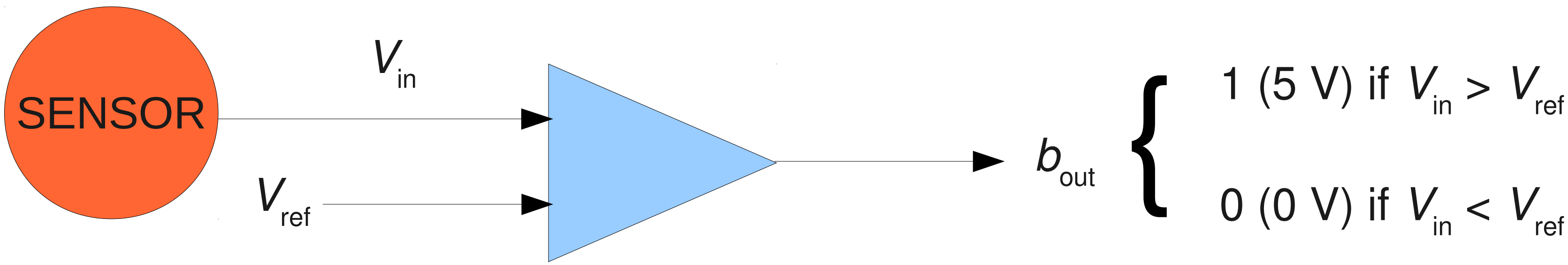
Fourier/Laplace Transform

(Pattern recognition)

ADC/DAC

ADC (Analog-Digital converter)
DAC (Digital-Analog Converter)

Translate signal from analog to digital domain and back

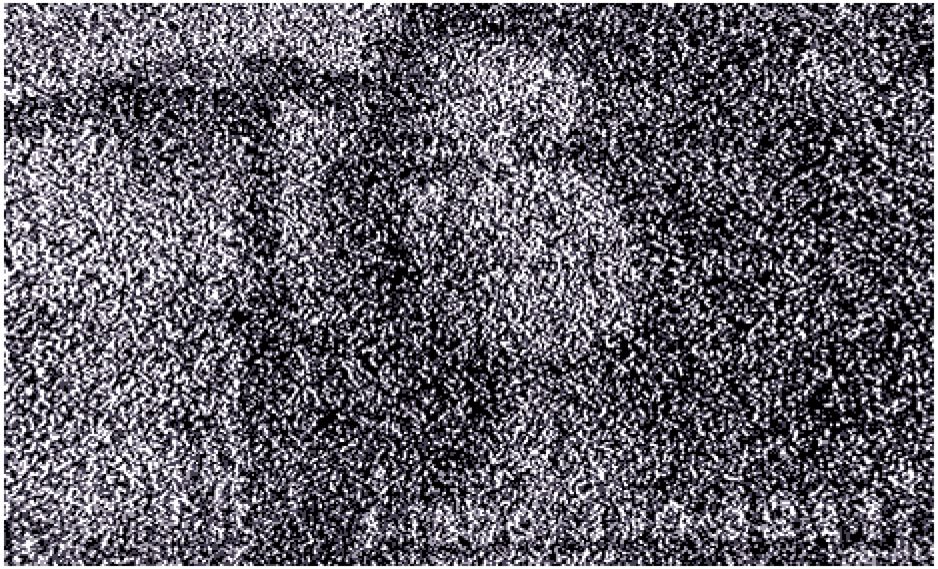


Simple 1-bit ADC:
comparator

Signal, Noise and S/N

Signal is that part of the incoming voltages (currents) that contain the **useful information**

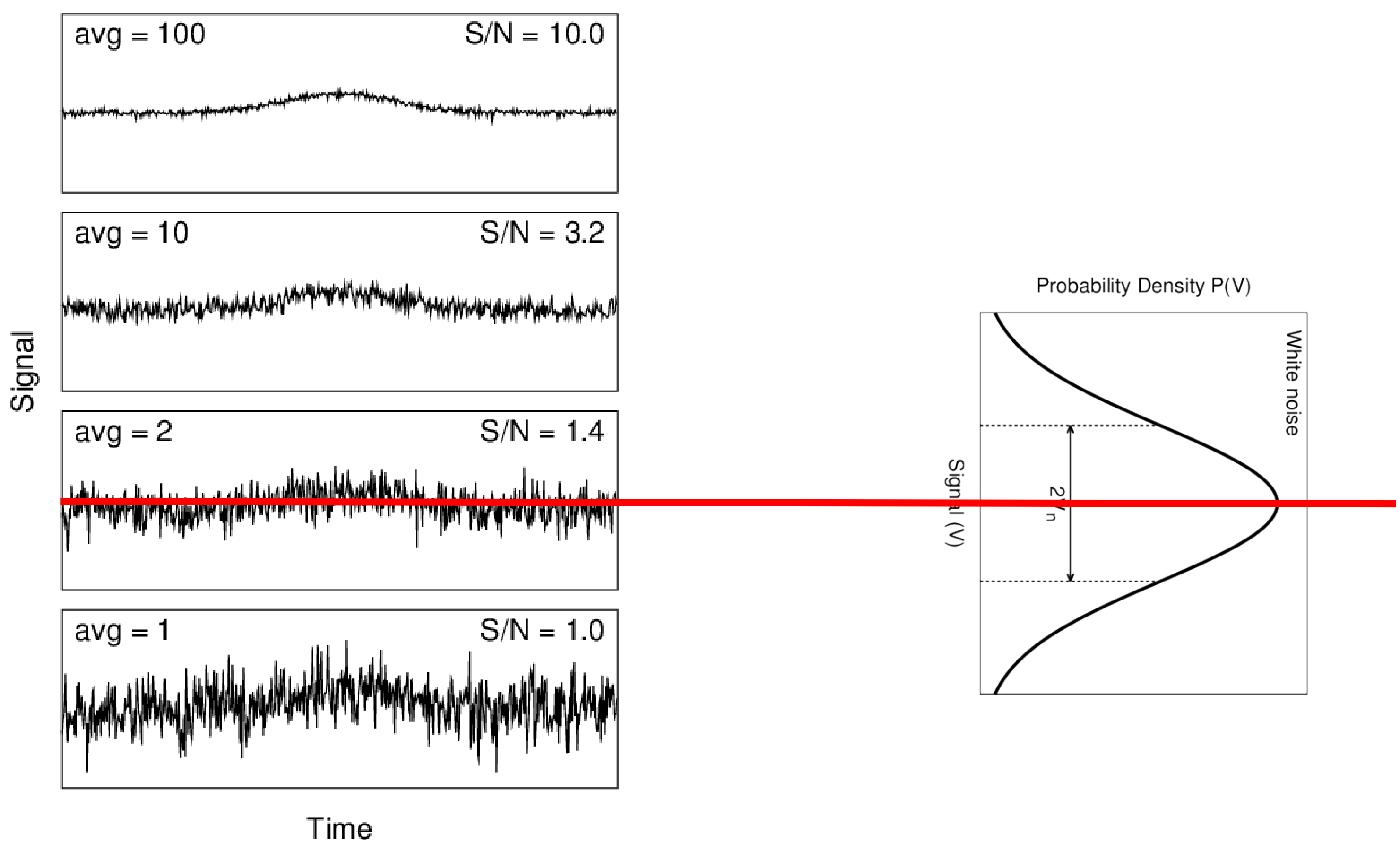
Noise is that part of the incoming voltages (or currents) that contain non meaningful or **no information**



The signal-to-noise ratio, S/N or SNR is the power ratio between the two (how much power, $\sim V^2$, is in them).

Signal, Noise and S/N

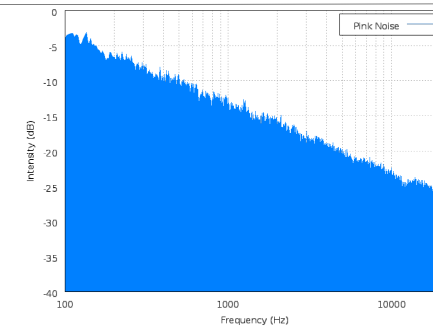
Noise is random (or looks like it to us). It has a certain **probability function**.
It also often has a certain **frequency spectrum** (which shows the correlation between measurement points)



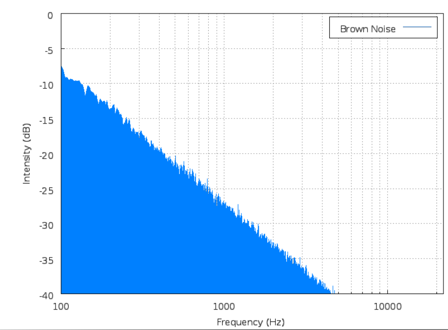
Noise types

White Noise: Spectrum: flat (~1). Equally loud at all frequencies

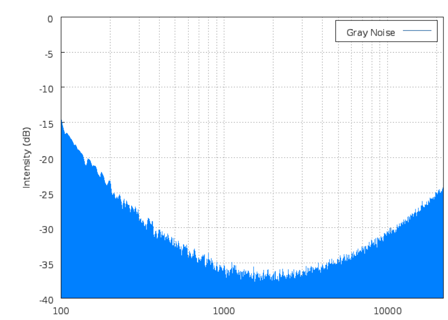
Pink Noise: Spectrum: ~1/f. Lower frequencies louder



Brown(ian) Noise: Caused by random motion of particles. Spectrum: $\sim 1/f^2$



Gray Noise: Spectrum is inverse of sensitivity spectrum of ear (<u>sounds</u> equally loud at all frequencies)



Frequency →

White noise

White Noise: Spectrum: flat (~1). Equally loud at all frequencies

Pink Noise: Spectrum: ~1/f. Lower frequencies louder

Brown(ian) Noise: Caused by random motion of particles. Spectrum: ~$1/f^2$

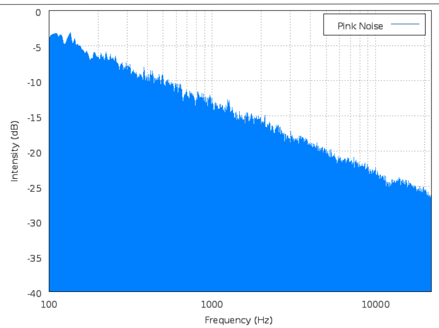
Gray Noise: Spectrum is inverse of sensitivity spectrum of ear (sounds equally loud at all frequencies)

Frequency →

Pink noise

White Noise: Spectrum: flat (~1). Equally loud at all frequencies

Pink Noise: Spectrum: ~1/f. Lower frequencies louder



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Frequency →

Brown noise

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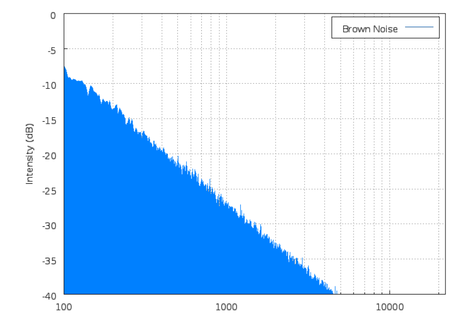

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Frequency →

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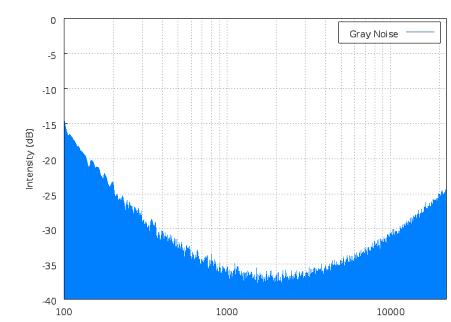
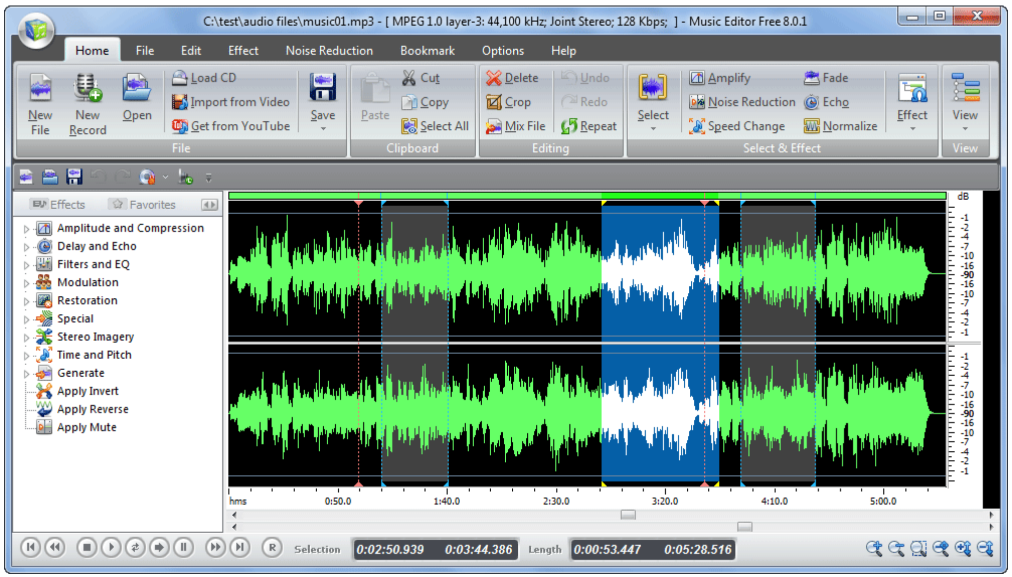
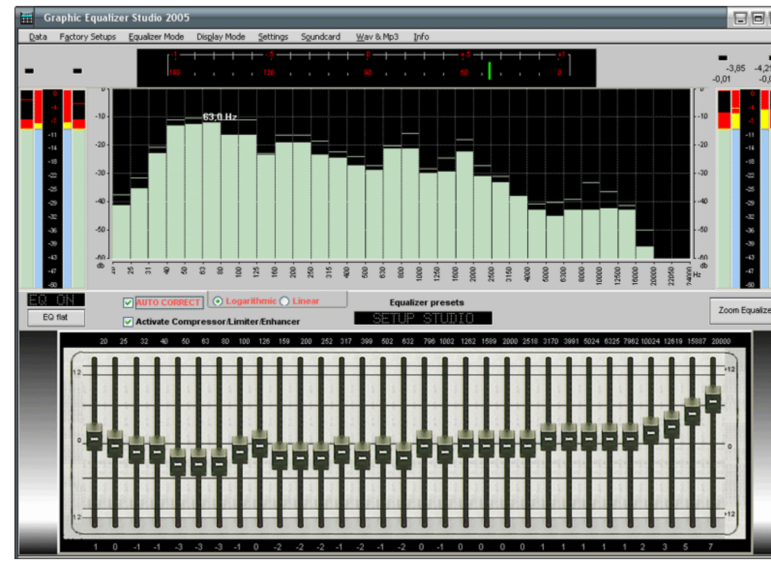


Frequency →

Time vs. frequency





Signal in time

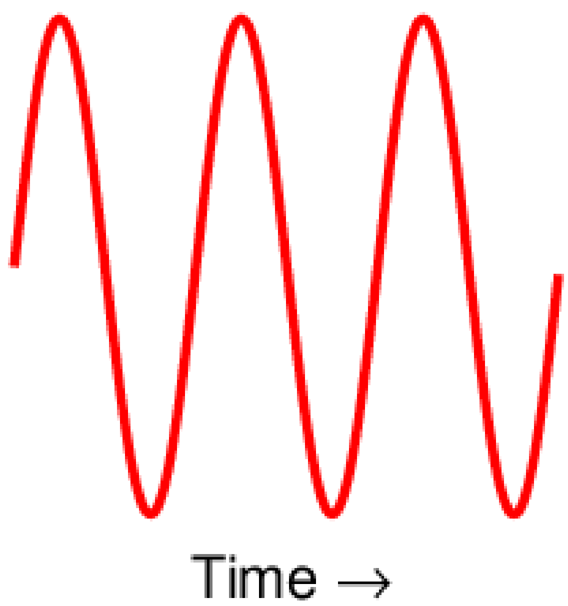
Example: $V(t) = \cos(\omega t)$

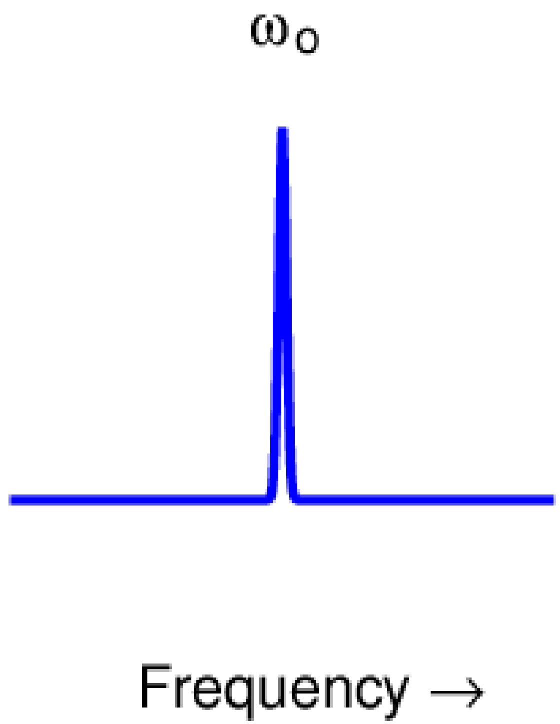
Signal in frequency

$V(\omega) = f(\omega)$

Fourier/Laplace Transform

To convert from time domain to frequency domain we can use **Laplace Transform** and **Fourier Transform**



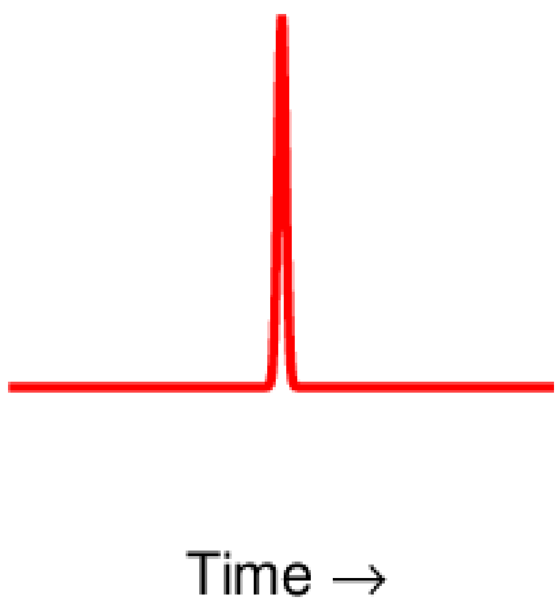


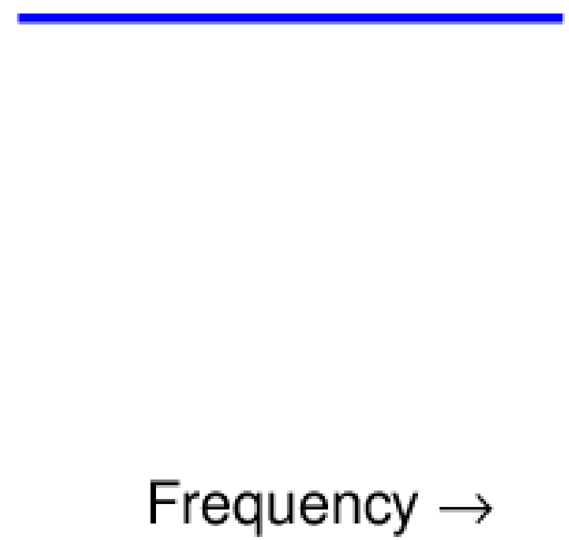
Example: $V(t) = \cos(\omega_o t)$ $V(\omega) = \delta(\omega-\omega_o)$

Single-frequency signal → Single-frequency spectrum (duh!)

Fourier/Laplace Transform

To convert from time domain to frequency domain we can use **Laplace Transform** and **Fourier Transform**



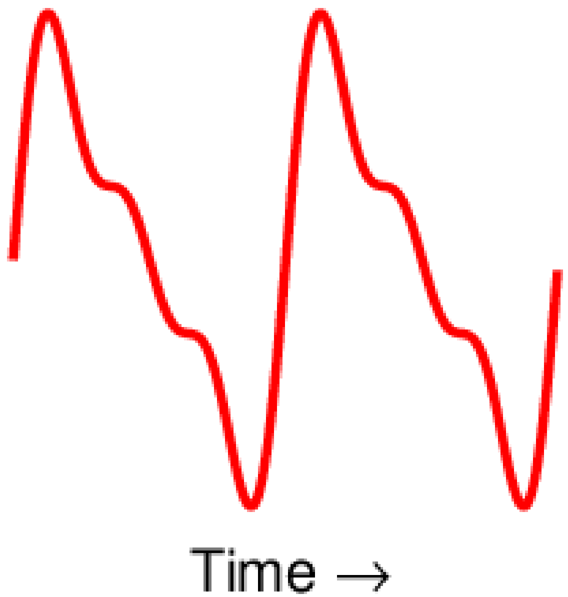


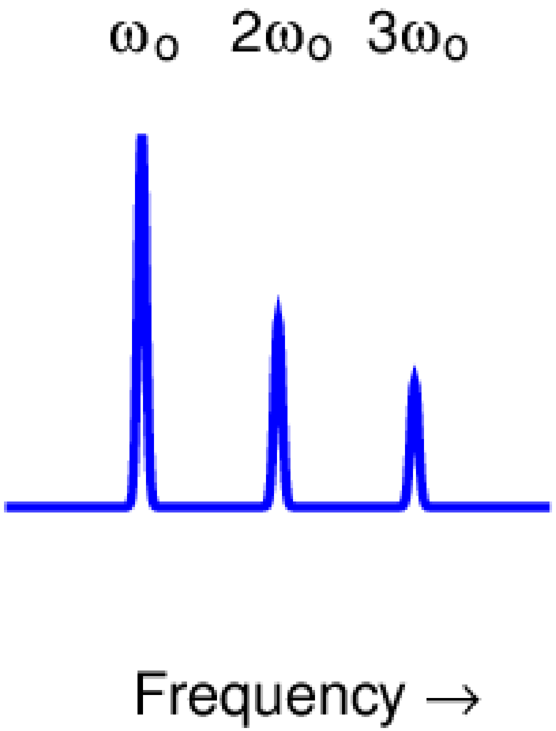
Example: $V(t) = \delta(t - t_o)$ $V(\omega) = 1$

'Spike' signal → Constant spectrum!!

Fourier/Laplace Transform

Fourier Transform for **periodic signals** ($Ae^{if(\omega)\omega t}$)

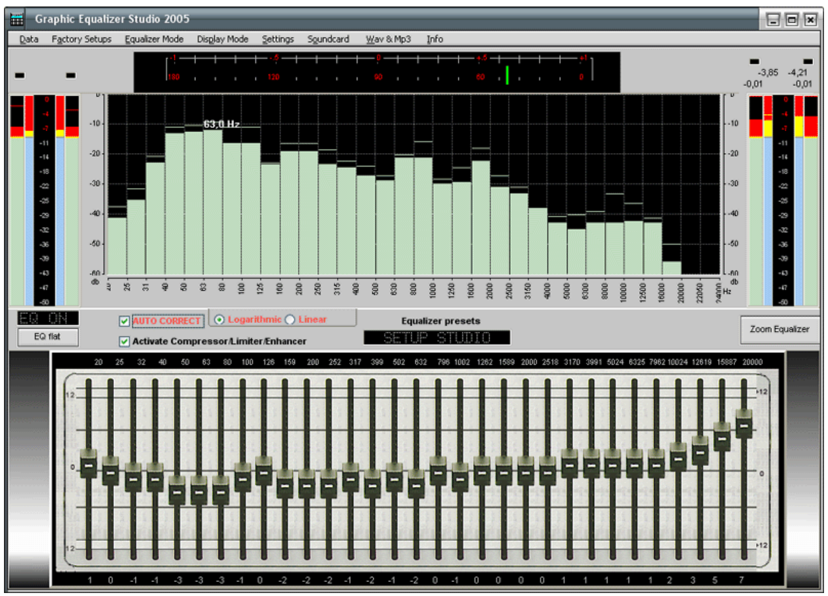


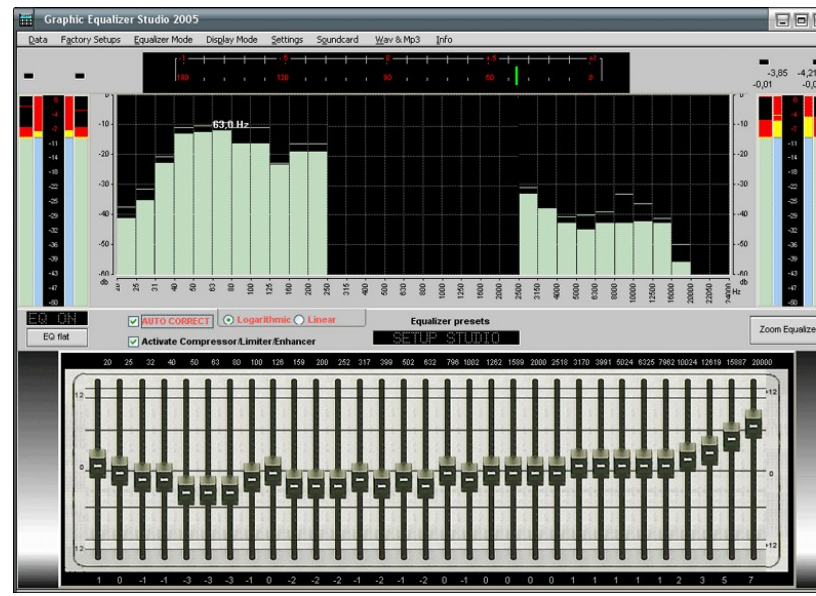


Periodic signal → ω, 2ω, 3ω, 4ω, 5ω, …. etc.

$\omega = 2\pi/T$

Filtering then is the process of letting through only part of the spectrum

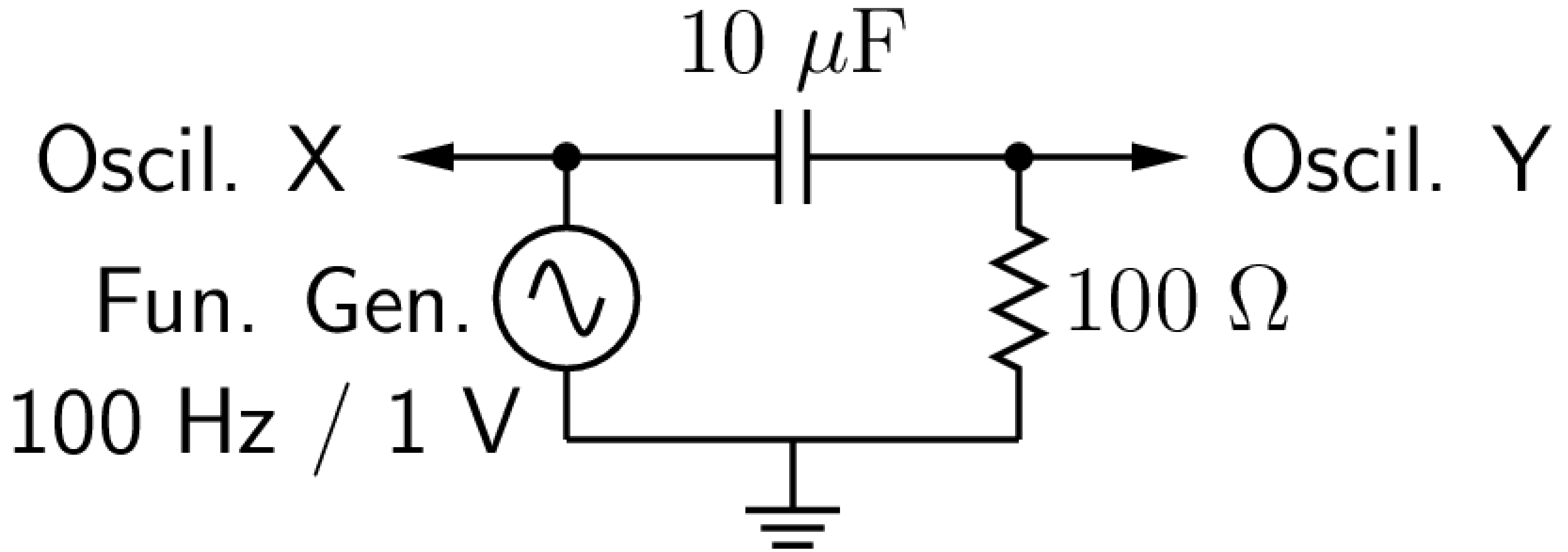


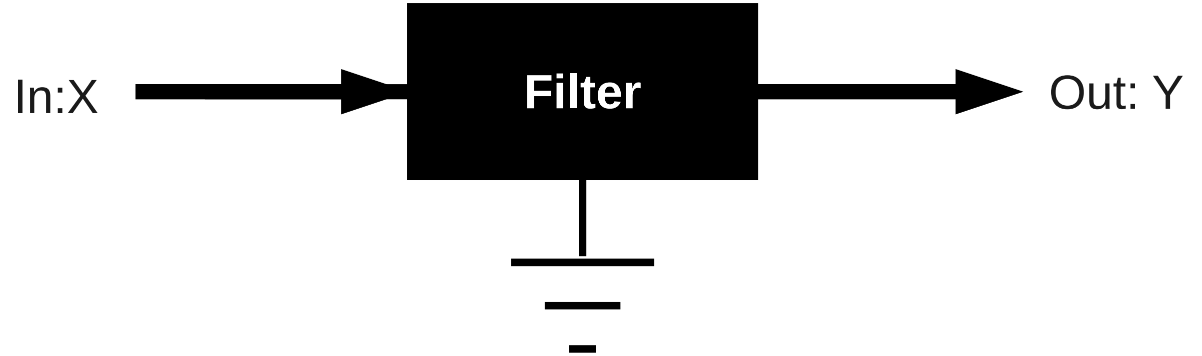


Example of a 'notch' filter (blocking part of the spectrum)

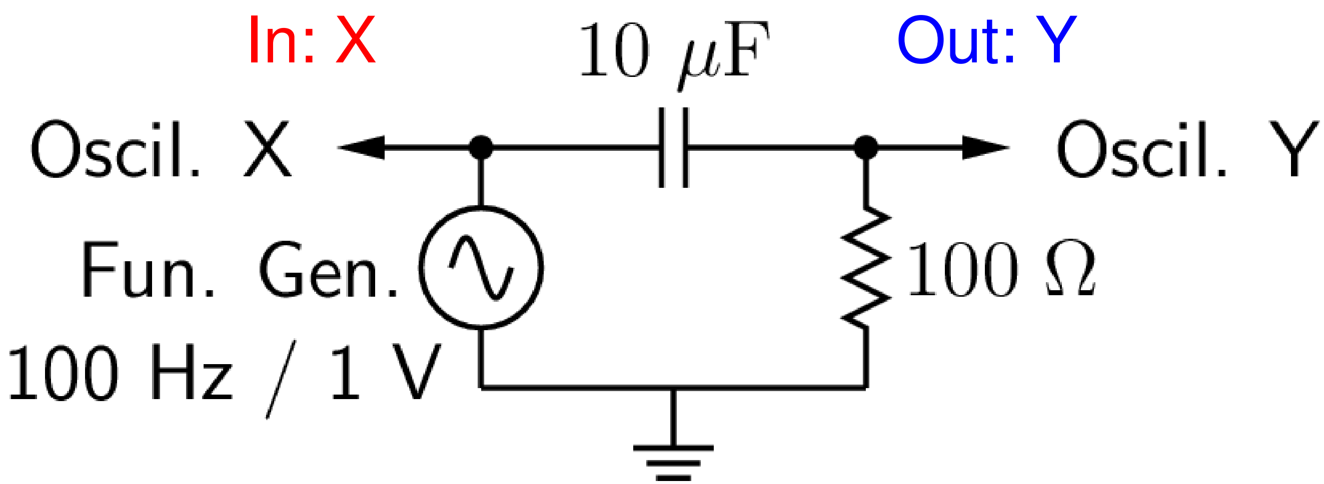
Simple pass-filters

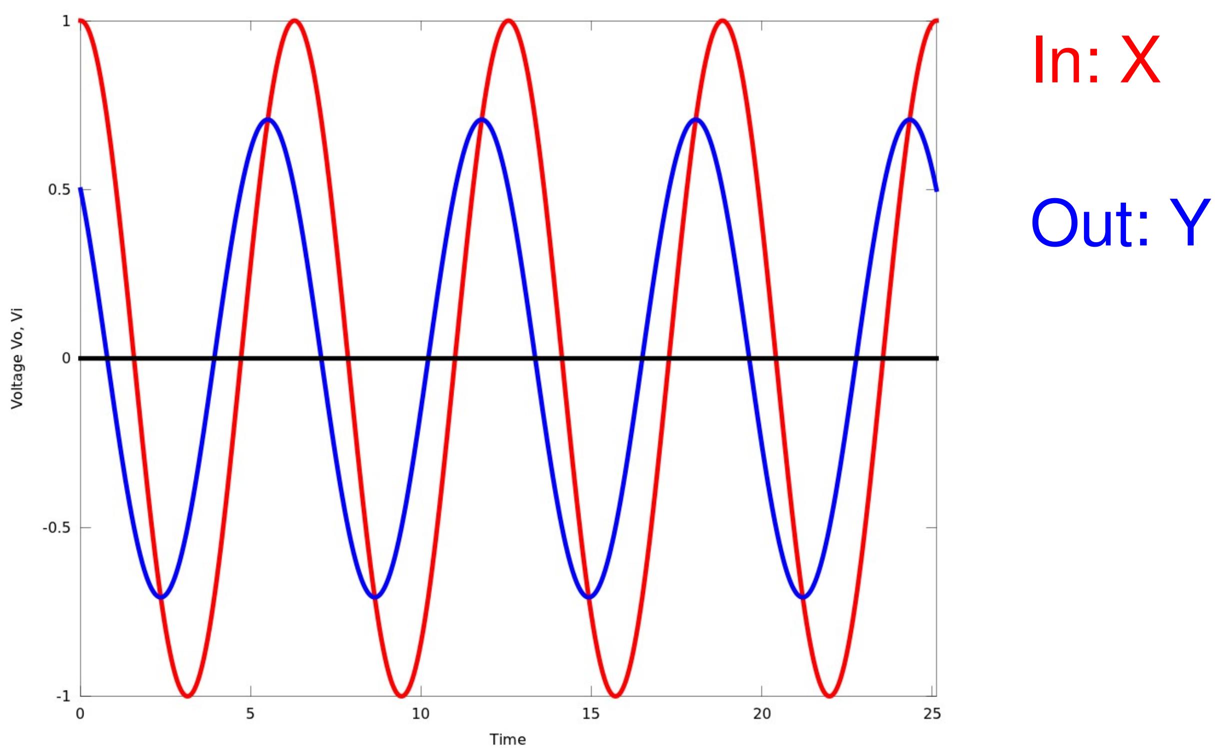
Simple examples of filters.
Practical lecture on Analog Electronics:



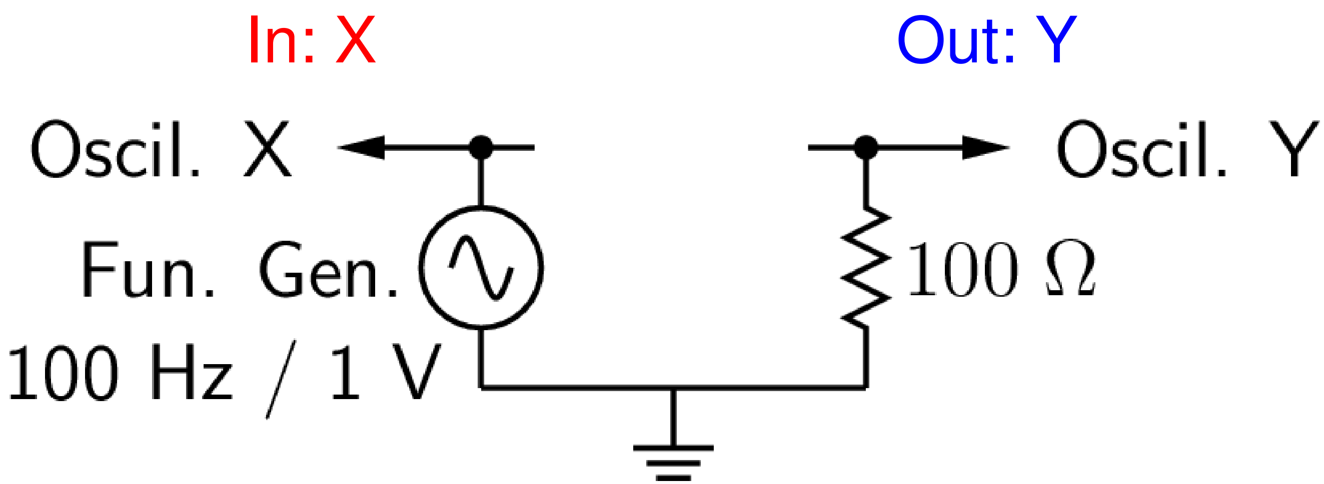


Simple Low-Pass Filter





Simple Low-Pass Filter

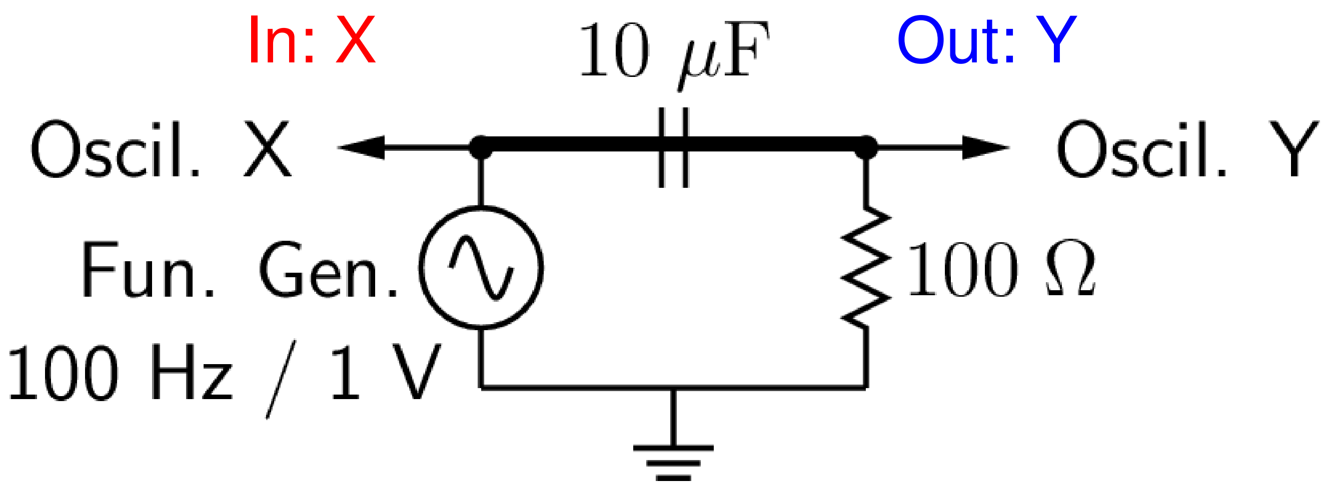


Capacitor is <u>open</u> circuit for low frequencies!!

$\omega = 0$. Y (out) = 0

$$Z_C = \frac{1}{i\omega C}$$

Simple Low-Pass Filter

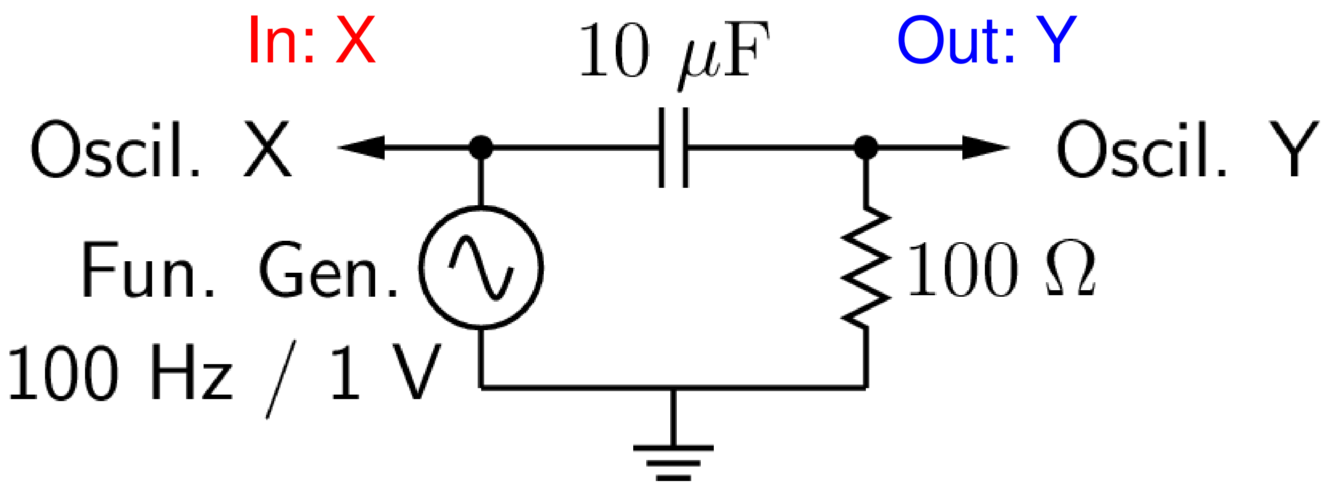


Capacitor is short circuit for high frequencies!!

$\omega = \infty$. Y (out) = X (in)

$$Z_C = \frac{1}{i\omega C}$$

Simple Low-Pass Filter

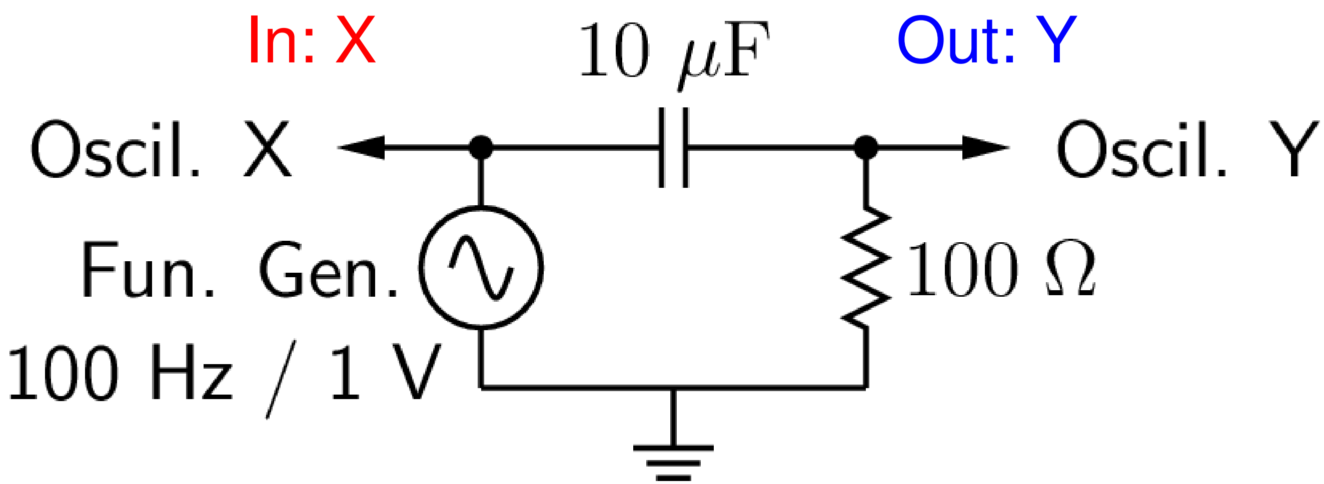


$$\frac{V_o}{V_i} = \frac{R}{R + 1/i\omega C} = \frac{1}{1 + 1/i\omega RC}$$

$\omega = 0$: $V_o/V_i = 0$

$\omega = \infty$: $V_o/V_i = 1$

Simple Low-Pass Filter



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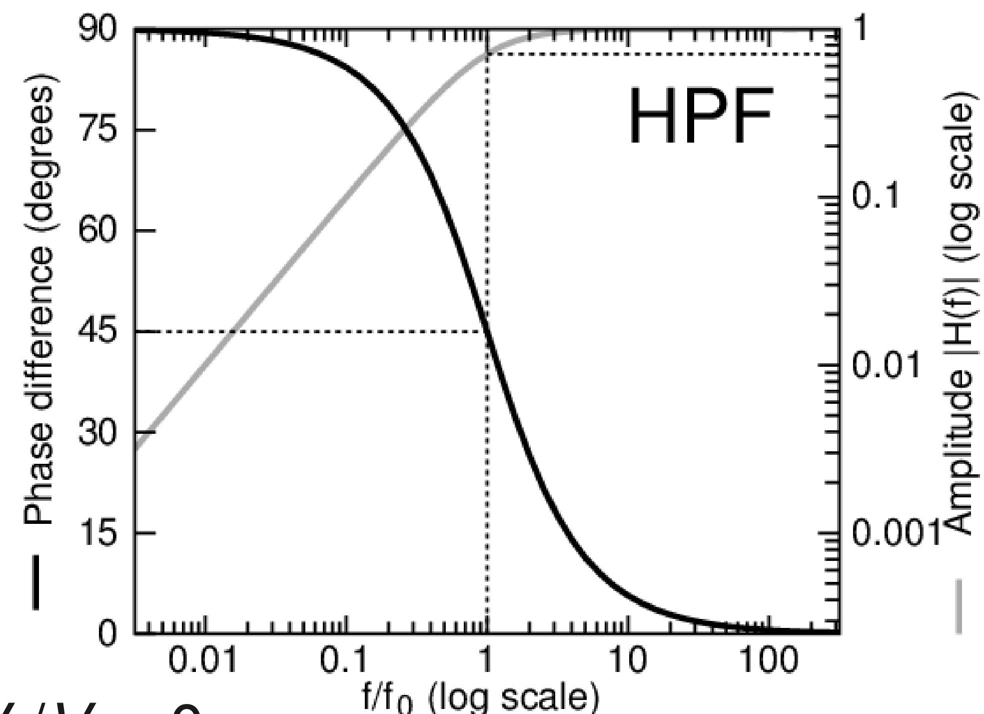
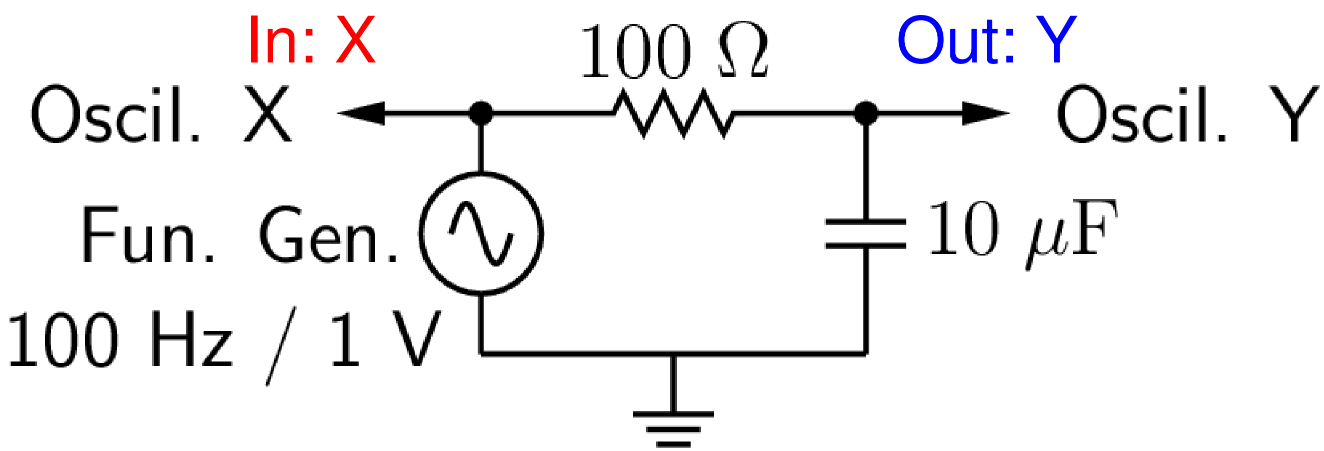


$$\frac{V_o}{V_i} = \frac{1}{1 + 1/i\omega RC}$$

$\omega = 0$: $V_o/V_i = 0$

Simple Low-Pass Filter

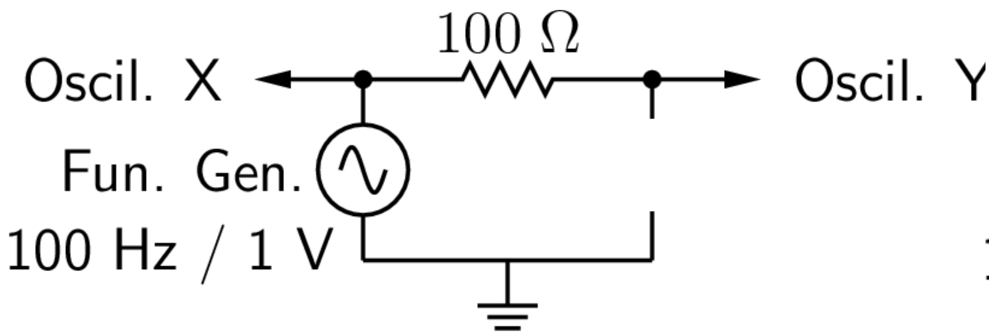


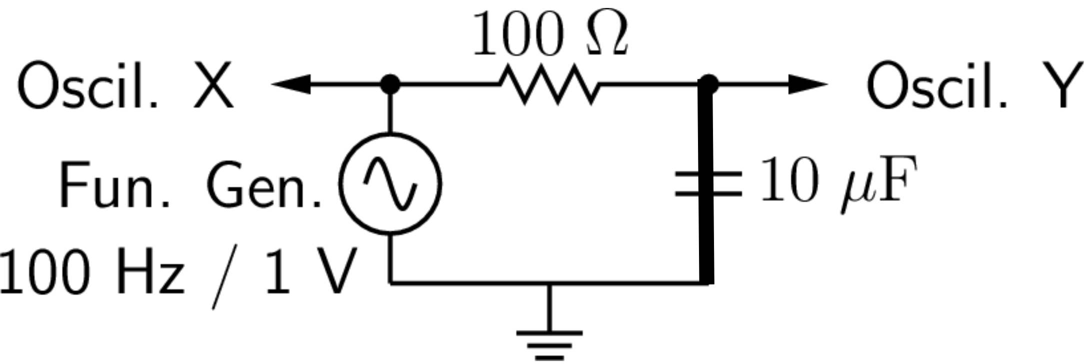
$$\frac{V_o}{V_i} = \frac{1/i\omega C}{R + 1/i\omega C} = \frac{1}{1 + i\omega RC}$$

$\omega = 0$: $V_o/V_i = 1$

$\omega = \infty$: $V_o/V_i = 0$

Simple Low-Pass Filter





$\omega = 0$: $V_o/V_i = 1$

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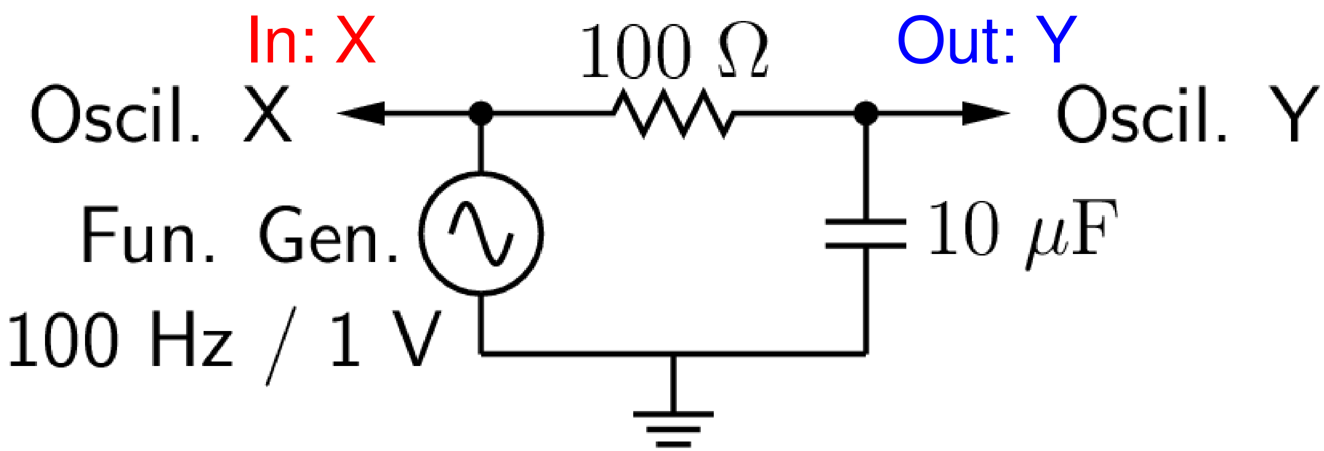
Simple Low-Pass Filter



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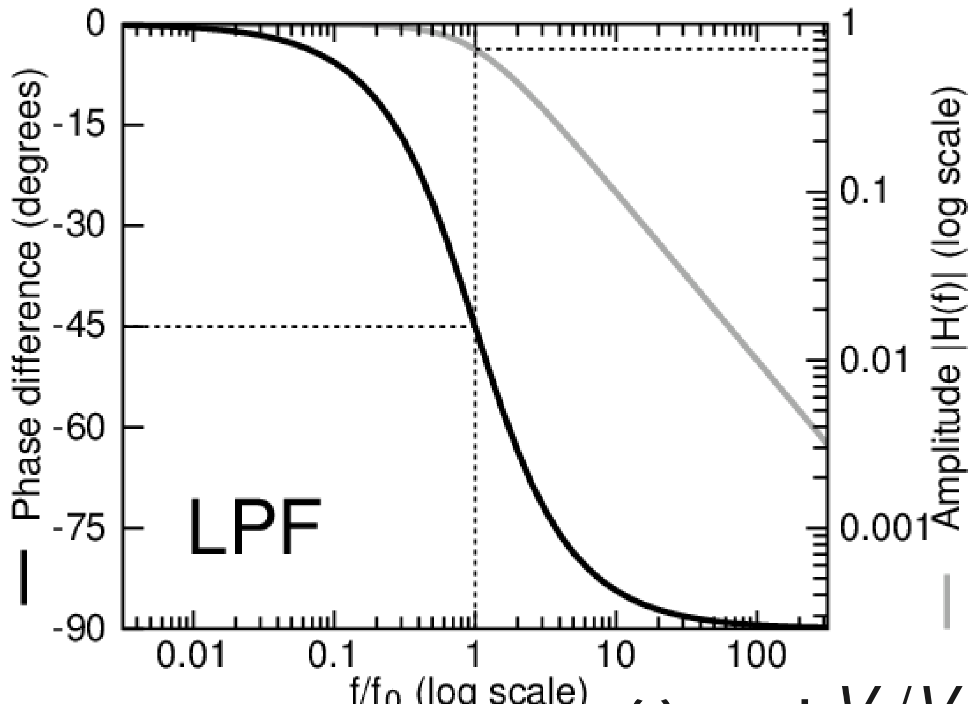

$\omega = \infty$: $V_o / V_i = 0$