Biomedical Engineering Summer School, Wilhelmshaven 2018

Instrumentation, Acquisition and Signal Processing for Biosignals

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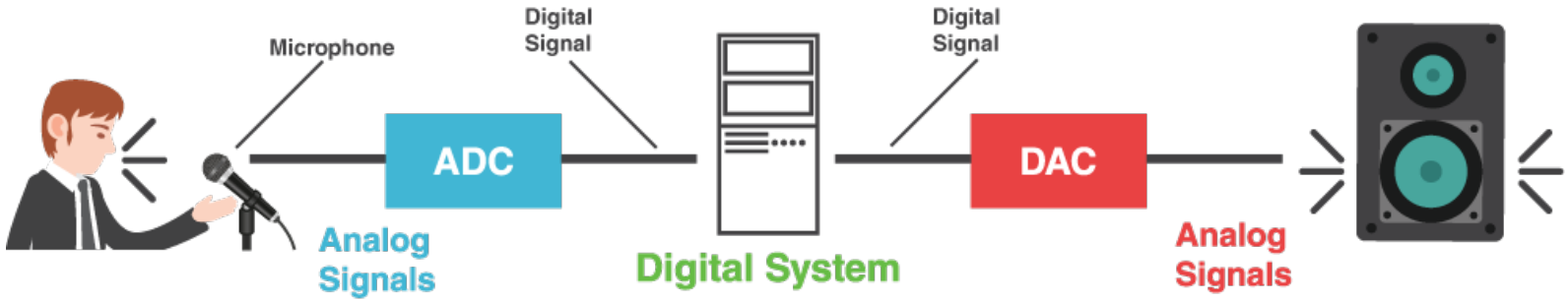
Updated: 2018/08/24

Contest

Introduction



Digital Signal Processing (DSP) basic scheme

What to do with the signal?

Once you have the signal in the digital domain, you can manipulate it, measure it and what ever you can imagine.

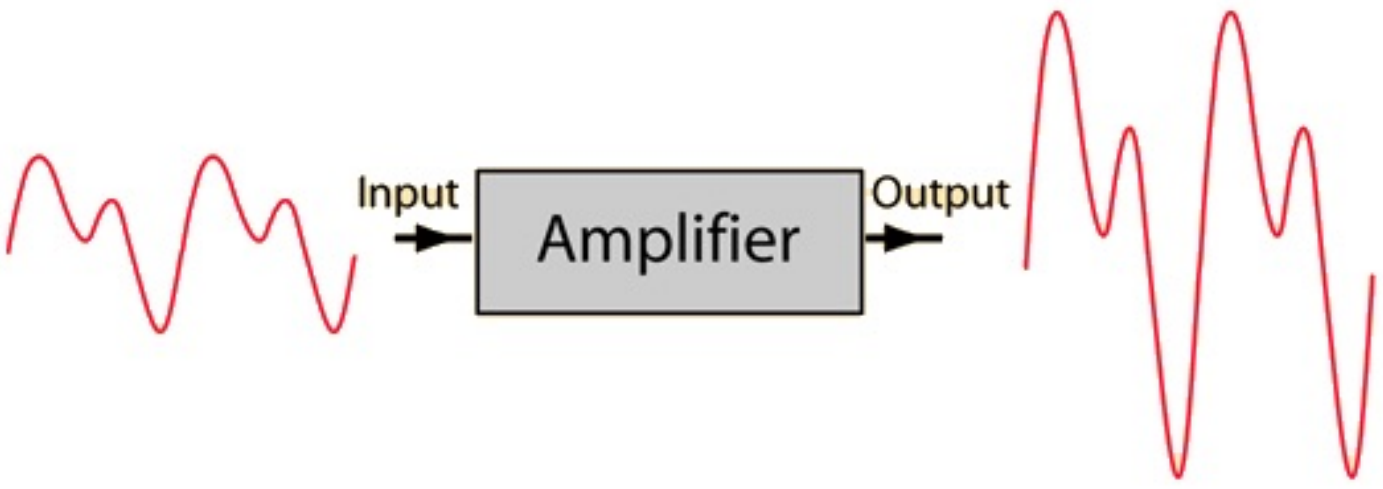
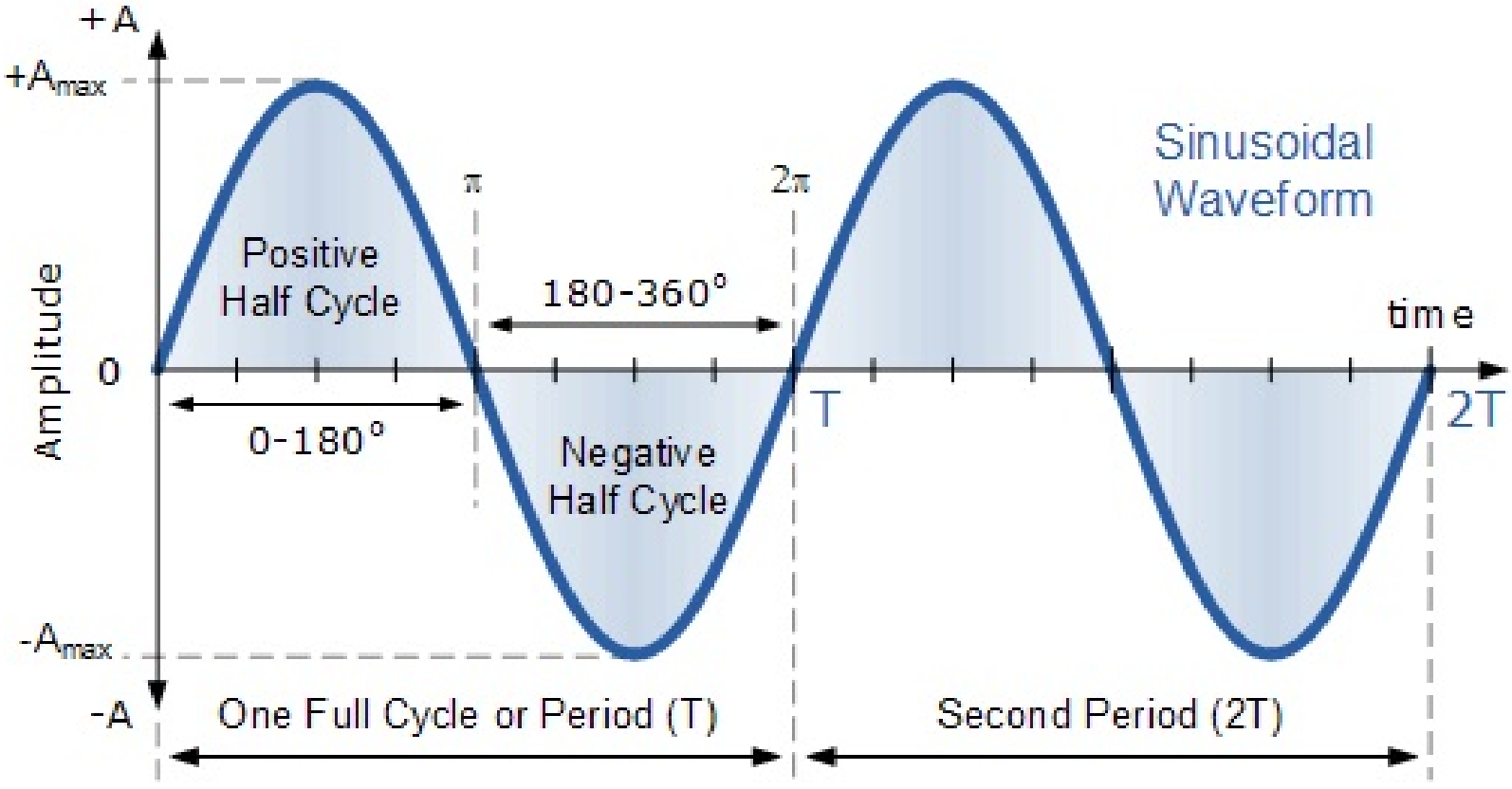
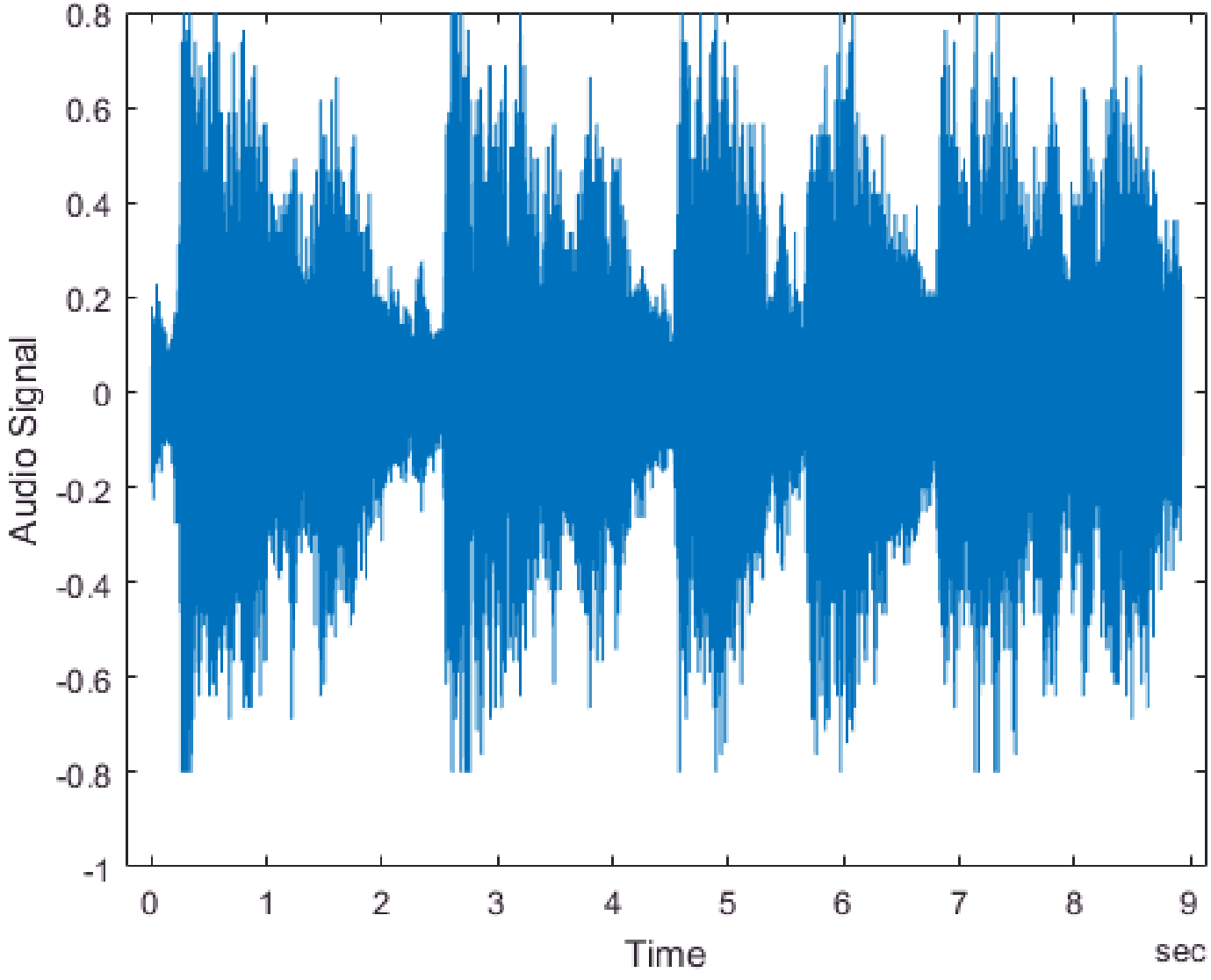


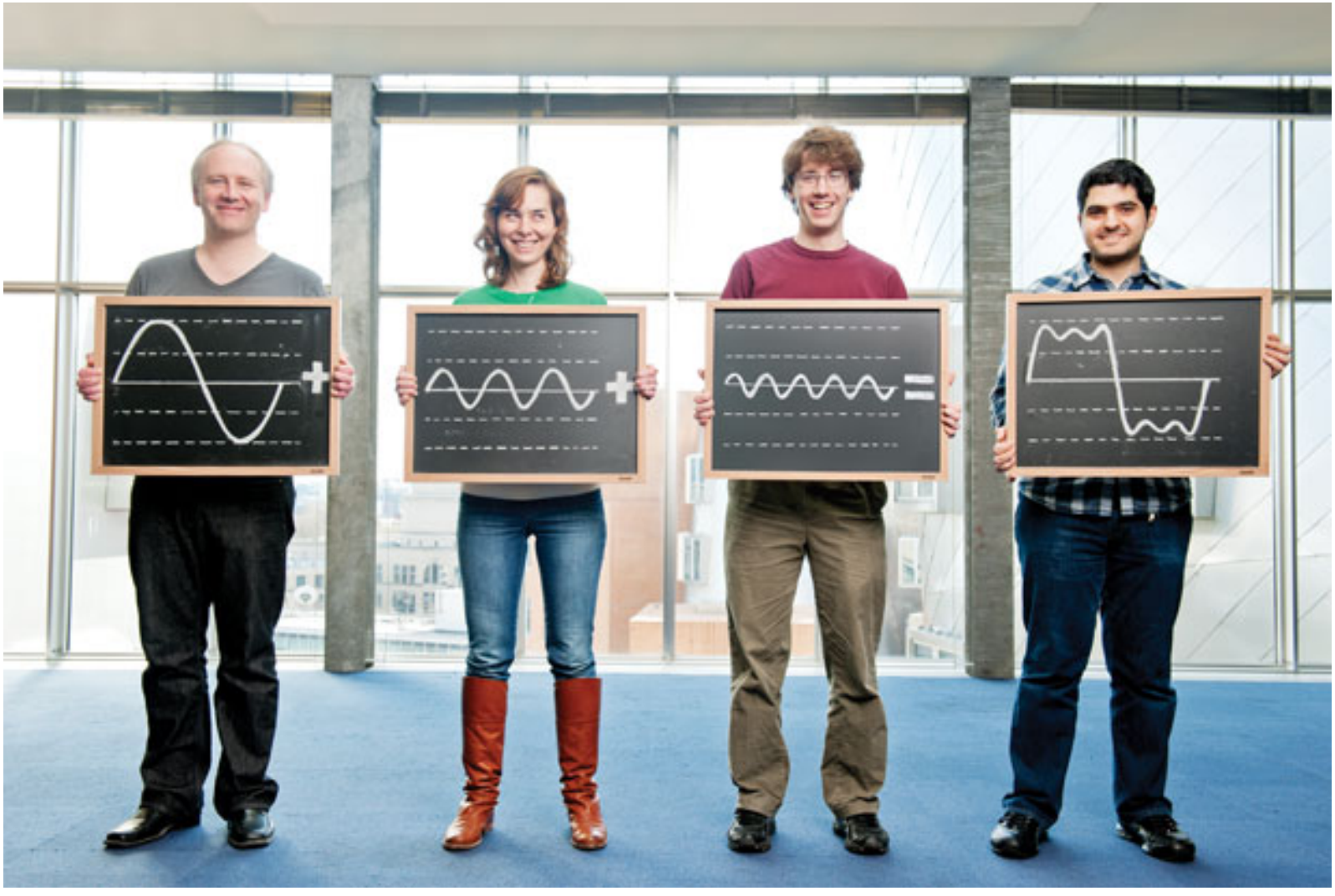
Figure: e.g. Amplifying a signal $y = 5x$



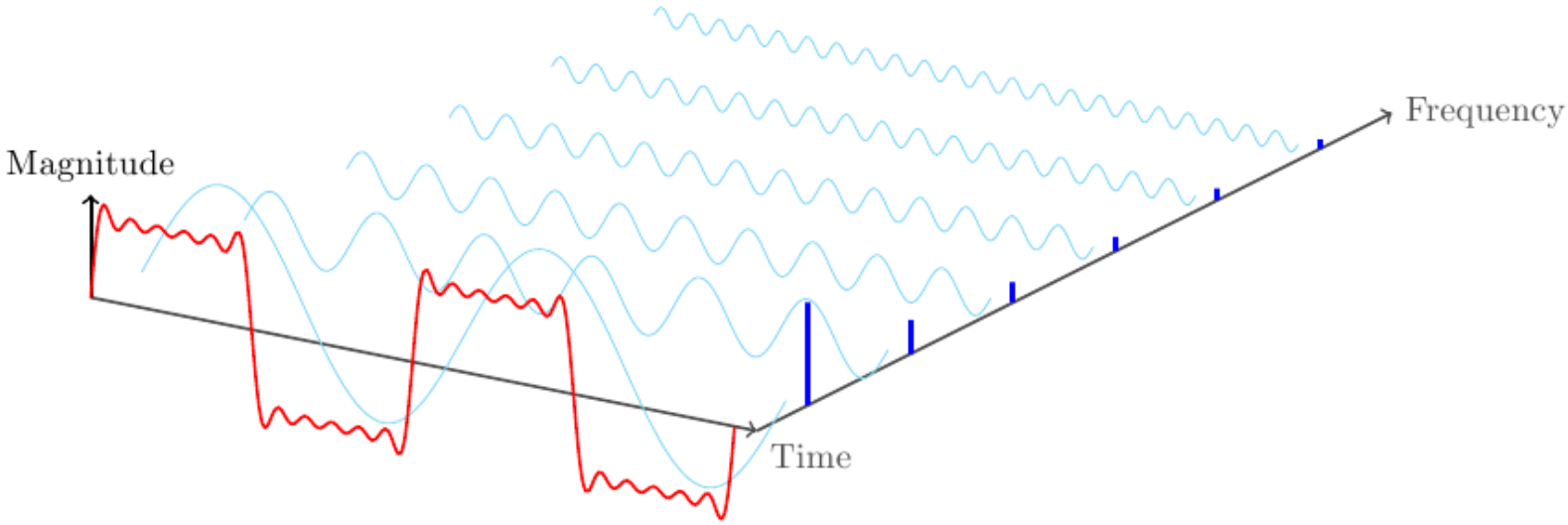
Measure it, also known as feature extraction.



How can we do that in more complex signals?



The Fourier Transformation (FT).

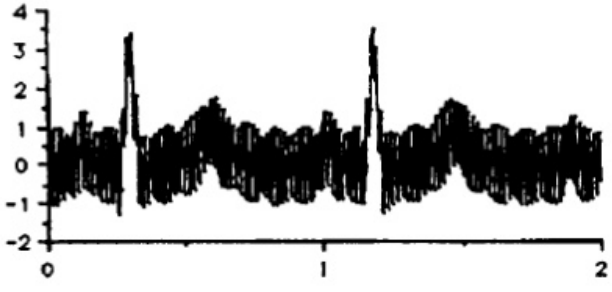


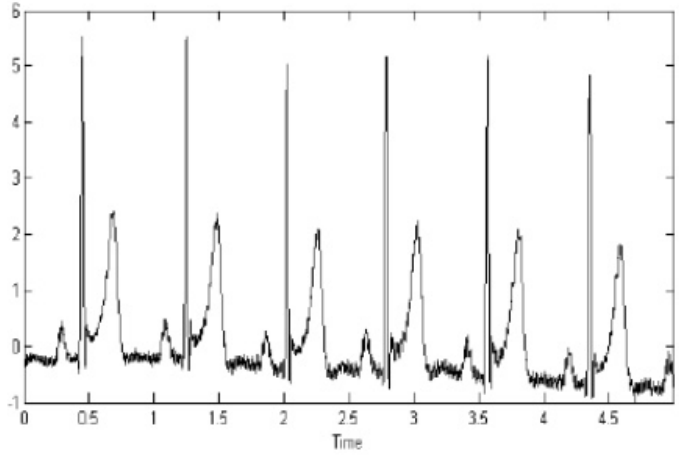
FT allows to identify frequency components upon complex signals.

Examples of FT Applications

Signal Filtering using Fourier Transform

- Rejection of the selected parts of the frequency spectrum H(f)

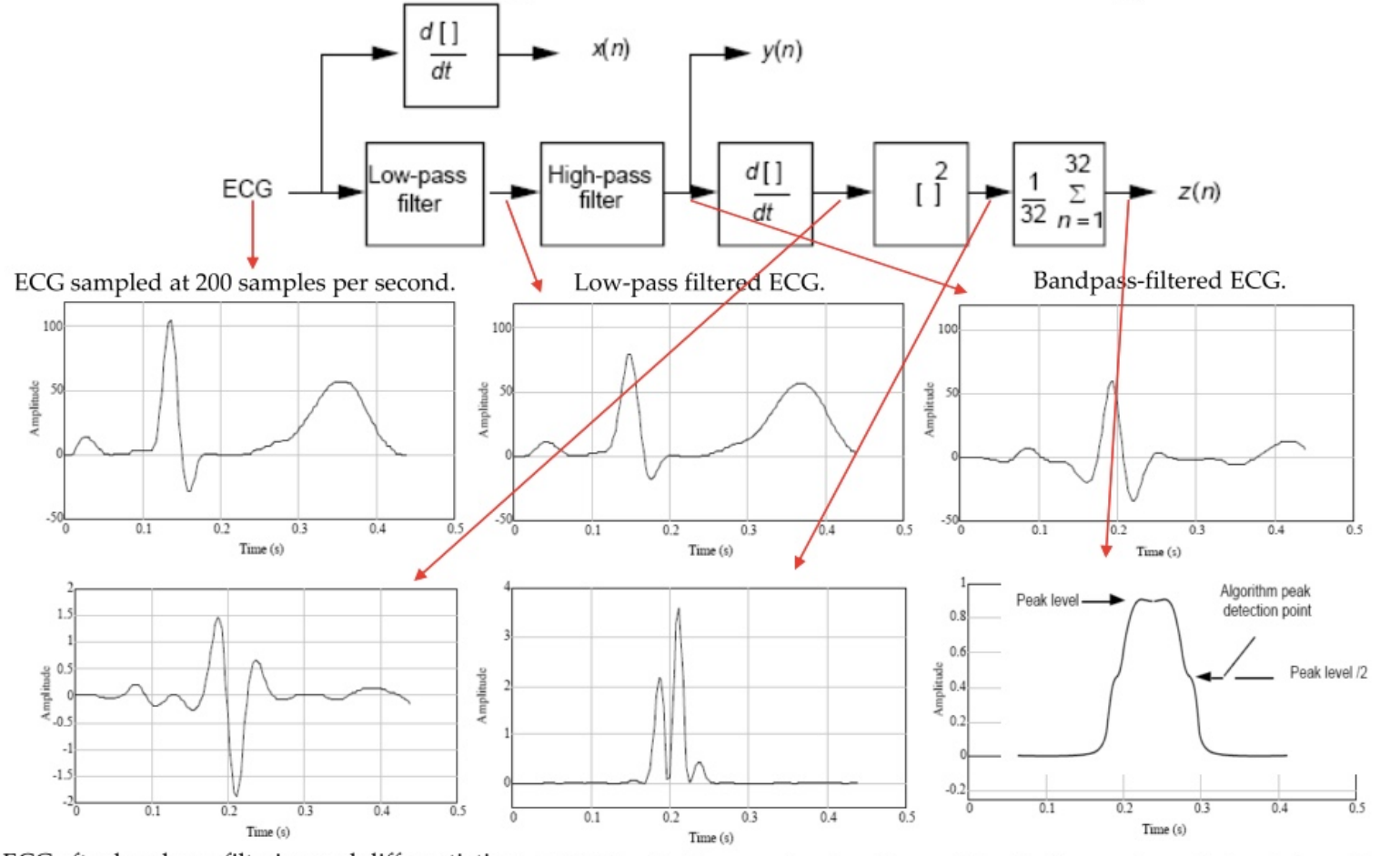




Notch Filter

Pan, J. and Tompkins, W. J. 1985. A real-time QRS detection algorithm. IEEE Trans. Biomed. Eng. ***BME-32****: 230–36,*

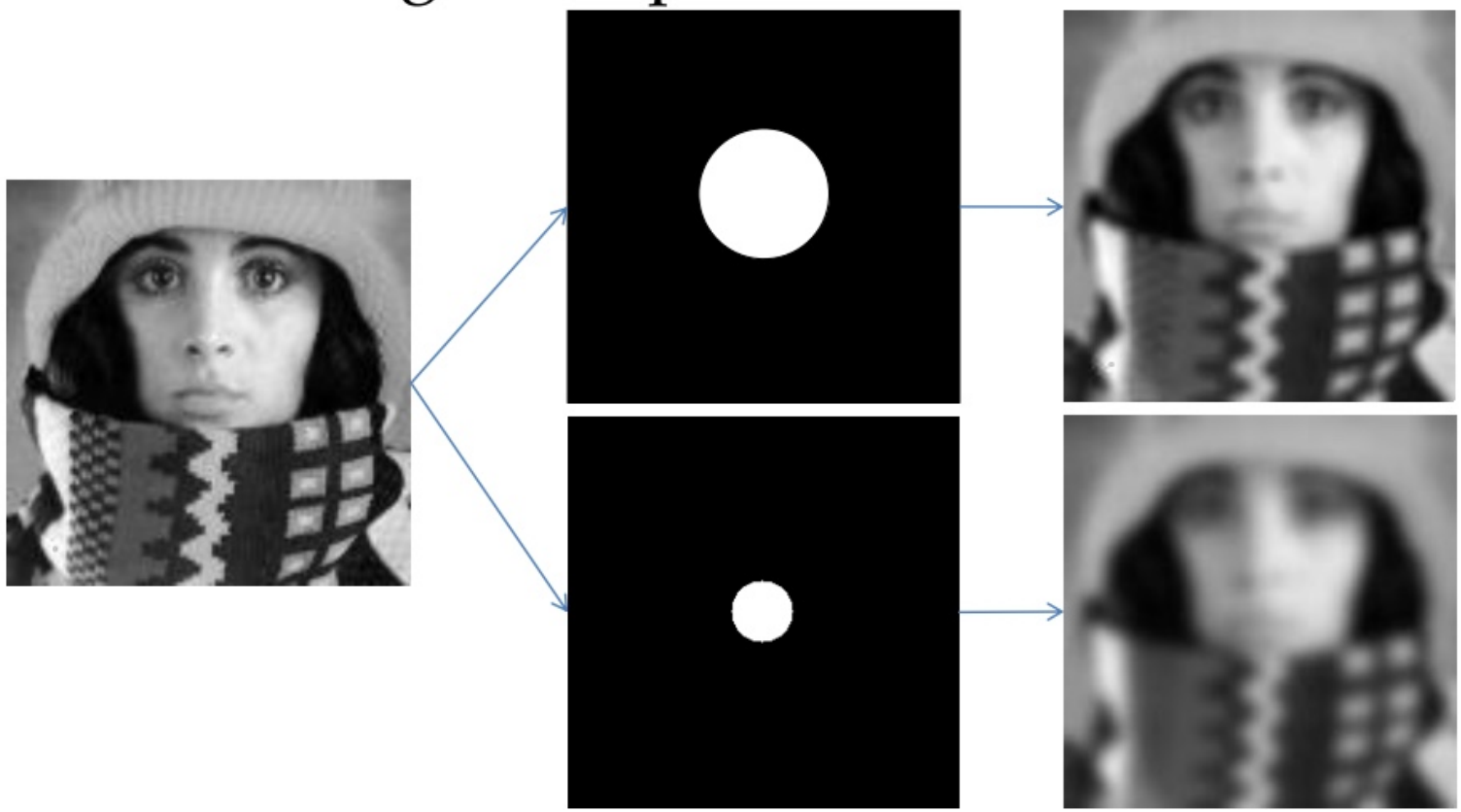
A Real-time QRS Detection Algorithm



ECG after bandpass filtering and differentiation. ECG signal after squaring function. Signal after moving window integration.

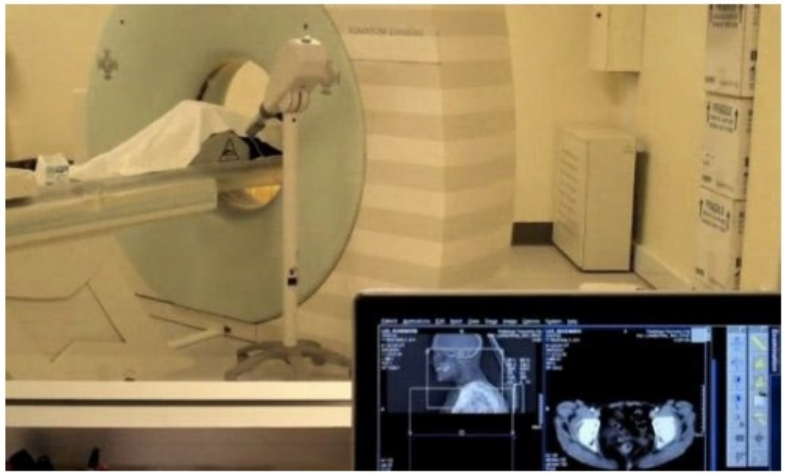
Image Processing using Fourier Transform

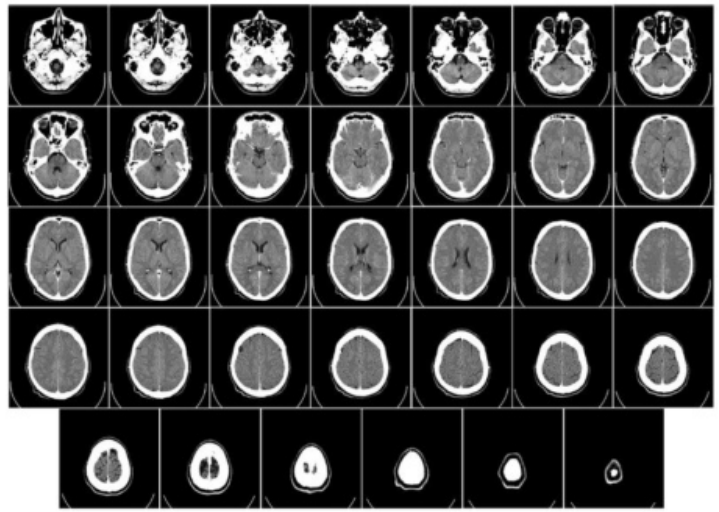
- Smoothing LPF operation;



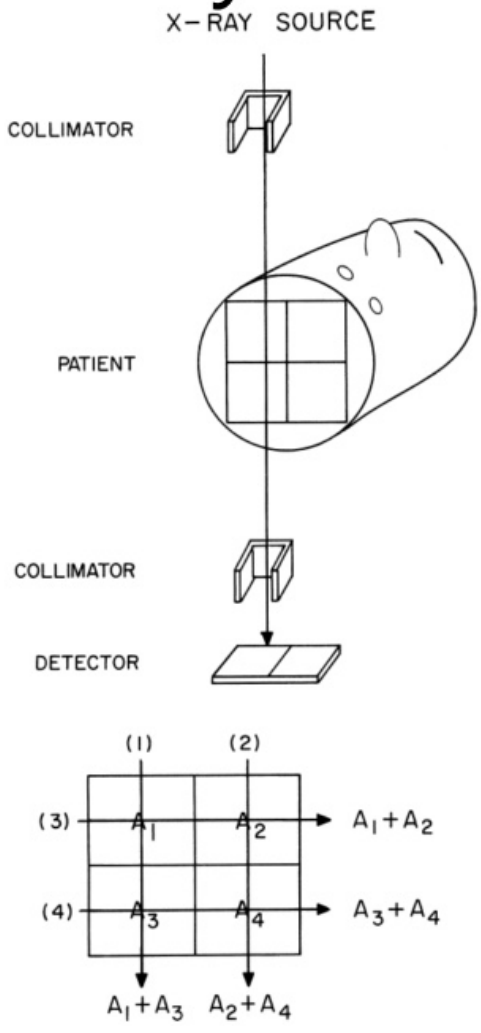
X-ray computed tomography

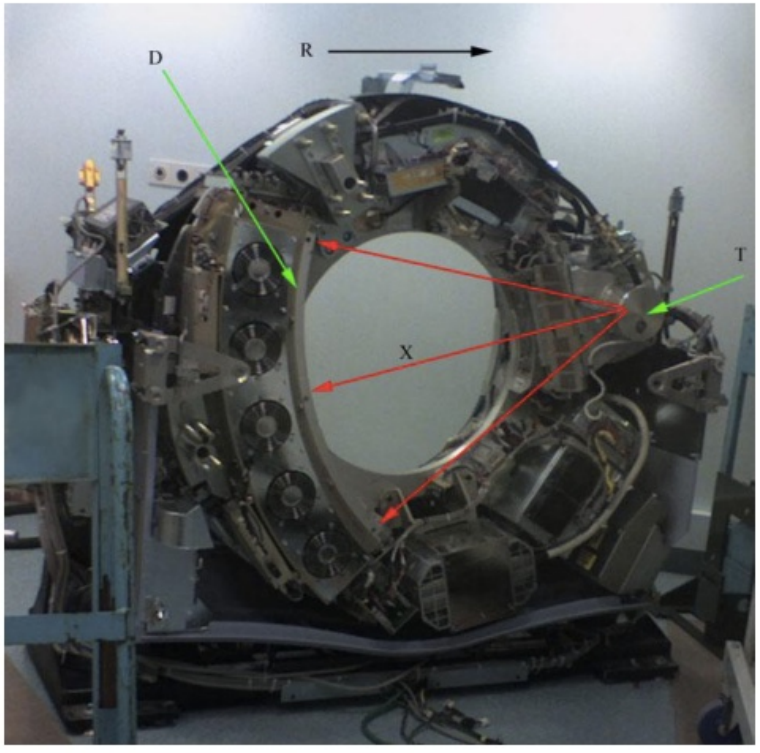
- computed tomography (CT scan) or computed axial tomography (CAT scan), is a medical imaging procedure that utilizes computer-processed X-rays to produce tomographic images or 'slices' of specific areas of the body.





X-ray computed tomography





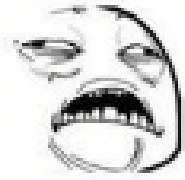
CT scanner with cover removed to show internal components.
T: X-ray tube, D: X-ray detectors
X: X-ray beam, R: Gantry rotation

Fourier Transformation

f(x,y) → **F(U,V)**

Four year Transformation

→

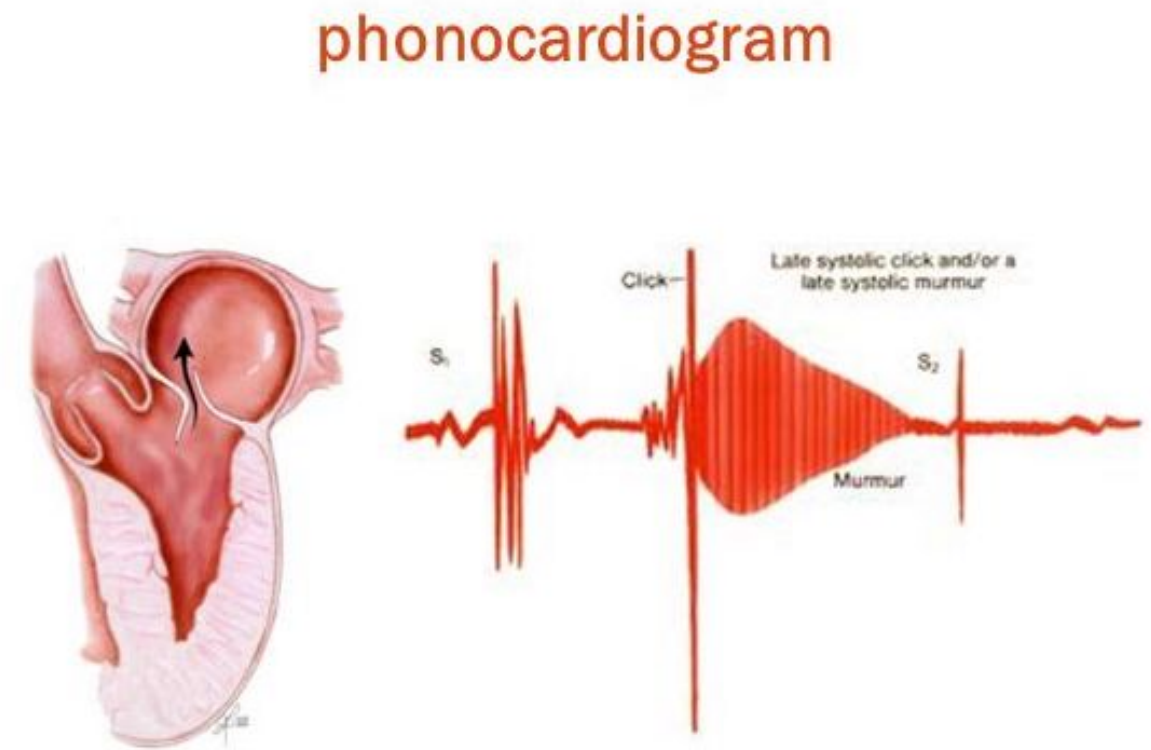


Engineering Student → **ENGINEERING STUDENT**

The Phonocardiogram Project

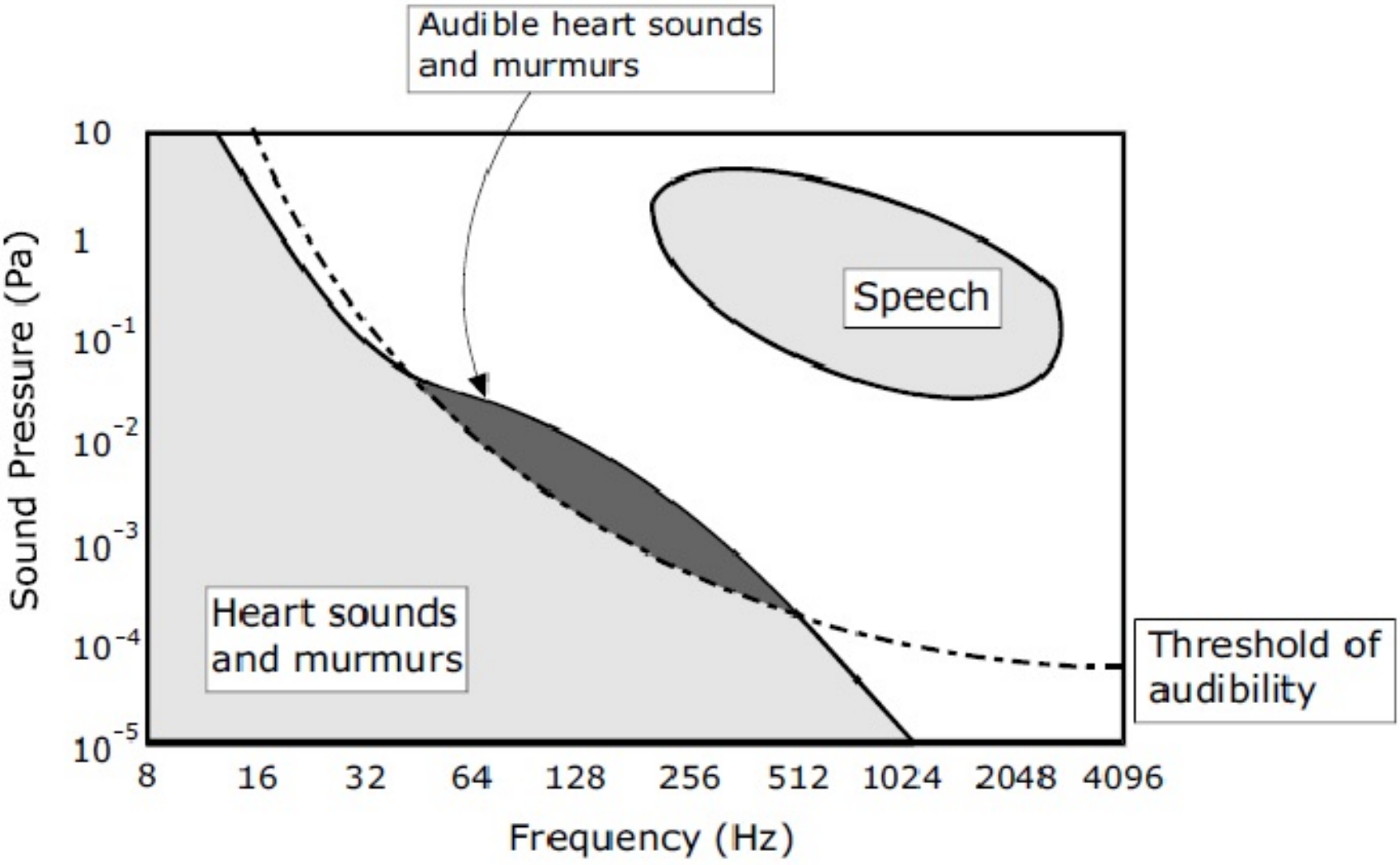
PhonoCardioGram (PCG)

A PhonoCardioGram, also known as PCG, is a representation of heart's audio signal ploted against time.

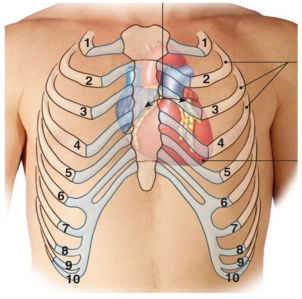


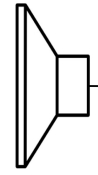
Which frequencies heart use to sing?

In order to acquire the heart's audio signal, is important to know where the heart's frequencies are.

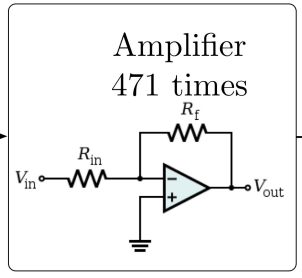

Audible heart sounds
and murmurs
Speech
Heart sounds
and murmurs
Threshold of
audibility
Sound Pressure (Pa)
10
1
10-1
10-2
10-3
10-4
10-5
8
16
32
64
128
256
512
1024
2048
4096
Frequency (Hz)

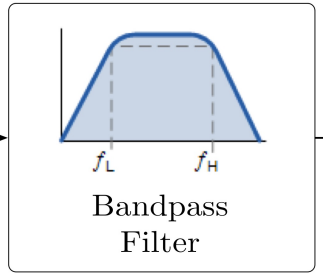
Electronics Design Proposal

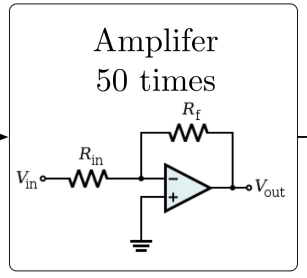


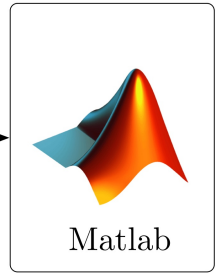


Sound
Sensor





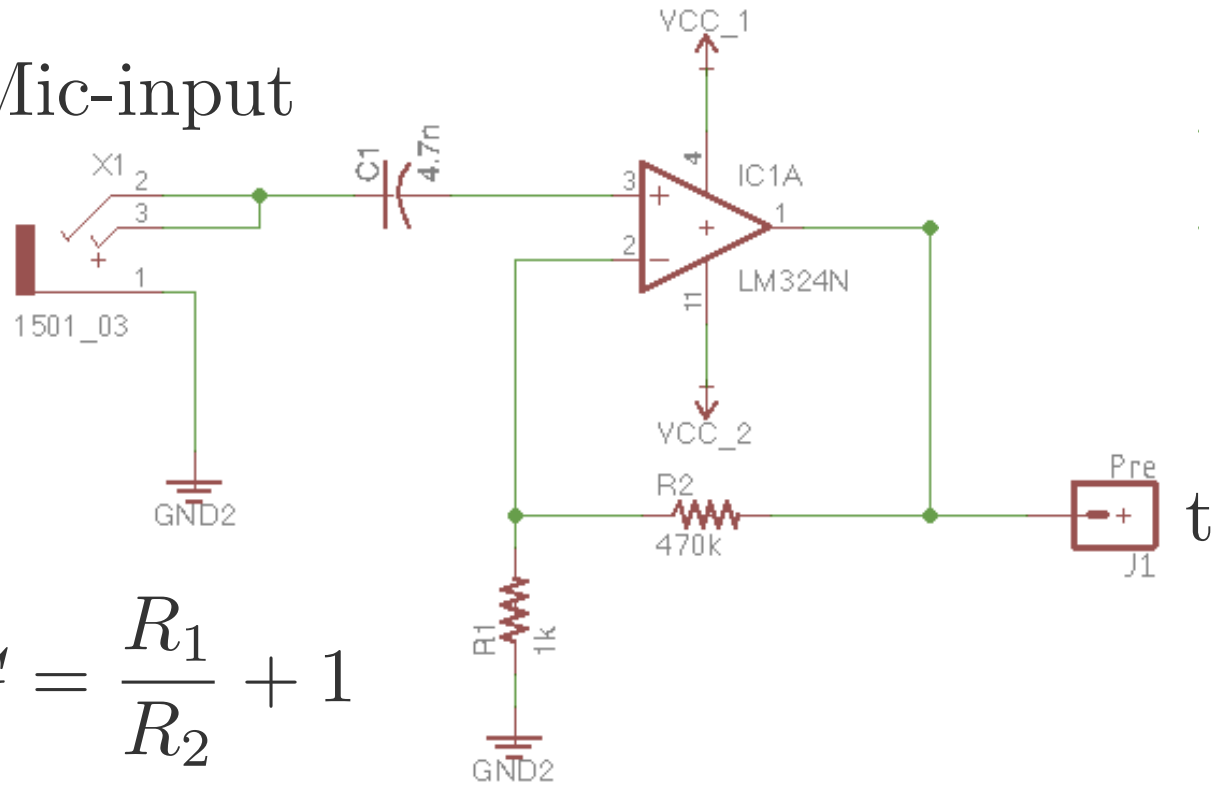




Pre-Amp Stage

Non-inverting amplifier

Mic-input



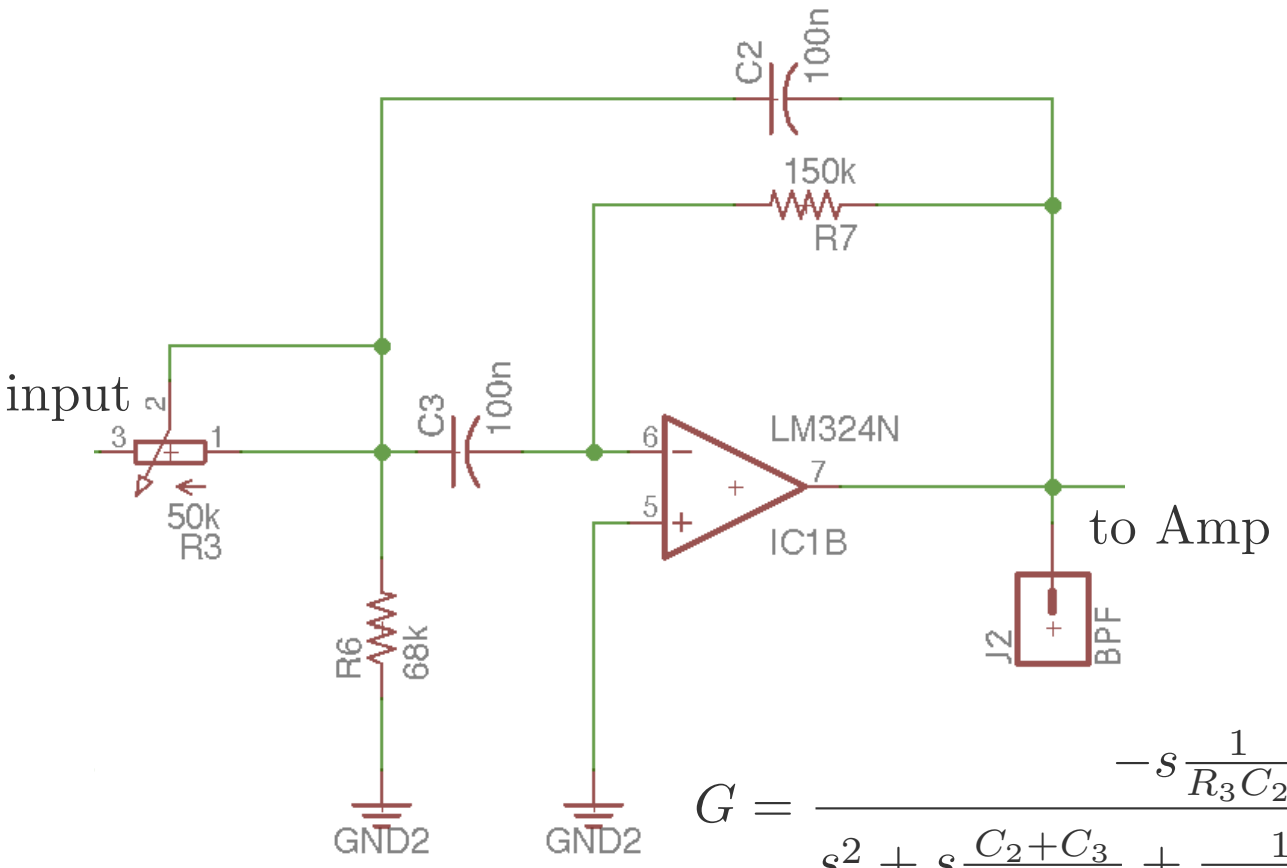
to Filter stage

$$G = \frac{R_1}{R_2} + 1$$

Band-pass

BPF

Multiple feedback bandpass filter



$$G = \frac{-s\frac{1}{R_3 C_2}}{s^2 + s\frac{C_2+C_3}{C_2 C_3 R_7} + \frac{1}{R_7 C_2 C_3}\left(\frac{R_1+R_2}{R_1 R_2}\right)}$$

Filter design

The filter is defined by:

$$k = 2\pi f_0 C_3$$

$$C_2 = C_3$$

$$R_3 = \frac{1}{Hk}$$

$$R_6 = \frac{1}{(2Q - H)k}$$

$$R_5 = \frac{2Q}{k}$$

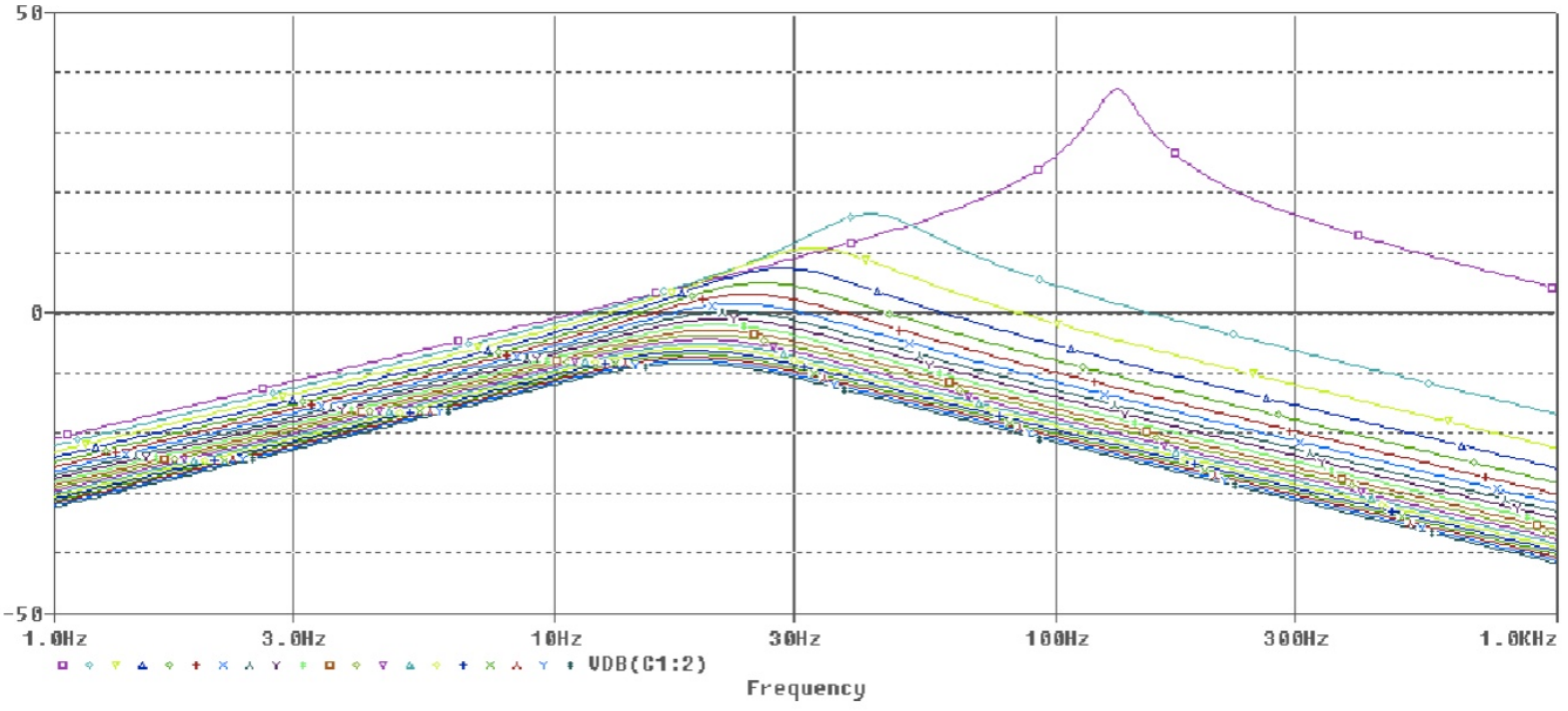
Design was tuned in:

$$Q = 2, f_0 = 33$$

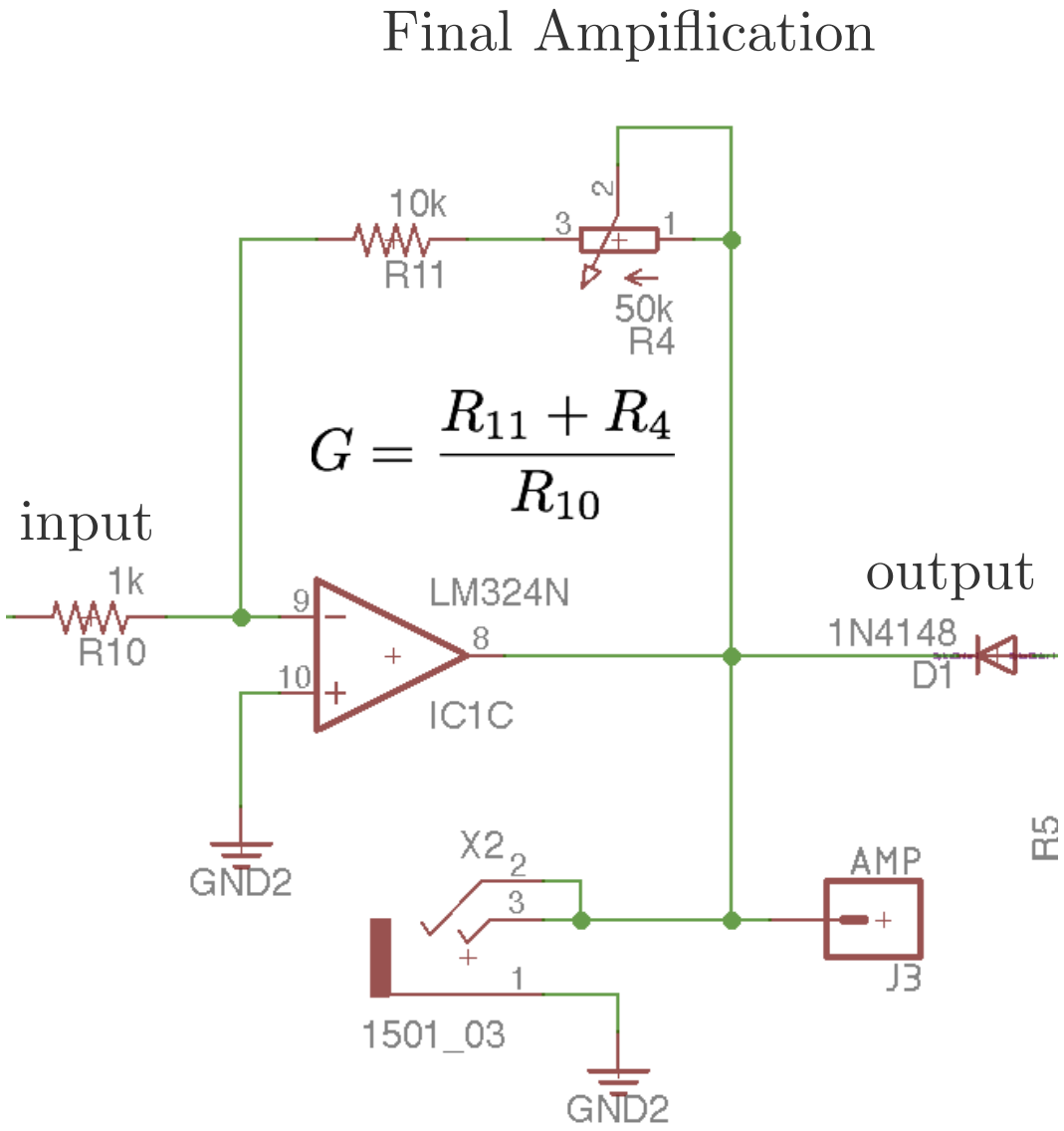
$$C_2 = C_3 = 100nF$$

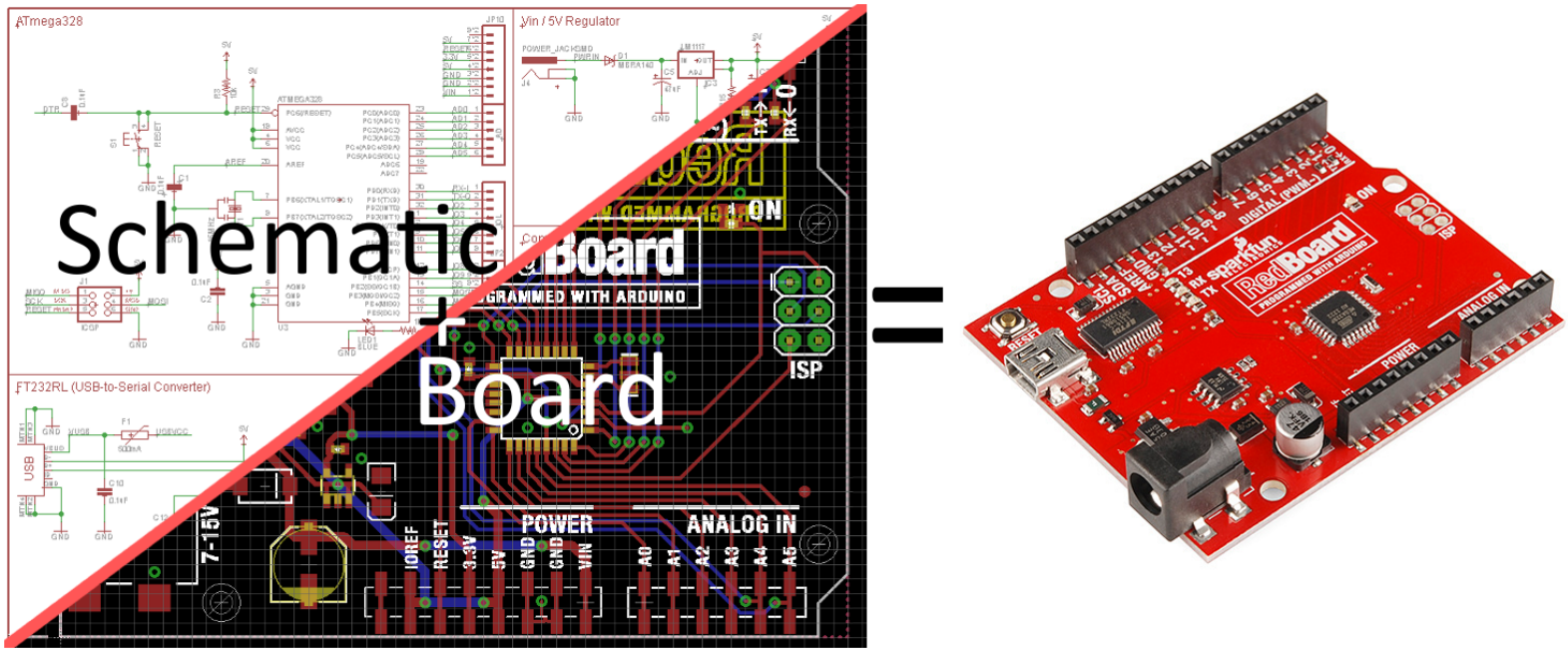
$$H = 2$$

Filter's behaviour



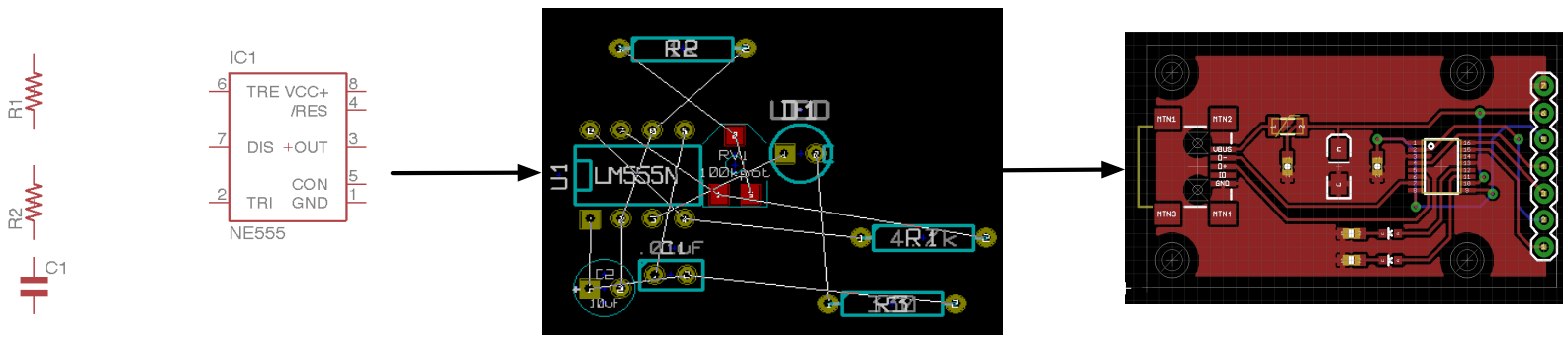
Inverting amplifier





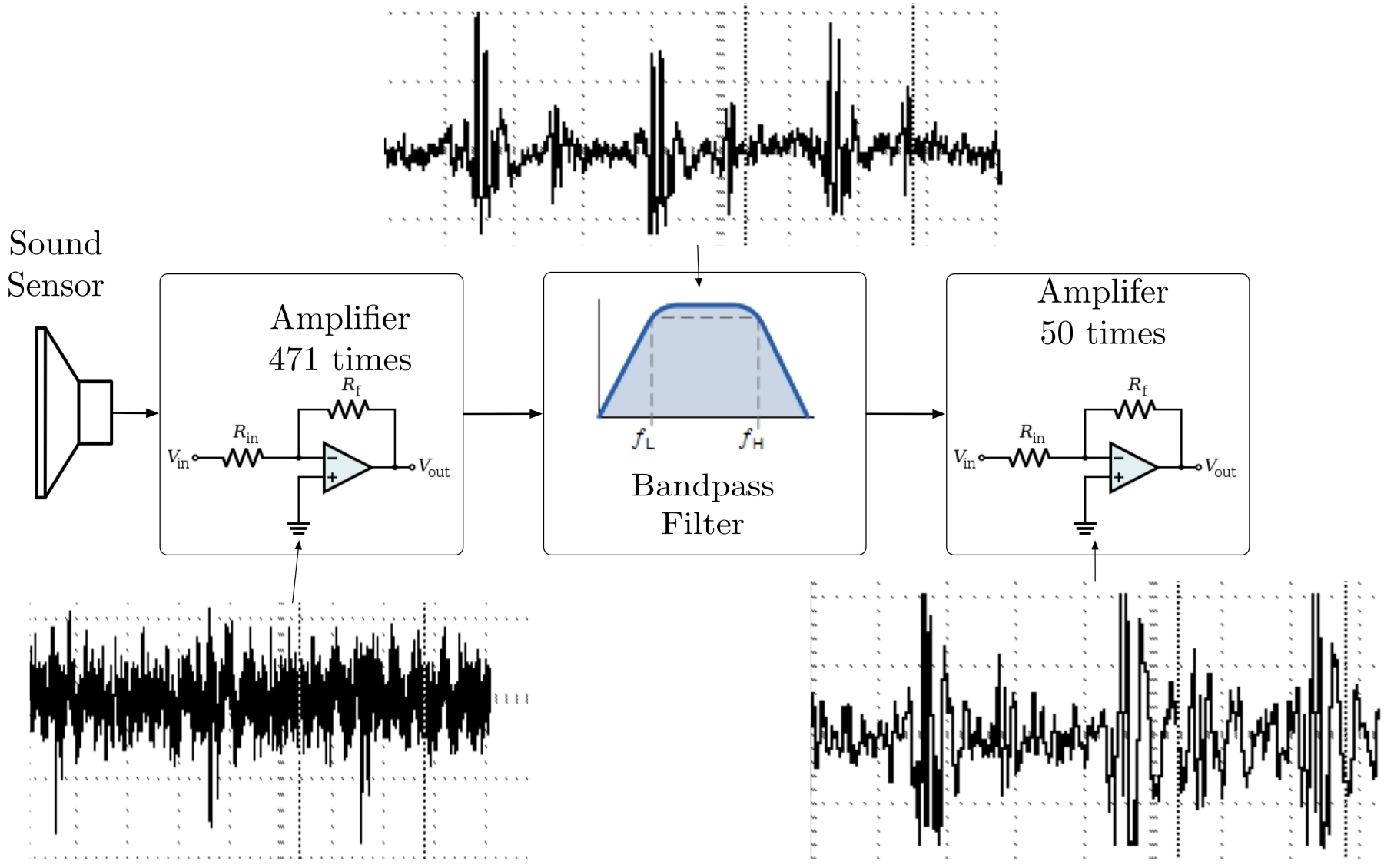
The IDE to create your own design

Schematic Rat nest PCB



Eagle, OrCAD, TINA, Altium, ...

Lets built our PCB


Sound
Sensor
Amplifier
471 times
R_f
R_{in}
V_{in}
V_{out}
f_L
f_H
Bandpass
Filter
Amplifer
50 times
R_f
R_{in}
V_{in}
V_{out}

References

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  Differential Equations with Boundary-Valuer Problems,
  7th Editions, 2009
- Earl W. Swokowski
  Calculus with analytic geometry
  Prindle, Weber & Schmidt, 1979