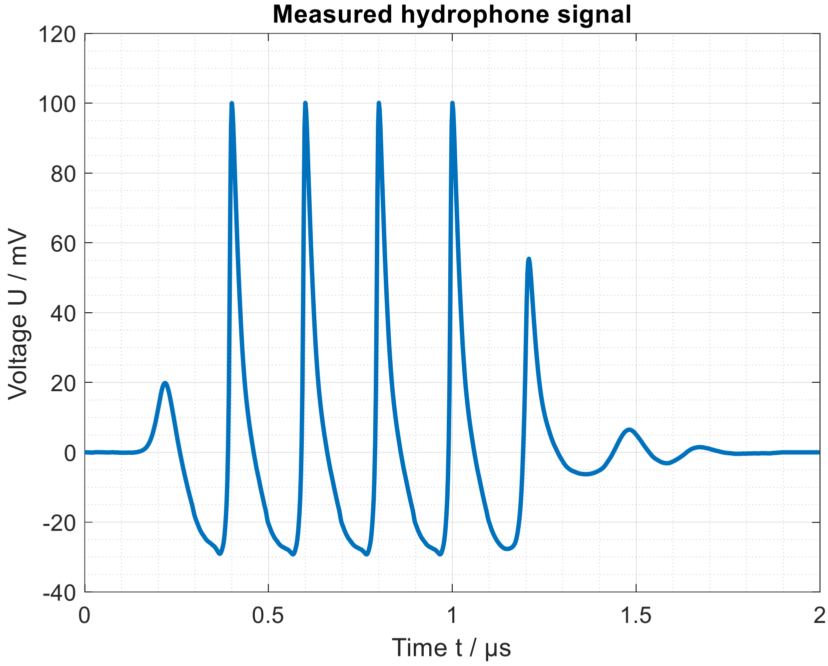
Ultrasonics 2025
Demo exercise 2 (Exercise 7)

Be prepared to present your solutions in the exercise session on Wed 12.3.

1. Evaluation of hydrophone measurements (2 pts)

An ultrasonic signal was measured with a hydrophone and recorder with an oscilloscope. The waveform is shown in the following figure. This signal is a slightly idealized and simplified waveform of the pulse-Doppler-signal emitted by a medical ultrasonic device.



The hydrophone sensitivity level is given in the following table:

Frequency f (MHz)	2	4	6	8	10
Sensitivity level L_M (dB)	-154.8	-154.5	-154.1	-154.0	-153.7

The uncertainty of the calibration is 6 % of the hydrophone sensitivity value $M(t)$ at the given frequency f. The relation between the hydrophone sensitivity level $L_M(f)$ given in dezibel and the hydrophone sensitivity $M(f)$ given in V/Pa is expressed in the following equation:

$$L_M(f) = 20 \cdot \log_{10}\left(\frac{|M(f)|}{M_{ref}}\right) \text{dB}$$

With $M_{ref} = 1\,\frac{\text{V}}{\text{Pa}}$.

a) Determine the fundamental frequency of the burst.
b) Calculate the peak positive and peak negative pressure and its uncertainty. Use the sensitivity at the fundamental frequency. For the voltage chose a reasonable uncertainty from the ability to read the value from the diagram.

2. Signal deconvolution (6 pts)

In the course material, you find electronic datasets. One is the hydrophone voltage in the time domain (voltage.csv) as shown in the previous task. The second one is the hydrophone sensitivity (hydrophone.csv) in the frequency domain given as cartesian complex numbers ($C = a + bi$ with $i = \sqrt{-1}$). The datasets have been already adjusted to match the number of points, sample rate and frequency range. So, after transforming the time domain voltage signal into the frequency signal, it will have luckily the same frequency scale as the data set of the hydrophone sensitivity. Therefore, you do not need to modify the datasets.

a) Convert the voltage signal (voltage.csv) into a pressure signal by scaling it with the (absolute) hydrophone sensitivity at the fundamental frequency of the burst. This is the equivalent approach as in task 1.
b) Plot the amplitude (absolute value) of the hydrophone sensitivity against the frequency in the range from 0 to 100 MHz. This shows the amplitude response of the hydrophone. What will happen if the hydrophone is used to measure high frequency signal components above 20 MHz?
c) Deconvolve the voltage signal by the given hydrophone data set and plot the pressure signal together with the signal from a). The equation for the deconvolution can be found in the presentation for the demo.
d) Determine the peak positive and peak negative pressure from the deconvolved signal and compare it with the result from the previous task. What do you notice? What implication might that have for measuring ultrasonic pressure with a hydrophone.

Hints: Reading the datasets can be performed with the MATLAB function readmatrix("filename.csv"). Use the MATLAB functions fft for transforming from time domain into frequency domain and ifft for the reverse transformation. For elementwise multiplication or division of two vectors (A and B) use the notation A.*B and A./B. The exercise can also be solved with any other computing program.