Virtual model for piezo sensors adjustment

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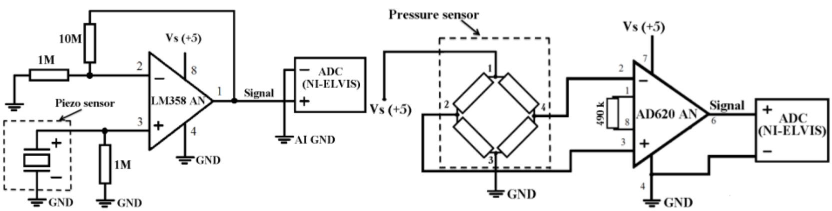
Introduction. Sensors that convert one form of energy to another are widely used in biomedicine. Piezoelectric sensors convert mechanical energy into electrical energy and vice versa, therefore they are widely used for various applications. Piezo sensors are used for the detection of biomedical signals [1-4]. They can be employed to register the pulse wave of the carotid artery [5]. The main issue here is that piezoelectric sensors in their physical nature show a nonlinear transfer performance when affected by different pressure values, frequencies, directions of impact on crystal, etc. [6]. Therefore every piezo sensor must be tested and adjusted. The adjustment can be performed by implementing a scheme of integral and differential elements. Nowadays, as digital technologies and various modelling methods (especially for piezo sensors [7]) are developing, the adjustment is possible by implementing digital methods. The goal of the adjustment is to adjust the performance of piezo sensor to a "standard" sensor (e.g. pressure sensor). Thus we can simplify the device by abandoning complex circuits and their elements. Therefore the main goal of our work is to estimate the transfer function of piezo actuator by comparing a "standard" (pressure sensor) with a piezoelectric sensor.

Methods. Pressure and piezo sensors signals amplifying schemes were designed using the NI ELVIS mounting panel to estimate the transfer function of a piezoelectric sensor (Fig. 1). The schemes were designed considering the specifications of the sensors.



a) b)

Fig. 1. The schemes of implementing the amplification of the signal of a piezoelectric (a) and pressure (b) sensors

The signal of piezoelectric sensor „piezo element LD-BZPN-2730" was amplified 10 times, whereas the signal of pressure sensor „Honeywell -26PC SMT" was amplified 100 times. The signals of these sensors were prepared using a 16-bit NI ELVIS analogue to digital converter. The frequency of discretization – 1 kHz. In this case it is crucial to know the amplitude and frequency transfer characteristics of the sensor and of the whole electrical circuit. During the experiment, a vacuum cylinder was constructed that had a piezoelectric sensor installed at one end. The sensor was actuated by the pressure of the airflow. During the next stage of research, an impulse pressure signal was generated and synchronically sent to both sensors. Using LABVIEW 2012 software, an application was developed that registered and computed the signals of the above mentioned sensors. Diagrammatic signal-registering form shows that the signal of piezoelectric sensor differs from that of a standard air pressure sensor (Fig. 2). The equation model was used to identify the differences and to determine the transfer function of the system.

$$Y(s) = G(s) * u(s)\,, \tag{1}$$

where: *Y*(*s*) – signal of piezo-sensor (outgoing), *G*(*s*) – transfer function between input and output signals (2), *u*(*s*) – pressure sensor signal (ingoing).

$$G(s) = \frac{b_0}{1 + ts}\,, \tag{2}$$

where: b_0 – amplification coefficient of polynomial function, *s* - Laplace operator, *t*– time constant.

Thus, as the transfer function of the system and the output signal are known, it is possible to adjust the input signal. It was calculated by employing the formula (3).

$$Y_1(s) = G(s) * Y(s)\,, \tag{3}$$

where Y_1(s)- the signal of piezo sensor after using the transfer function (outgoing signal), G(s) – calculated transfer function, Y(s) – piezo-sensor signal after first operation (ingoing signal).

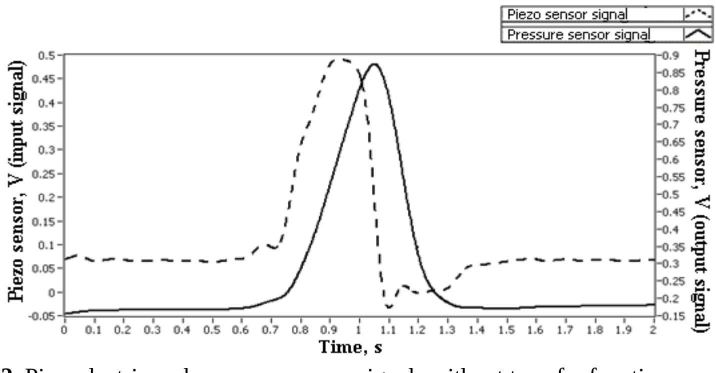


Fig. 2. Piezoelectric and pressure sensors signals without transfer function operation

Results. After calculations were done, a new signal was obtained that could be compared with that of pressure sensor (Fig. 3). It is evident that the newly obtained signal is not equal to the original one. However the differences remained merely in a constant constituent and in the ending part of the signal. The front and the peaks of the signals are almost identical.

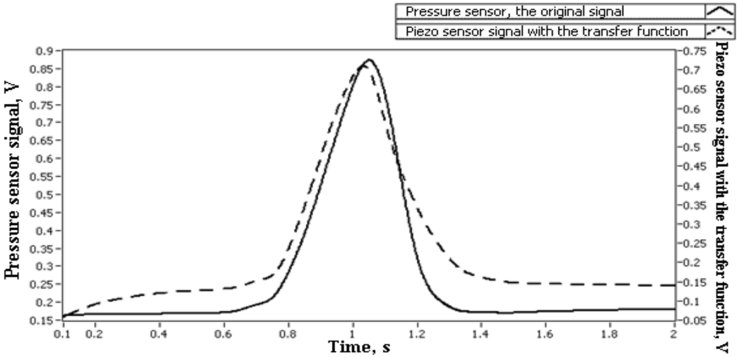


Fig. 3. Pressure sensors (dotted) and piezoelectric sensor after processing with transfer function (continuum) signals

The goal of the application of piezo actuator is to register the pulse wave at carotid artery. The most important information collected from registering the pulse wave is found at the front and the peak of the wave. Therefore it is assumed that such piezo sensor with an adjustment system is suitable for this task. Having performed the experiment using the designed system of measurement, the first order transfer function between the input and the output signals of piezoelectric sensor and pressure sensor was assessed. The transfer function derived is as follows (4):

$$G(s) = \frac{0{,}33274}{1 + 0{,}125024 s} \ . \qquad (4)$$

The amplification degree of designed system is equal to 0.33, time constant – 0.13 sec. By applying the transfer-function ratios it is possible, considering a standard signal, to design amplitude and frequency characteristics of the sensor for a desired goal. The designed virtual model for assessment of the transfer function of piezoelectric sensor shows that the usage of electronic elements is not always necessary to achieve the modification of amplitude and the frequency characteristics of the sensor. The amplitude and frequency-characteristics of the sensor can be modified using an RC circuit, however, in this case, in the first instance, it is also necessary to determine the values of the transfer function between original sensor signal and the signal of a standard sensor in order to choose necessary electronic elements. It is performed using various calculating applications. Therefore, in our opinion, the method suggested simplifies the electronic part of the adjustment system by transferring its functions into virtual environment.

Conclusions. A virtual model for assessment of the transfer function of piezoelectric sensor was designed. The method shows that using a piezo sensor for determining of the pulse wave main parameters makes it possible to do without RC adjustment circuit. The transfer function ratios were calculated: the degree of amplification is equal to 0.33, time constant – 0.13 sec. Obtained difference between the signals of pressure and piezo sensors shows that piezo actuator thus adjusted can be applied in measuring key parameters of pulse wave (the front and the peak of the wave).

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Purpose of this work was to determine piezo-electric actuator transfer function according to the air pressure sensor signal using virtual instruments. During work was created a virtual piezo-electric sensor transfer function measurement model proving that in order to change the sensor frequency amplitude do not need to use electronics items.