System for Measurement of Biomechanical Characteristics of the Fingers and Hands

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Abstract—**In this paper an dedicate system for force measurement is presented. This system is capable to measure force produced by fingers, and hands. It has 4 independent force sensors which are capable to measure stretch force as well as squeeze force produced by the fingers and hands. The developed system enables dynamic force measurements for the fingers and hands for the goal of hands rehabilitation due to damage of the central nervous system as well as to biomechanical test of healthy people during exercise. System is also designed to follow a rehabilitation to the patients with the hand injures, brain stroke rehabilitation etc.**

Key words - fingers, hand, force sensor, data aquisition, measurement, biomechanics

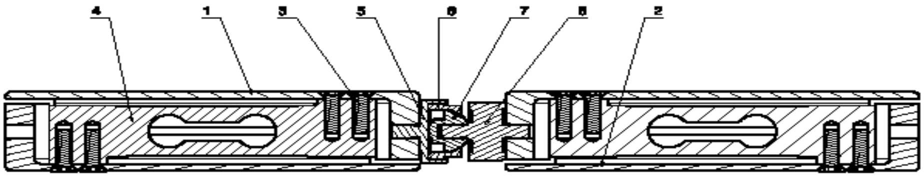
I. INTRODUCTION

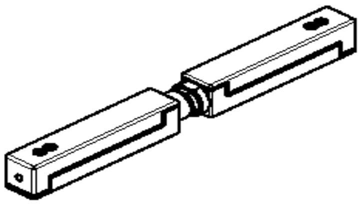
Measurements in biomechanics require special sensitive devices capable of real-time detection of the smallest changes. In addition to sensitivity, the measurements must take into account the biomechanical characteristics of the human body (dynamics, forces, constraints). Because the measurement systems in biomechanics are demanding, technically and technologically they are complicated and not easily realized. The development of computer technology and sensors has greatly facilitated measurements in biomechanics, but the systems that make it possible are mechanically very complex. Note that the first measurements were made in the biomechanics of the early 20th century by Elftman, Bernstein and Fischer [1-5]. Measurements in biomechanics are of great importance in many fields of science. Starting from rehabilitation in medicine and sports to humanoid robotics for more accurate modeling of humanoid systems. Precise biomechanical measurements give valuable results in a better understanding of trends in humans and the realization of humanoid robotics motion. In addition, these measurements can be of great effort as well as in rehabilitation and in active training of athletes to achieve the best results and the prevention of injury.

II. SYSTEM DESCRIPTION

Hand grip strength and synergistic effect of hand grip and arm stretching or compressing is a diagnostic approach of damage degree in various nerve disorders, such as stroke, myocardial infarction, or brain damage and central nervous system damage occurred as a result of many accidents and disasters. The difference of measured of force values and measured dynamics provide a more complete picture of the patient and the extent of rehabilitation required. Also, in sports activities, progress in training can also be traced by measuring of all of these parameters.

Implemented system who is capable to realize dynamic measurement of these parameters is shown in Figure 1 It can be seen from the drawing that the system are based basis to the force sensor type SW-20L (shown in position 4 in Figure 1). The force sensor can measure force up to 200N with a linearity of 0.03% full scale and hysteresis of 0.03% of full scale. These two sensors provide measurement of grip force both left hand fingers and right hand fingers. To measure the force of stretching and compression of the arms it is responsible implemented sensor FUTEK Model LCM300 [6]. (position 8 in Figure 1). It is possible to measure the force of stretching and compressing up to 450N with non-linearity of 0.5% full scale and hysteresis of 0.5% of full scale. Figure 2 shows the realized solutions at the laboratory during the testing.





8	MERAČ ZATEZANJA	1	LCM 300	GOTOVA ROBA	Ø25 x 30,5
7	SFERNI OBLONAC	1	MSPR 11.007	PCuSn 14	SØ18 x 13.2
6	KONIČNI OBLONAC	1	MSPR 11.006	Č.0545	Ø24 x11.5
5	SPOLJNA ČAURA	1	MSPR 11.005	Č.0545	Ø30 x 19
4	MERAČ PRITISKA	2	MSPR 11.004	GOTOVA ROBA	112x15x28
3	ZAVRTANJ	8	SRPS M.B1.128	GOTOVA ROBA	M5 x 18
2	DONJI POKLOPAC	2	MSPR 11.002	AlSi12Cu	142x29x30
1	GORNJI POKLOPAC	2	MSPR 11.001	AlSi12Cu	142x29x30
POZ.	NAZIV	Kom.	BROJ CRTEŽA	MATERIJAL	DIMENZIJE

Institut "Mihajlo Pupin" Projekat INŽENJERING Beograd

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Figure 1. Set drawing of the system for measuring of finger grip.

Figure 2. Real view of the system

The device consists of two identical subsystems for measuring fingers grip, left and right, and between them is placed intersystem for measuring stretching and compression of the arms. The measurement is accomplished by the 4 fingers of one hand acts on the top cover (1) until the thumb of the same hand acts on the bottom cover (2). In this way, the acting forces are applied to the sensor (4) for pressure and the measurement is done by associated electronics. It should be noted that given relatively inexpensive sensor are also implemented in the household scales. Precisely considering the given system can be seen to a certain extent on the accuracy of the data that affect schedule their own fingers and stiffness covers (1 and 2) that transmit force, so that in a next phase of the development should be take into consideration such effects. Ideally, the analysis of grip force should be measured between two fingers, one of which is the thumb and whose position on the cover was accurately determined, for example by recesses of their position, however, and in this way, taking into account the breadth of the human hand, and in relation to the dimensions of the covers, as well as characteristics of the full forces range, this position is relatively defined and obtained measurement values do not differ significantly from the place of applied forces, and regarding of available resources as the compromised solution is adopted this system.

To realize on the same device measure the force of spacing and holding of the hands (stretching and compression of the arm) between these two subsystems has been inserted another one independent sub-system, where is implemented in a slightly different sensor (8), which can simultaneously measure the pressure and stretching of the arms. It has the form of cylinder type of sensor with two screws to expose mounting structure. One side of screw is used to mount directly into one half of one subsystem, while other is mounted separately. The reason for this mounting method is that because, if we were the same way stiff twisted, the sensor devices in the second half, then there could be up to fracture, ie. damage the force sensor, but also to the incorrect measurements, because the request that the force sensor is vertical. Because of that it is constructed a spherical joint that avoids the "breaking" of the sensor while the normal force acting on the sensor. In fact, it's for sure, to primarily, when measuring the pressure can get to the angular deformation, ie. falling out of the axis, but this is compensate by using the spherical joint. Inaccuracies that arise due to the change of the angle is not significant because of small angles cosines projection of force is close to 1, and the measured values do not differ significantly in this case. Of course, during the tension, this has no effect because the device is linearized itself, rather it corrects himself. Other positions in the drawing has only functional role.

III. Electrical Amplifiers and Data Aquisition

Realized amplifier electronics which is collect and amplify the signals from the sensor is shown in Figures 3 and 4.

By using precision voltage reference LTC1021-5 the power supply for the force sensor SW-20L it is realized. These sensors operate with a voltage of 5V, with 1% of accuracy. Voltage reference LTC1021-10 is responsible for the power supply of sensors LCM300 FUTEK model. It uses 10V voltage with accuracy of 1%. The gain for each input signal is provided using ultra precision instrumentation amplifier INA128. This solution is provided with measurement accuracy in the range of 1%. Such amplified signal is then fed into data acquisition system NI-6008, which is in charge of collecting and processing of the measured data. LABWIEW software package is used.

Designed electronic and their own built in sensors provided temperature range from 0 to 30^0C for the laboratory equipments. Precision measurements at a given temperature range is ensured by selecting sensors and electronic components.

System calibration was carried out with the help of measuring weights and acquisition equipment before the normal operation. The calibration results of the sensors for the finger grips are given in the Figures 5 and 6 and the calibration results to stretching and compression are given in Figures 7 and 8 From the calibration results it is shown the linearity of the system and the required accuracy. Calibration of the system is necessary to do once a year due to time-aging components.

IV. Conclusion

A system for measuring the force of the fingers grip of the hand and hand stretching and compression force is presented in the paper. The developed system enables dynamic force measurements for the fingers and hands for the goal of hands rehabilitation due to damage of the central nervous system as well as to biomechanical test of healthy people during exercise. The system has 4 independent force sensors. The system was developed that allows different types of measurements, alone or in synergy. The system provides measurement accuracy up to 1% for laboratory conditions at a temperature of 0 to 30^0C with linearity up to 1%. The system was implemented to allow measurement of the biomechanical properties of the arm movements.

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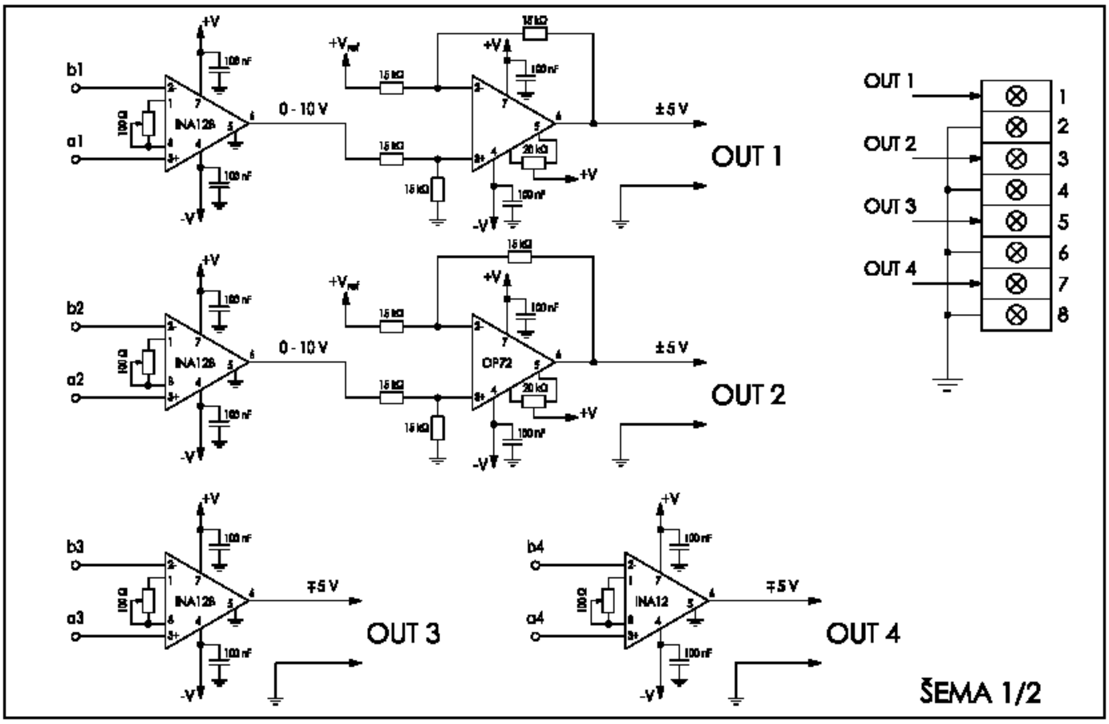

Figure 3. Electrical drowing of the amplifiers realised

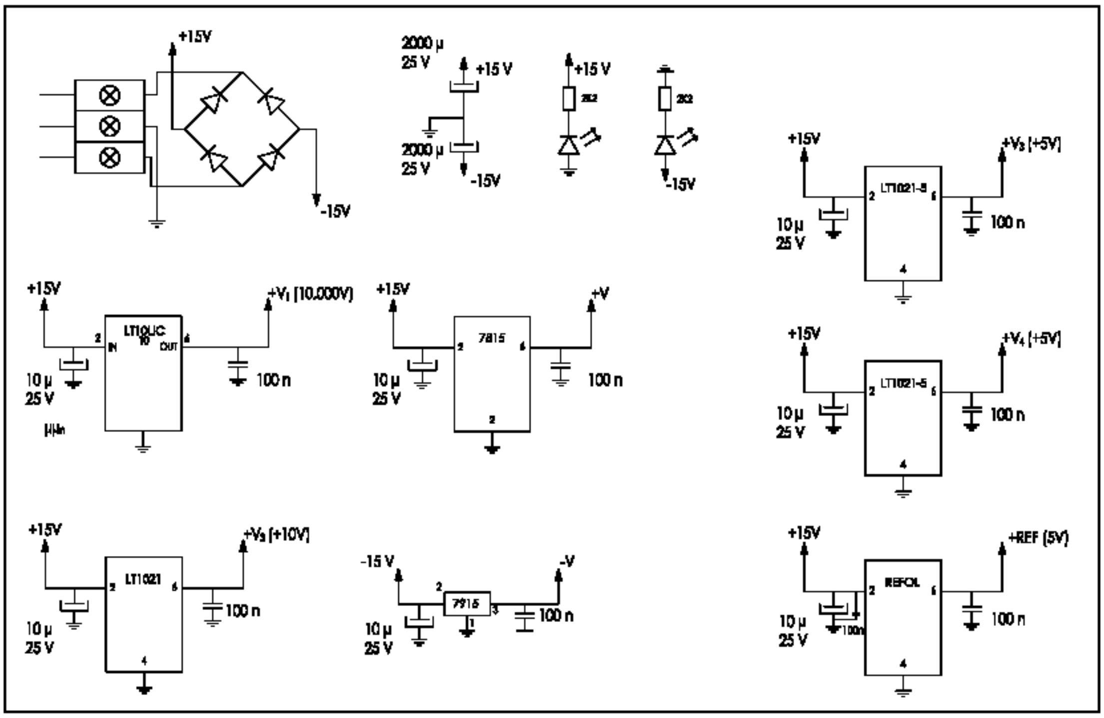

Figure 4. Electrical drowing of the precise power suplly for the sensors and the system

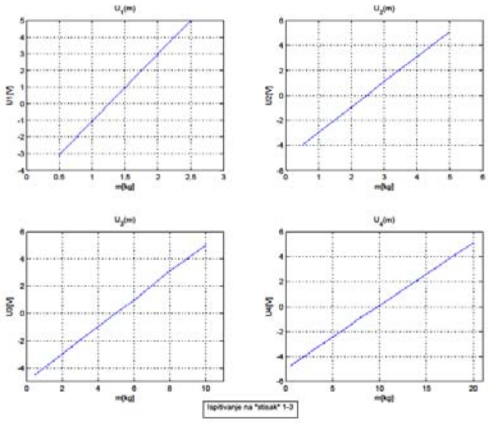

Figure 5. Left hand calibration results for the force sensor

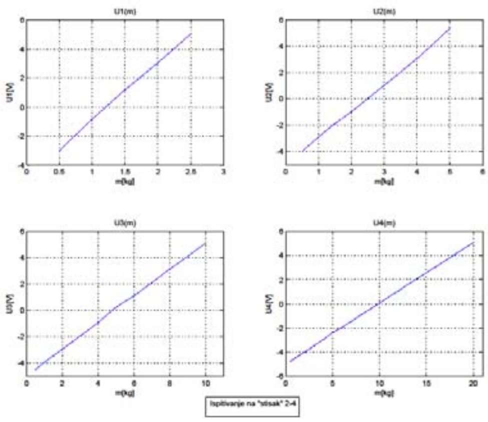

Figure 6. Right hand calibration results for the force sensor

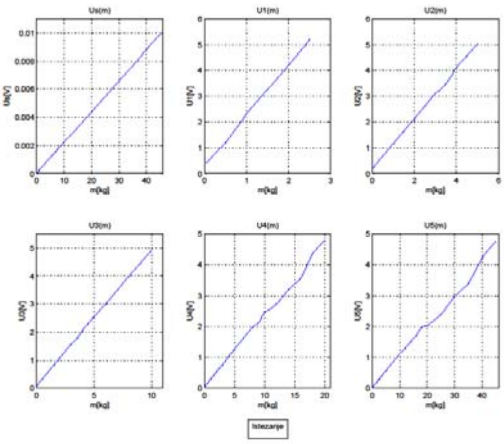

Figure 7. Extension force calibration results

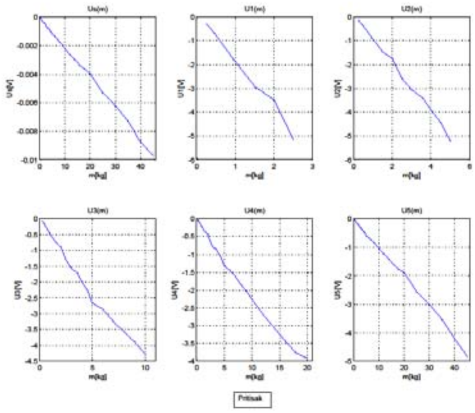

Figure 8. Stretch force calibration results

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