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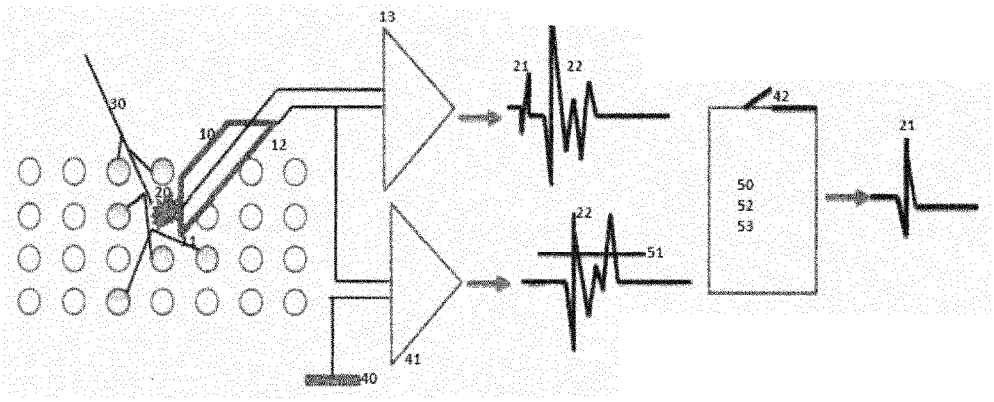


**Figure 4**

(57) **Abstract:** The invention relates to medical diagnostics and in particular to the electromyographic measurement of muscle-nerve diseases. In electromyography measurement, muscle cell membranes simultaneously produce both diagnostic and disturbing signals (21, 30, 130). The measurement is used routinely to analyze the voltage difference between the tip (1 1) and the shaft section (12) of the measuring needle (10). In the method according to the invention, the voltage differences between the tip portion (1 1), the cannula portion (12) and the skin surface (40) are separated using two simultaneous channels ( 13, 41). This processing and analysis improves the selectivity of measurement and reduce the proportion of interfering transients (130) in the analysis results.

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# /IETHOD AND DEVICE FOR SELECTIVE MULTICHANNEL MEASUREMENT N ELECTROMYOGRAPHY

## :HE FIELD OF THE INVENTION

'he invention relates to medical diagnostic measurements, more exactly to the ıeasurement of electrical properties of the muscular membrane used for medical diagnosis f neuromuscular (muscle and nerve) disorders.

## ;ACKGROUND OF THE INVENTION

'he electrical properties of muscle cells are studied in medical diagnostics using lectromyography (EMG, also electroneuromyography or ENMG). The amplitude of the lectrical voltage variation of the muscle cell membranes is between 20 microvolts to few ıillivolts in the extracellular needle electrode measurement of the muscle cells. The requency range of the voltage fluctuations of interest is eg. from 5 to 3000 Hz and the uration of the voltage transients between 10 microseconds and 20 milliseconds. The ctivity is monitored using a special medical device, called an electromyography device or :MG device. The EMG device consists of a differential amplifier, which may include one r several units used for one or several simultaneous measured channels. The signal is iltered using a band pass filter to visualize the interesting frequency range, e.g. 5-10,000 Iz of the signals. The device has a display unit for visual monitoring of the signal. The creen display may be continuous or may consist of separate, selected graphs. Frequently, ıe signal also is converted to an audio signal to monitor the frequency characteristics of ıe signal using the audio channel through the loudspeaker. When used in the clinical :NMG study, an electronic stimulator is also included to produce peripheral nerve stimuli. 'he nerve and muscle responses produced by stimulation are used to determine latencies, elays and nerve conduction velocities.

'ypically, in clinical EMG the electrical activity of the muscle cells is studied using a thin eedle electrode. The electrode is inserted through the skin into the muscle near and etween to the muscle cells. Muscle responses can also be obtained and measured using lectrodes attached to the skin surface. The activity of a single or a few muscle fibers are ıeasured using the EMG needle measurement. Skin surface plate electrodes are used to ıeasure the activity of several cells and especially the evoked responses produced by the lectrical stimulation.

:MG measurement is typically performed both during muscle relaxation and during ariable degrees of muscle tension. Healthy relaxed muscle cell membranes do not produce ny electric activity. As the muscle tension increases, the amount of muscle electrical ctivity increases. In nerve and muscle diseases there are qualitative and quantitative bnormalities in these activity patterns which are monitored in the EMG measurement.

)ne of the important steps of the EMG study is to evaluate the possible spontaneous lectrical activity of the cell membranes of relaxed muscles. This may occur e.g. as short ·ansients in the range of 20 to 100 msec, and called fibrillation potentials of fibrillations nd positive sharp waves. These phenomena are generated after damage to the nervous or ıuscle tissue causing thereby the individual muscle cell membranes to become electrically

nstable. These findings are an objective indication of the nerve-muscle disorder, illness or ysfunction. Detection these disorders is crucial to the diagnosis of neurological nerve ıuscle diseases, ie. neuromuscular disorders and in neurological diagnostics. The istribution of these transients also demonstrates the distribution and the etiology of these iseases.

n a routine EMG patient study, the concentric needle electrode is used in the ıeasurements. It is inserted into the muscle between and near to the muscle cells. The eedle is hollow and there is an insulated wire inside the needle. The uninsulated tip acts as ıe active measuring point. The thickness of the needle is about 0.3 - 0.5 mm and it is e.g. 0-50 mm in length. The outer tube, cannula, act as a reference electrode of the ıeasurement. The needle thus measures the voltage difference between the active (tip) and ıe reference (cannula) contact surfaces. Needle material (steel, platinum, plastic) and hape (thickness, sharpness) is advantageous to measure electrical phenomena in living ssues. Needles are disposable and cheap. The voltage variation measured through the eedle is led to the above-mentioned EMG amplifier, amplified and band-pass filtered sing the advantageous frequency band (e.g. 5-10,000 Hz). The signals are visualized sing a digital or analog display. The signal is simultaneously converted into an audio ignal to the loudspeaker. Differential amplifier consists of the active and reference signals ut it also requires a ground signal. This is typically a surface electrode with a silver hloride - silver plate or disk attached to the surface of the skin. Such a differential mplifier measure is routinely used in all clinical EMG equipments and in ENMG studies.

'he muscle cell acts as a resistance and amplitude suppressing tissue in EMG ıeasurement. In addition, the shape of the measuring electrodes (small needle tip and ırger needle cannula) is affecting to the measured potentials. Therefore the amplitude of ıe interesting voltage transients decreases rapidly when the distance between the active oltage source (muscle cell membrane) and the above-mentioned measuring electrode tip ıctive electrode) is increased. In the research literature the typical distance range between ıe EMG needle electrode and the muscle cell membranes (the voltage source) is reported ɔ be 0 - 5 mm. The voltage measured by the active electrode (needle tip) exponentially ecreases when the distance to the muscle cell membrane increases. Especially the ıedically interesting short, fast frequency, and low-voltage fluctuations and transients may e measured only very near to the voltage source. Therefore the insertion of the needle lectrode has to be directed near to the interesting damaged or diseased area within the ıuscle.

'he above mentioned transient of the unstable muscle cell membrane called fibrillation, is short electric transient with duration of 1 to 5 msec and with an amplitude of the order of 0-150 μV. The shape of the fibrillation is characteristic, either monophasic (so-called ositive sharp wave potential) or biphasic (fibrillation potential). Fibrillation occurs often ıythmically e.g. at frequency of 2 to 10 Hz. Its occurrence often stops gradually within a ɛw seconds and is increased as a result of the insertion or movement of the measuring eedle electrode. The amount of fibrillation correlates with the number of totally or artially damaged or degenerated muscle cells. Damage may be caused by a disease of ıuscle cells or motor nerve cells. Fibrillation thus reflects the electrical activity of a ıuscle cell membrane of a single damaged muscle cell, it is generated locally near to the ıuscle cell and it is measurable only using the measuring electrode located near to the cell.

n a completely relaxed muscle no motor nerve action potentials are conducted from the entral nervous system to the muscle. In voluntary muscular tension the activity of the notor nerve is producing the activation of the motor units (MU) of the muscle. The motor ierve is divided into numerous branches within the muscle within a range of several nillimeters. The branches activate each one muscular fiber. Thus, ten to hundreds of nuscle fibers are activated synchronously when one motor nerve and one MU is activated. 'his activation occurs e.g. at a frequency of 5 to 30 Hz. The electrically active muscle ibers of MU form a summation potential called motor unit potential (MUP). MUP is thus nuch higher in amplitude (ad 1-2- mV), longer in duration (ad 20 msec) and distributed in vider area (1-20 mm) in the muscle than the fibrillation. MUPs are thus caused by the 'oluntary electrical activity while fibrillation potentials are produced by spontaneous ıathological muscle cell membrane activity occurring very locally.

n a routine needle-EMG measurement, the muscle electrical signals reflect the voltage lifference between the active measuring point of the concentric needle electrode, the tip, nd the reference part of the needle, the cannula. The signals are monitored and visualized ın the display unit of the measuring instrument and signals also are converted into sounds ıy the loudspeaker. This measurement arrangement enables detection of both transient ocal signals and more widespread muscular signals. Typically, spontaneous small ibrillation transients are monitored by higher gain and detection of high amplitude MUP ransients with lower gain of the amplifier. This makes it possible to visualize and detect he accurate shape of the whole transients reliably.

/IUP transients are present during the voluntary and reflector muscle tension. If the muscle s not completely relaxed during the monitoring of the fibrillation potential using the high ain of the EMG amplifier, there may be repeated simultaneous MUP transients of high mplitude occurring. This may greatly disturb both visual and auditory detection of the ibrillation of small amplitude. Most often the muscles are relaxed and the voluntary ctivity and MUPs will cease or decrease and the measurement of the fibrillation is uccessful with no disturbance caused by the simultaneous MUP activity. Sometimes this s not the case. This may be caused by the feeling of pain, or by some voluntary muscle ension, or in the measurement of muscles with automatic and autonomic involuntary ctivity (respiratory muscles, muscles in the oral cavity, muscles supporting the back, etc.). n those situations the accuracy of the measurement will deteriorate unfavorably and the eurological diagnostics will be more difficult. When the measurement is prolonged, it also nay become more painful for the object of the measurement.

Clinical EMG measurements are also used to evaluate the distribution of MUPs generated y the healthy and diseased muscle fibers and to evaluate the changes in the shape of of the epeated MUPs demonstrating the reliability of the neuromuscular function. This is articularly important in those neuromuscular disorders which are causing typical changes ı the distribution of the nerve fibers and of the muscle cells during the disease rogression. Those changes are particularly important to detect the possible repair progress regeneration, reinnervation, nerve sprouting), when the distribution of the muscle fibers enerating MUPs is changed from the normal uniform distribution to patchy uneven istribution or when the muscle fibers are atrophied and are thus situated closer to each ther. Other features of nerve and muscle electrical signals may also be transformed locally ı such situations. The muscle cell can produce recurrent transient bursts, discharges or eries or the repeated signals may be variable in shape, reflecting the unreliable electrical ransmission of the signal in the nerves and muscle cell membranes or in the region of the

euromuscular junction (synapse). This variability of the shapes and patterns is called euromuscular jitter.

Measurement of these aberrant or pathological phenomena of the abnormal neuromuscular unction requires various modifications of measurement system typically to increase the electivity or sensitivity of the measurement. These include e.g. progressive modification f high-pass filter and increasing the lower frequency limit of the recording, the use of ıeasuring electrodes of very small recording contact area (so called Single Fiber EMG, FEMG technology), increase of the measuring electrode surface area (so-called Macro MG) or gradual movement of the measurement electrode during the measurements (so alled Scanning EMG). These measurement modifications are intended to increase the pecificity and sensitivity of the measurement to detect abnormality of the desired cells or ell groups of interest.

he features and statistical properties of the neuromuscular signals are typically epresented using the common statistical characteristics like frequency content, voltage and mplitude, duration, area, the potential rise time etc.. The complexity of the shape is escribed using the number of separate spikes or of phases or of time-locked transients, hich are characterized eg using the turning points of the signal or using the number of eparate but time-locked transients included into the potential. To achieve this statistical nalysis, it is necessary to obtain very accurate and statistically standardized and accurately ırgeted measurement of the muscle and nerve cell site of interest. However, the signals of oth healthy and especially of diseased muscles are generated extensively and widely ıside the muscle. Therefore, it is not always easy to estimate which portion of the ıeasurement signals and transients originates from local signal sources and which part omes from far sources. The same problem is present when the reliability of very focal ɔcal activity is measured in Jitter EMG to avoid the effects of other voltage sources from istance cells and cell groups.

ı a clinical EMG study of a patient the professional specialist like a physician has to select ıe proper measurement electrode, the proper amplifier gain and filtering of the signal and as to make the proper statistical analysis of the EMG signals to demonstrate the possible ormal (physiological) or abnormal (pathological connected to diseases or disorders) lectrical properties of the muscle cell membranes. This may be difficult especially in non-ptimal measuring situations with plenty of simultaneous and overlapping activity of ifferent cell groups as disturbing artifacts. This electric disturbing activity often makes it ifficult to obtain the proper statistical analysis to distinguish, quantify and quantitatively haracterize the signals.

ı real-time patient EMG study and signal measurement is described above. It is oteworthy that the signals described may be stored in digital or analogue form, and a orresponding analysis can also be directed to the stored signals.

## UMMARY OF THE INVENTION

he advantageous solution provided by the present invention to these problems described bove in the separation of the voltage sources of the needle-EMG measurement is based on ıe fact that the signal (e.g. fibrillation potential or MUP) generator of a clinically ıteresting signal or transient is distributed differently within the muscle than the verlapping and disturbing other potentials or transients. They are generated by different

:ells, cell groups or different part of the same cell. These interesting and disturbing ransients can therefore be detected and discriminated selectively and advantageously using ı simultaneous measurement of the signals with several recording channels. This is ıchieved using the analysis system of the present invention using a needle measurement :lectrode which is applied in a routine single channel measurements and applying the tatistical analysis of the present invention simultaneously to the all or both measurement :hannels.

'he fibrillation transient is generated in the EMG measurements by the instantaneous .ction of a single muscle fiber membrane and it is therefore recorded only locally and neasured by the tip of the EMG needle electrode. The MUP transient is the sum of ıotentials generated by several (10 - 100 -) muscle fibres located in the area and diameter ıf several millimeters inside the muscle. The MUP transient is measured through both the :MG needle tip and the needle cannula (shaft) of the needle. The interesting signals are nost frequently measured through the needle tip but this signal often includes other listurbing interference signals. In the present invention, this difference in generators and heir locations is advantageously utilized by removing, treating, or attenuating the listurbing signals from the clinically interesting signal (measured as needle tip signal). Jsing the present statistical analysis and processing of the signals originating and neasured through the needle cannula, the aim is to diagnose, filter, and attenuate the imultaneous needle tip signals if there are any transients disrupting the needle tip signal. 'his helps to detect the diagnostically important, e.g. fibrillation transients or MUP ransients using the needle tip. If interfering transients (e.g., MUP) do not appear in the ıeedle cannula measurement, neither needle tip signal needs to be processed and uppressed and the measurement proceeds as usual single channel measurement. The ıvention thus aims to increase the diagnostic accuracy, sensitivity, specificity and electivity of the needle EMG study and to improve the technical performance. Using the eatures of the invention, the analysis of the interesting signals can also be selectively .irected to those transients which are generated near to the needle tip. The invention is mplemented so that the professional measurer can select, by means of a switch, e.g. a push ıutton, or automatically select the proper type of signal or signals of high clinical mportance.

n one embodiment of the invention, the statistical analysis of the invention helps to select, ıose transients with an a muscle cell generator located near the tip of the needle for further nalysis of the signals. This is important when attempting to improve repeated accuracy nd quantitative analysis of measurements. The invention thus enables automatic ttenuation of the disadvantageous transients and the selection of preferred transients for urther analysis.

'he measurement and analysis system of the invention is characterized by what is defined ı the claims.

## 3RIEF DESCRIPTION OF THE DRAWINGS

n the following, the invention will be described in more detail by reference to the attached rawings, wherein

'igures 1-3 depict the current EMG measurement technique by describing patient EMG ıeasurements including normal or abnormal muscular activity.

'igure 4 illustrates an embodiment of the invention where measurement is performed to letect fibrillation transients occurring in diseases like muscle or nerve disorders.
'igure 5 shows another embodiment of the invention, wherein the method of the invention ielps in the selective measurement of muscle fibers and attenuates disturbing signals rising further from the muscle fibers of interest..
'igure 6 depicts another embodiment of the invention where the measurer can select the ieasurement mode using a switch located on the measuring cable to use the selective ieasurement of according to the current invention or to use the current EMG measurement echnique.
'igures 7 and 8 are flow diagrams representing the potential steps of the method of the nvention to selective measurement of signals.

)ETAILED DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

'igures 1 to 3 visualize EMG measurements of the current state of the art. Figures 4-6 how some embodiments of the invention.

)ETAILED DESCRIPTIONS OF THE EMBODIMENTS AND FIGURES

'igure 1 visualizes the EMG measurement of the current state of the art. The the concentric eedle electrode (10) is inserted between the muscle fibers to measure the electrical ctivity of the muscle tissue which is shown in cross-section. The voltage difference etween the tip (11) and the shaft or cannula (12) of the needle electrode is amplified using ie differential amplifier (13), the voltage is filtered (14) and the signal is visualized by the isplay unit like the oscilloscope device (15) and it is processed by the audio amplifier 16). Figure 1 shows inside the muscle an abnormal muscle fiber (20) to which the nerve onnection (30) is damaged. The tip of the measuring needle (11) is situated just next to ie fiber and the unstable function of the muscle cell membrane is causing a fibrillation otential (21) occurring repeatedly and detected by the measuring needle. The amplitude of ibrillation in this figure is about 0.1 mV and duration 5 msec.

'igure 2 further illustrates the current EMG measurement of the prior art. The motor unit MU) including several muscle fibers inside the muscle tissue is partially described. The ction potential passes through the intramuscular nerve fibers (30) to the muscle fibers ctivating in synchrony to form a motor unit potential (MUP) (22). The measuring EMG eedle tip (11) and the needle cannula (12) are located near to and between the muscle ibers and measuring the synchronous action potentials generating MUP. Further the oltage difference is amplified and filtered (14) and the signal is fed to the display device 15) and the audio amplifier. MUP (22) is significantly higher in amplitude than ibrillation transient potential (21) in Figure 1, and in this figure the amplitude is 1.0 mV nd duration10 msec.

'igure 3 further illustrates the EMG measurement of the current technology, combining the vents in Figures 1 and 2. In this measurement both the fibrillation (21) and the MUP (22) re activated inside the muscle. Both are recorded as in Figures 1 and 2 and are led to the isplay device and the audio amplifier. The MUP is considerably larger and more rolonged and thus it disturbing interferes with visual or automatic detection of fibrillation.

'igure 4 is one possible embodiment of the invention. The concentric needle electrode 10), its tip (11) and the cannula (12) are located inside the muscle and the differential

mplifier (13) is used to amplify the voltage difference between them as shown in Figure -3. In addition, a separate surface electrode (40) is placed on the surface of the skin and nother corresponding differential amplifier (41) is applied to amplify the voltage ifference between the cannula of the measuring needle (12) and the surface electrode (40). Vhen the fibrillation (21) takes place, it only appears in the signal of the differential mplifier (13) which measures the voltage difference between the needle tip and cannula. Vhen MUP (22) takes place, it is detected and displayed in the amplified signals of both ıe amplifier (13) and the second amplifier (41). At an advantageous situation for the ıeasurement, the user will apply the signal analysis and processing module (50) using a witch (42). The processing module (50) consists of filters and a detection circuit module 52) suitable for monitoring the statistical properties of signal (41). If the signal rises above ıe reference amplitude level (51) or the signal's statistical properties are otherwise ifferent from the reference signal, it indicates the occurrence of a MUP. The delay circuit 53) is used to delay the signal (13). When the processing module (50) detects a MUP in ignal (41), the amplifier signal (13) is attenuated significantly and markedly. The ttenuation of signal 13 will continue as long as the MUP occurs on signal (41). In result, uring the attenuation, the MUP signal (41) may not disturb the detection of the smaller ignal (13). Fibrillation transients are generated only locally and they do not appear in the ignal of amplifier (41) and they are therefore not detected by the processing module (50). 'herefore, when the fibrillation occurs, no attenuation occurs and the fibrillation is ıonitored by the amplifier (13), visualized on the display unit (15) and the audio amplifier 22) without any distortion or attenuation. When interfering MUP signals are not present ıe user release the switch (42). In this case, the processing module (50) is inactive and the ignal produced by the amplifier 13 is monitored like in Figure 1-3 and as the EMG ıeasurement of the current state of the art.

ı addition to the fixed detection level, an adaptive or automatic detection level may be sed to replace the switch (42). The signal from the amplifier (41) is filtered and reprocessed digitally by the computer software of the measuring device (50-52). By tatistical analysis of the amplitude variation of the EMG signals, the signals describing the verage noise levels of the signal are processed. These parameters are then used to evaluate : the signal contains MUP potentials. In addition to the amplitude values, the parameters ɔr the MUP detection may be e.g. the limit values of integrated area of the signal in time, ıe derivation value of the rising velocity of the amplitude, the pattern and shape of the ignal etc. The MUP detection may therefore take place adaptively and automatically at arying threshold values and not using a fixed voltage level (51) as shown in Figure 4. Vhen the user of the device with present invention wishes to examine the occurrence of ıe fibrillation, he/she selects the measurement program of the device including the pplication of the invention. The software monitors the signal from the amplifier (13) and isplays it on the display unit. Signal processing module includes a delay line to pass the ignal onto the visual display to the visual analysis and to the speaker for audiological valuation. Simultaneously, the software module processes the signal of amplifier (41) tatistically. If the signal (41) includes features or patterns typically for detecting the MUP 22), the signal of the amplifier (13) is attenuated during the occurrence of MUP and the referred fibrillation of smaller amplitude (21) can be advantageously detected. If no such eatures typical for a simultaneous MUP exists, the signal is monitored as the signal in the urrent state of the art measurements Figures 1-3.

igure 5 shows one embodiment of the invention when measuring multiple MUP transients 30 and 130) while ensuring that the needle electrode measuring tip is preferably as close

s possible to the muscle fibers to be measured inside the area of the motor unit and to uppress the effect of far-off potentials on the needle tip. The measurement is performed ke in Figure 4 in two-channel mode. The concentric needle electrode (10), including the p (11) and the cannula (12) are located inside the muscle and the differential amplifier 13) amplifies the voltage difference between them as shown in Figure 1-3. In addition, a eparate surface electrode (40) is placed on the surface of the skin and another similar ifferential amplifier (41) is applied to amplify the voltage difference between the cannula f the measuring needle (12) and the surface electrode. When there are transients occurring ear to the tip of the measuring needle they are primarily measured in the signal of the first ifferential amplifier (13). When there are electrical activity and transients occurring urther away from the needle, they are measured by both the first amplifier (13) and the econd amplifier (41). The signal analysis and processing module (50-53) is performing ıe statistical analysis to determine the distribution and localization of the transients orrelating to the needle tip localization. When the signal (30A) of the amplifier (13) is tatistically different (amplitude, voltage rising rate, frequency contents, etc.) measured by ıe tip, compared to the signal (41) transmitted through the cannula, the measurement is dvantageous including and targeting to the fibers close and near to the tip of the needle. 'his is the most advantageous situation to study for example the amplitude, shape, omplexity, duration, and area of the transients because the resulting statistical variables in ıis case describe the exact physiological activity of the nearest fibers. In contrast, when ıe signal (130A) is statistically similar (amplitude, amplitude rising time, frequency ontent, etc.) measured by the tip as compared to the signal (130B) coming from the annula portion, the signal generators are far from the tip of the needle and should not referred to be included in the medical analysis.

igure 6 shows a measurement arrangement to include advantageously both the needle tip ıeasurement according to the invention and a needle measurement according to the state f the art. The measurement takes place as shown in Figures 4 and 5 in two-channel mode. 'he concentric needle electrode (10), the tip (11) and the cannula (12) are located inside ıe muscle and the differential amplifier (13) amplifies the voltage difference between ıem as shown in Figure 1-3. In addition, a separate surface electrode (40) is placed on the ırface of the skin and another similar differential amplifier (41) is applied to amplify the oltage difference between the cannula (12) of the measuring needle and the surface lectrode (40). When there are transients located near the needle tip, they are primarily etected and measured in the signal of the first differential amplifier (13). When there are lectrical activity and transients occurring farther away from the tip, they are detected and ıeasured both in the signal of the first amplifier (13) and the second amplifier (41). By ıeans of the switch (61), the investigator (e.g. medical specialist) may choose whether to ıeasure the needle tip signals according to the present selective invention technique or to ıeasure using the current routine technology. The switch is advantageously located as ixed to the connector of the needle cable to allow the user to change the measurement ıode by pressing the switch. As the alternative, the switch may also be a foot switch or be ɔme other part of the measuring device that the user can easily control (using voice, peech or other method of control). There may also be an analyzing computer program that ıdicates and signals the occurrence of interfering artifact transients to the user and thus ıggests to the user using visual, auditory or otherwise indication to start to use the ıeasurement technology according to the present invention. In this case, the specialist can hoose with the switch (61) what kind of analysis he wants to perform. The computer rogram may also monitor the existence of interfering transients and, when the user so

ermits and chooses, it can automatically enable the statistical processing, attenuation and iltering of signals according to the invention.

'low chart 7 shows a computer software analysis that is used in one embodiment of the nvention. Thereby the professional user is detecting a physiologically or medically nteresting small electrical transient in routine concentric needle EMG tip measurement.
. An interesting electrical signal is found in concentric EMG measurement.
. Comparison of the statistical characteristics of the signal to the needle cannula EMG neasurement
. The needle cannula measurement confirms the statistically significant correlation etween the tip and cannula measurement - the detection is rejected and moved to step 1.
. The needle cannula measurement does not indicate a statistically correlation between the ransient in needle cannula measurement compared to the transient in the tip measurement.
. Analysis of the advantageous, desired statistical properties of the signal derived from the oncentric needle tip EMG measurement is performed.
. Go to the new measurement and step 1.

'low diagram 8 shows the characteristics of the use of the selection switch in the control of ne embodiment of the invention.
. An interesting signal is detected in concentric EMG needle measurement.
. The user selects the switch mode and function to suppress the display and analysis of the oncentric needle tip EMG measurement if there is a simultaneous significant EMG signal n needle cannula measurement indicating a far field signal in both recording channels.

'igures and flow charts 1-8 show only some preferred and advantegous embodiments of ne invention. The scope of the invention can be found in the following claims. However, ne invention is not limited to the solutions just described, for example by the size, form, umber of measuring sensors or other physical properties of the electrodes and the neasuring sensors or statistical analysis of the computer analysis, but the inventive idea an be applied in a number of ways by measuring the corresponding measurement signals nd locally comparing the muscular cell electrical signal to the other remote measurement oint and altering other features of the measurement the size, shape, signal filtering, tatistical analysis and detailed features of the measuring needle within the limits set by the laims.

ome embodiments of the invention using signal processing in digital format have been escribed above, but the invention can be accomplished by processing the signal by nalogue technology by filtering, amplifying, delaying and analyzing using analogous lectronic components, achieving preferred advantageous embodiments according to the nvention.

n particular, it is to be noted that the above described functions and measures take place in ne figures in real time, but the corresponding analysis can be achieved and analyzed to the esults using the digitally or analogously stored signals using the method of the invention. n this case, a suitable storage device is attached to the measuring system. From the storage evice, the signals can be transferred to an analysis system that performs the analysis and ne presentation of the results according to the present invention.

CLAIMS

1. An electronic electromyography (EMG) measurement system comprising a needle shaped EMG electrode (10) and a differential amplifier configuration (13, 41), **characterized** in that the system is adapted to produce at least two simultaneous intramuscular measurement signals of muscle electrical activity, at least one of which is produced using a first differential amplifier (13) based on the voltage difference between the tip (11) and the cannula (12) of the needle-shaped EMG electrode or some other reference electrode, and at least one of which is produced by a second differential amplifier (41), based on the voltage difference between the needle-shaped EMG electrode cannula (12) and a separate measuring electrode (40).

2. The measuring system according to claim 1, **characterized** in that it is adapted to process, attenuate, filter and analyze the measured signal produced by the needle tip (11), using statistical characteristics of the voltage variation of the same muscular activity that is simultaneously measured between the measuring needle cannula (12) and at least one separate measuring point (40) to start and stop processing and use it as a criterium of classifying the processing.

3. The measuring system according to claim 1, **characterized** in that it is adapted to process, attenuate, filter and analyze the measured signal (50, 52, 53) produced by the needle tip (11) and to start, stop or statistically otherwise modify the analysis of the said signal (11), using the statistical criteria of the simultaneous differences in the statistical properties and in the variation in the muscle electrical activity measured simultaneously between the separate measurement points (11, 12, 40) of the measuring needle.

4. A measuring system according to claims 1 - 3, **characterized** in that the processing of the measurement signal of the needle tip (11) is continuous or is initiated and terminated using a switch, push button, pedal or an electrical device (61) associated with the system or is initiated or indicated by an automatic computer analysis program (50, 52, 53).

5. A measuring system according to claims 1 - 3, **characterized** in that the processing of the measurement signal of the needle tip (11) is performed by selecting an analog or digital processing or computer program (50, 52, 53) performing the statistical analysis to attenuate the signal measured by the needle tip (30A, 130A) based on processing of statistical variables such as the amplitude, frequency, surface area, frequency content, rising rate, shape, shape complexity, shape variation of the simultaneous signals (30B, 130B) measured using the needle cannula.

6. A measuring system according to claim 1 - 3, **characterized** in that the processing of the measurement signal of the needle tip (11) is performed by selecting an analog or digital processing or computer program (50, 52, 53) that processes selectively, for statistical and diagnostic analysis, the signal measured by the needle tip (30A, 130A), based on processing of statistical variables such as the amplitude, frequency, surface area, frequency content, rise rate, shape, shape complexity, shape variation of the simultaneous signals (30B, 130B) measured using the needle cannula.

7. A measuring system according to claims 1 - 3, **characterized** in that the measurement signal processing and visual and auditory presentation is performed using delaying of measurement signals and the processing of signals analoguely or digitally with computer software (50, 52, 53).

8. The system according to claims 1 - 7, **characterized** in that the analysis and the production of the results are performed in real time.

9. The system according to claims 1 - 7, **characterized** in that the carried out analysis and production of the results based on digitally or analoguely stored signals, produced according to the invention, takes place at a later time.

10. Use of a system according to any one of claims 1 - 9 in the measurements of muscular electrical activity.

AMENDED CLAIMS
received by the International Bureau on 11 Septembre 2018 (11.09.2018)

1. An electronic electromyography (EMG) method comprising a needle shaped EMG electrode (10) and a differential amplifier configuration (13, 41), to produce at least two simultaneous intramuscular measurement signals of muscle electrical activity, at least one of which is produced using a first differential amplifier (13) based on the voltage difference between the tip (11) and the cannula (12) of the needle-shaped EMG electrode or some other reference electrode, and at least one of which is produced by a second differential amplifier (41), based on the voltage difference between the needle-shaped EMG electrode cannula (12) and a separate measuring electrode (40), characterized in that it is adapted to process, attenuate, filter and analyze the measured signal produced by the needle tip (11), using the statistical characteristics of the voltage variation of the same muscular activity that is simultaneously measured between the measuring needle cannula (12) and at least one separate measuring point (40) or using the statistical criteria of the simultaneous differences in the statistical properties and in the variation in the muscle electrical activity measured simultaneously between the separate measurement points (11, 12, 40) of the measuring needle to start and stop processing and use it as a criterium of classifying the processing.

2. An analysis method according to claim 1, characterized in that the processing of the measurement signal of the needle tip (11) is performed by selecting an analog or digital processing or computer program (50, 52, 53) performing the statistical analysis based on processing of statistical variables such as the amplitude, frequency, surface area, frequency content, rising rate, shape, shape complexity, shape variation of the simultaneous signals (30B, 130B) measured using the needle cannula.

3. Use of a method according to the claims 1 ¯ 2 in the measurements of muscular electrical activity.

# Statement under Article 19(1)

The claims have been amended to focus to the analysis method based on statistical computer software, to avoid any reference to the measurement hardware as a device or to the electrical properties of the devices, and to demonstrate the detection and analysis of the biological muscle action potentials advantageously characterized by the analysis system according to the invention obtained by the simultaneous measurement, analysis and comparison of the same action potentials detected using more than one simltaneous analysis channel.

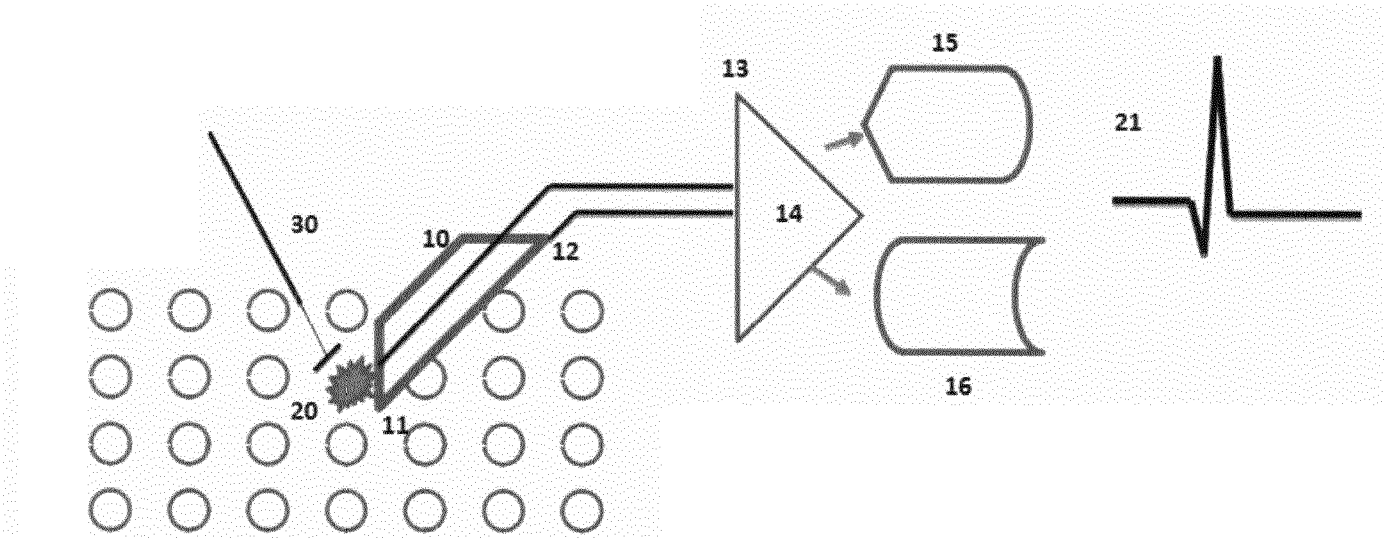



Figure 1

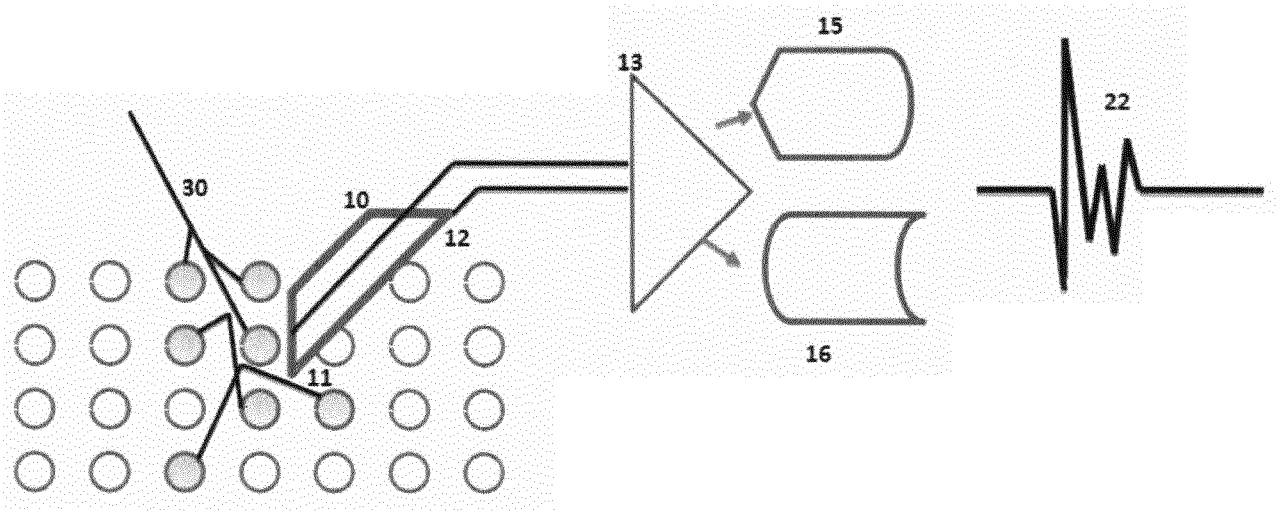



**Figure 2**

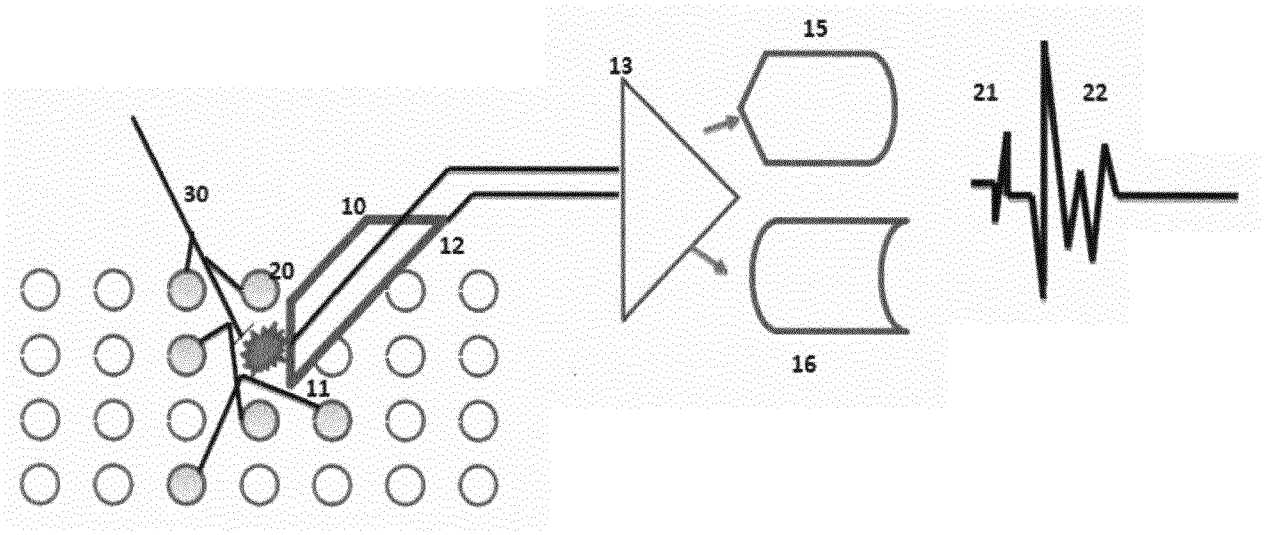



Figure 3

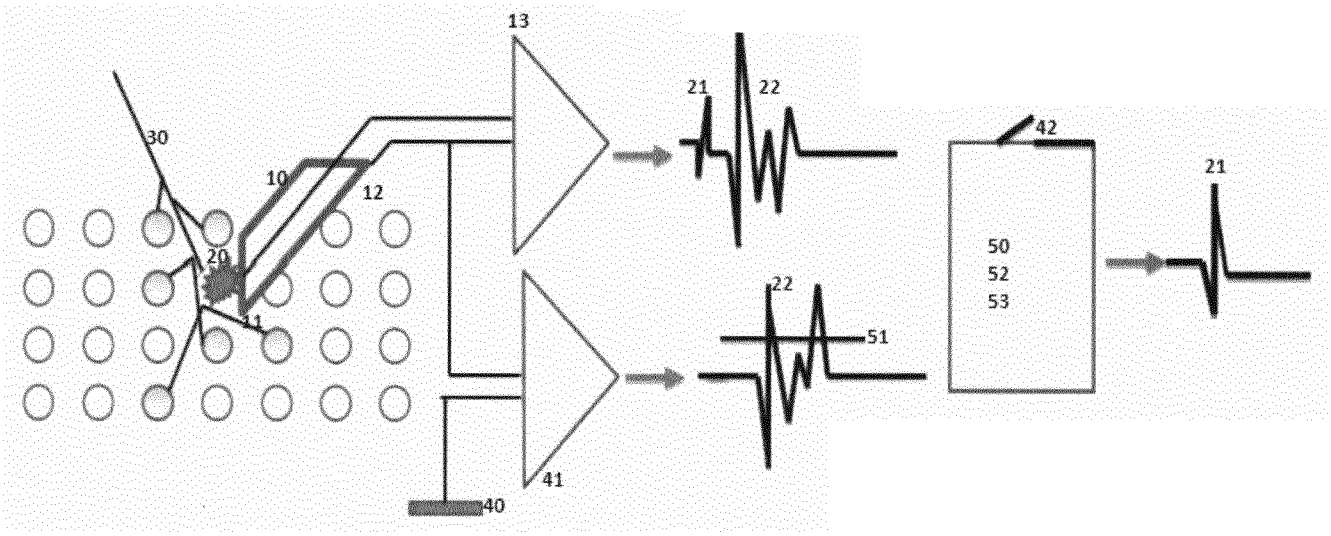



**Figure 4**

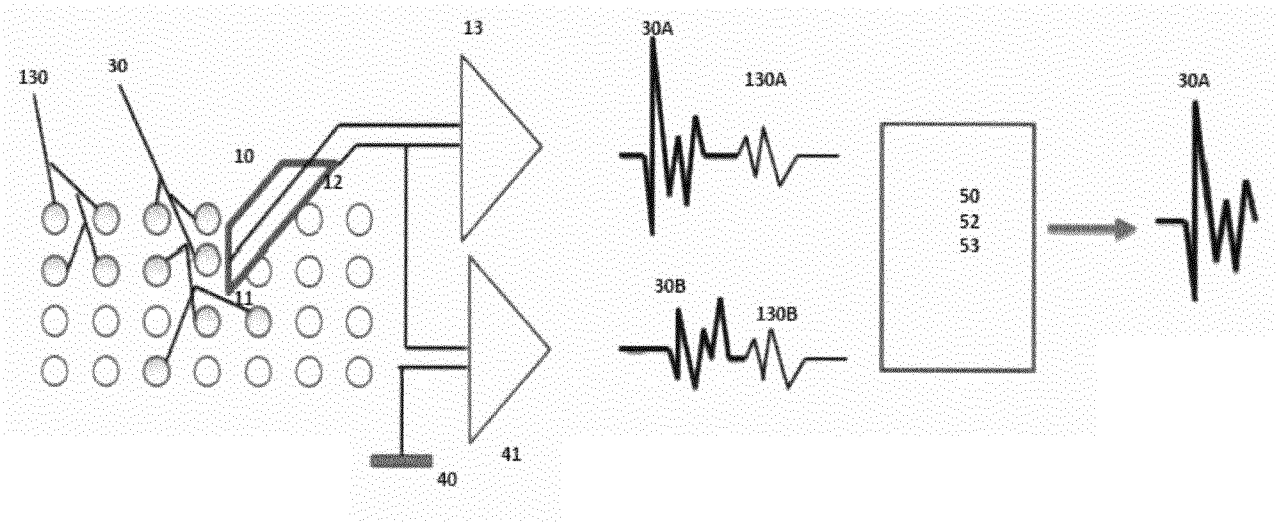



**Figure 5**

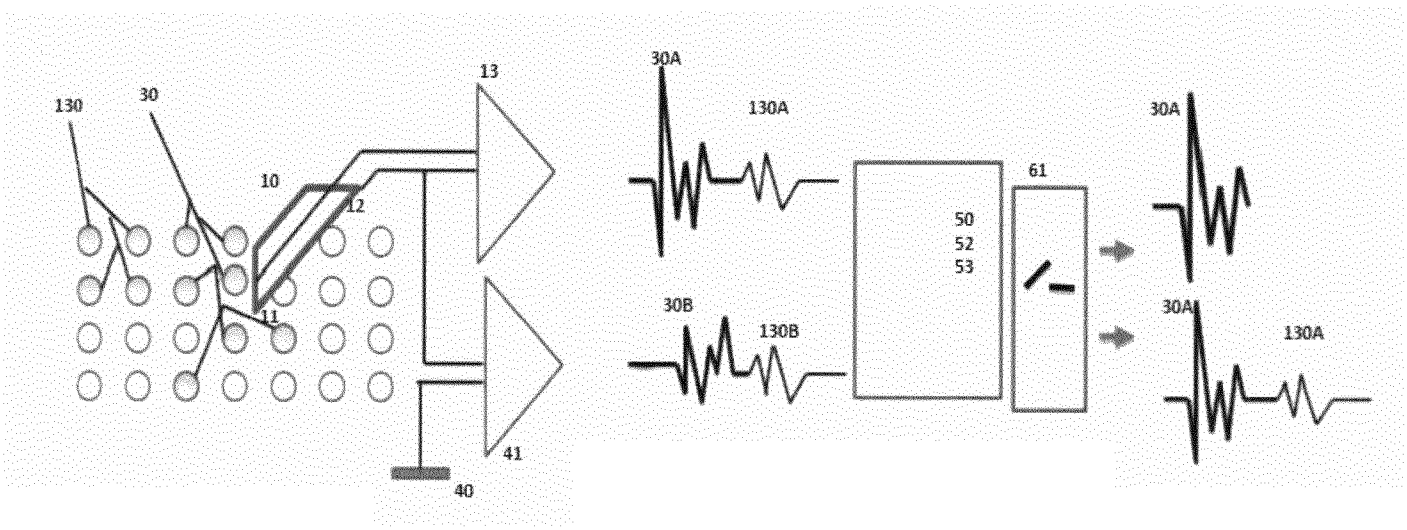
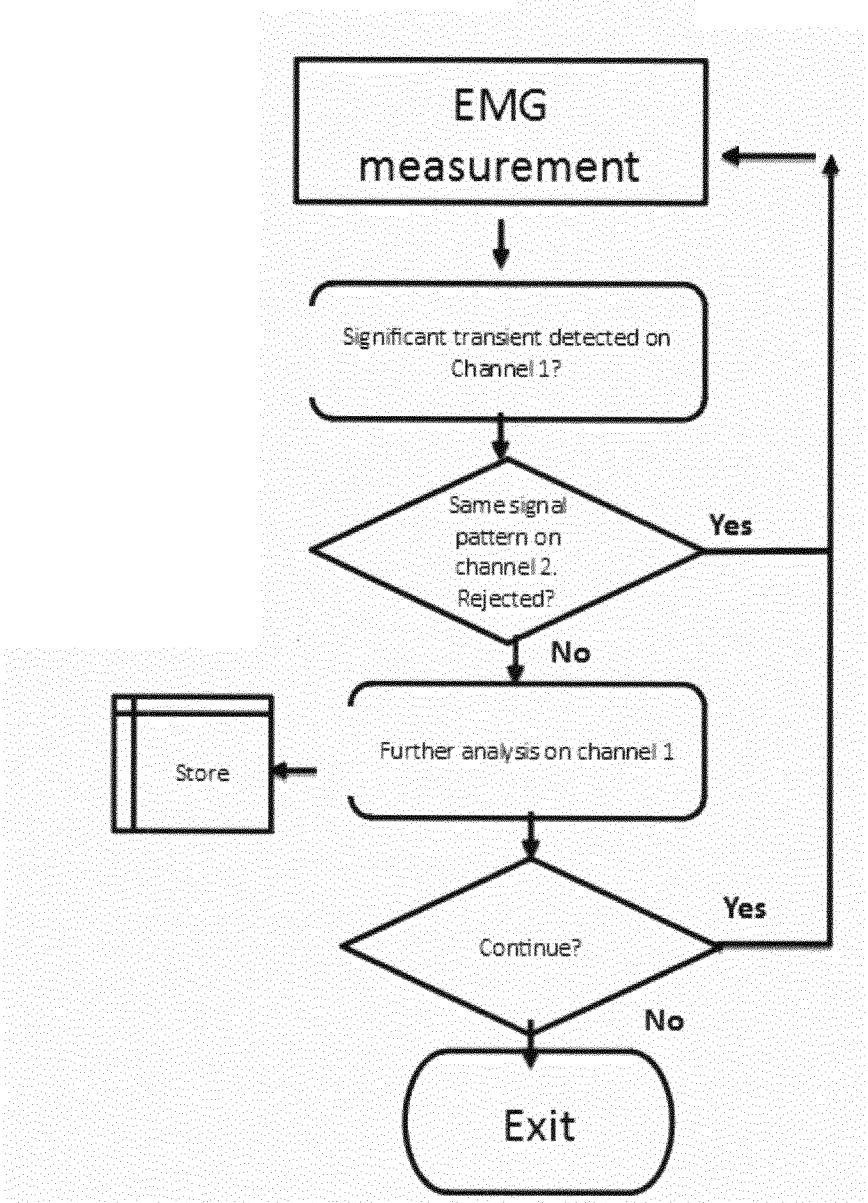
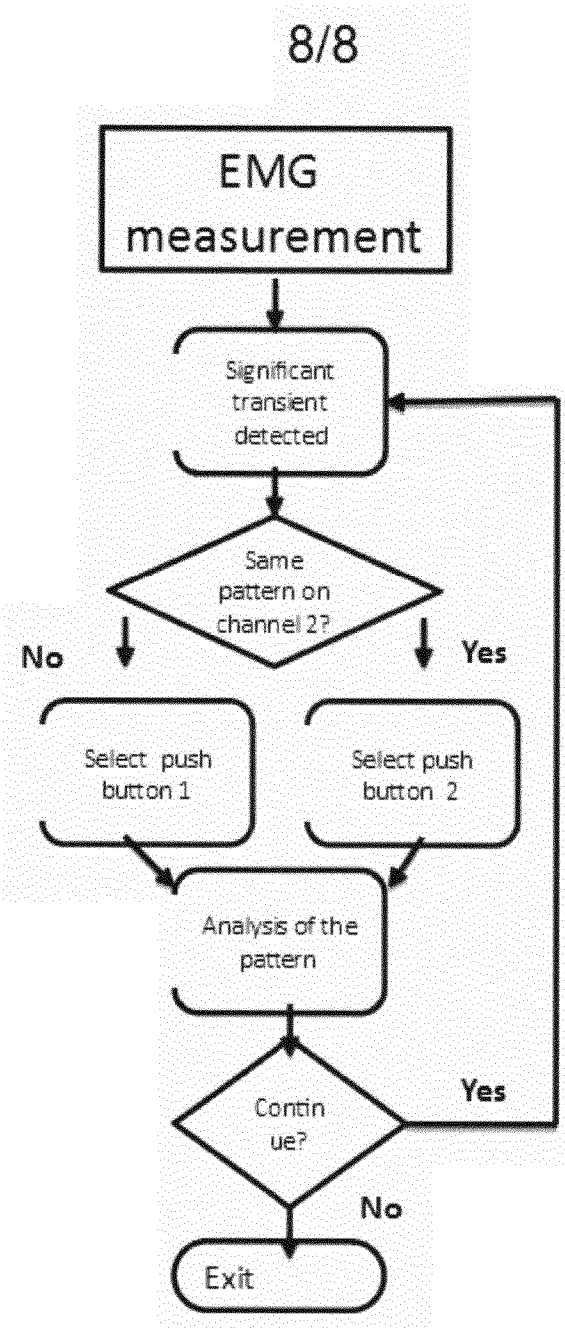



Figure 6


EMG measurement
Significant transient detected on Channel 1?
Same signal pattern on channel 2. Rejected?
Yes
No
Store
Further analysis on channel 1
Continue?
Yes
No
Exit

Flowchart 7


EMG measurement
Significant transient detected
Same pattern on channel 2?
No
Yes
Select push button 1
Select push button 2
Analysis of the pattern
Contin ue?
Yes
No
Exit

Flowchart 8

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/FI2018/000009

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPODOC, EPO-Internal full-text databases, WPIAP, Full-text translation databases from Asian languages, XP3GPP, XPAIP, XPESP, XPI3E, XPIEE, XPIOP, XPMISC, XPOAC, BIOSIS, EMBASE, NSPEC, MEDLINE, NPL, Internet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | Luca, C. & Forrest, W., An Electrode for Recording Single Motor Unit Activity During Strong Muscle Contractions, IEEE Transactions on Biomedical Engineering, no. 5, pg. 367–372, 01.09.1972<br>abstract; Chapter “Measurement of Electrode Impedance”, page 368; abstract; Chapter “Construction of Electrode”, page 368; Chapter “Frequency Response and Model of Microelectrodes”, pages 369–370; figure 4 | 1–10 |
| A | US 3313293 A (CHESEBROUGH JAMES A et al.)<br>11 April 1967 (11.04.1967)<br>the whole document | 1–10 |
| A | US 2009036792 A1 (DELUCA CARLO J [US] et al.)<br>05 February 2009 (05.02.2009)<br>the whole document | 1–10 |

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 13 July 2018 (13.07.2018) | 16 July 2018 (16.07.2018) |

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/FI2018/000009

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 2014187995 A1 (HU WEI-WEN [TW] et al.) 03 July 2014 (03.07.2014)<br>the whole document | 1–10 |
| A | US 2005261602 A1 (MUMFORD JOHN R [CA] et al.)<br>24 November 2005 (24.11.2005)<br>the whole document | 1–10 |
| A | US 2013237795 A1 (CARR JOHN CHRISTOPHER [GB])<br>12 September 2013 (12.09.2013)<br>the whole document | 1–10 |

**INTERNATIONAL SEARCH REPORT**
**Information on Patent Family Members**

International application No.
PCT/FI2018/000009

| Patent document cited in search report | Publication date | Patent family members(s) | Publication date |
|---|---|---|---|
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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/FI2018/000009

CLASSIFICATION OF SUBJECT MATTER

IPC
***A61B 5/0492*** (2006.01)
***A61B 5/0488*** (2006.01)
***A61B 5/00*** (2006.01)