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(71) Applicant: SANHILL OY [FI/FI]; Kiviharjuntie 11, FIN-90220 Oulu (FI).

(72) Inventor: ESKELINEN, Paavo; Kastellintie 40, FIN-90220 Oulu (FI).

(74) Agent: TEKNOPOLIS KOLSTER OY; c/o Oy Kolster Ab, Iso-Roobertinkatu 23, P.O. Box 148, FIN-00120 Helsinki (FI).

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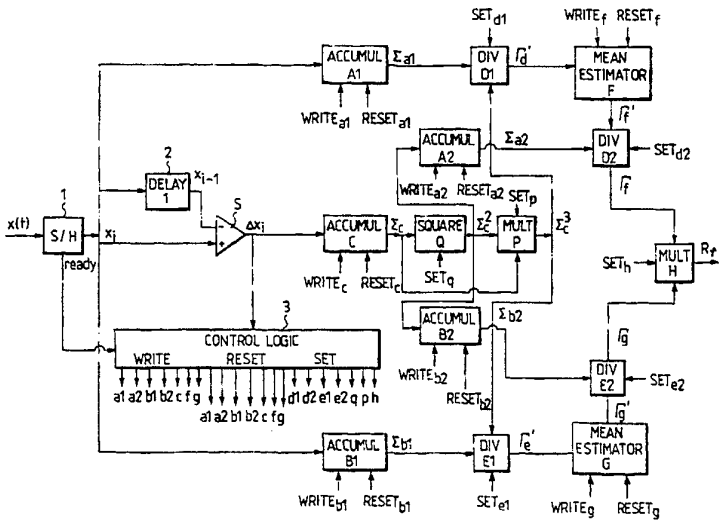

(57) Abstract

A method and apparatus for measuring muscle fatigue is disclosed, in which electromyographic (EMG) signals are measured from a muscle in order to determine the fatigue level of the muscle. The invention comprises the steps of: receiving an EMG input signal from electrodes attached to the muscle to be analyzed; sampling said input signal to a sequence of discrete signal values; calculating the difference between several pairs of successive sample values; depending on the sign of the calculated difference, adding cumulatively the sampled values in a first or second accumulator means, and said difference values in a third accumulator means; obtaining separate sequences of quotients between the values representative of the output from said third accumulator means and values representative of the outputs from said first and second accumulator means, respectively; obtaining for each of said sequences a single quotient having a weighted value representative of a number of said quotient; multiplying the obtained weighted values with each other in order to obtain an index indicative of fatigue during said time period in said muscle.

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Method and apparatus for measuring muscle fatigue

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a method and an apparatus for measuring muscle fatigue, in which electromyographic (EMG) signals measured from a muscle are used to determine the fatigue level of the muscle.

Description of Prior Art

There are two basic methods to assess muscle fatigue: mechanical and electrical. Mechanical methods are based on measuring direct force output from muscle performance. This is, however, mostly unpractical and unreliable due to inability to separate each muscle component force from the total output force. Muscular systems have a strong tendency of compensating weak muscles with stronger ones in a constant dynamic fashion. In practice, by measuring single muscular contraction indirectly through muscle electrical signals (EMG), more precise conclusions can be drawn about the neurophysiological status of the muscle. Consequently, it has become widely accepted to deploy certain signal processing methods for EMG to gain information about muscle fatigue. In the following, a first exemplary technique to be discussed is based on estimation of spectral parameters, and a second technique to be discussed uses simple time domain signal processing.

In the first case, a measure of some form of average frequency (spectral shift) is calculated through the signal (EMG) spectrum. The original signal is sampled to produce a discrete time series, which is then subdivided into shorter segments of N samples each. For each segment spectral components (Fourier Spectrum) are estimated exploiting commonly known Fast Fourier Transform (FFT) algorithms. Average frequency calculations normally resort to power

spectrum, which can be readily derived from the original Fourier spectrum. The two most popular frequency parameters used as fatigue descriptors are Mean Power Frequency (MPF) and Median Frequency (MF).

The second technique, called Zero Crossings (ZC), is a strongly simplified way of estimating average signal frequency in time domain, although it can be also defined through spectral calculations. Average intensity of rectified and smoothed EMG signal has also been correlated to some extent with muscle fatigue, but this has not gained as much popularity as the two other techniques.

In discrete form the two spectral parameters can be written by

$$MPF = \frac{\sum_{0}^{N-1} f_k P(f_k)}{\sum_{0}^{N-1} P(f_k)} \qquad (1)$$

$$\sum_{0}^{MF} P(f_k) = \sum_{MF}^{N-1} P(f_k) \qquad (2)$$

In the second technique (ZC) the time domain approach simply tries to determine the number of polarity changes in the signal during a given period of time.

$$ZC = \sum_{j} [s(\mathcal{J})_j + s(\mathcal{T})_j] \qquad (3)$$

where $s(\mathcal{J})_j$ denotes the j^{th} polarity change of the signal from negative to positive; and $s(\mathcal{T})_j$ denotes the j^{th} polarity change from positive to negative.

As mentioned earlier, there are ways of estimating ZC rates through spectral calculations, but they are rarely

used due to slower processing times and inherent uncertanties as compared to direct time domain estimations.

Several problems emerge as these methods are applied to assess fatigue reflected in EMG signals. To achieve fast spectral estimations FFT algorithms are commonly used. This implies limiting the source time series segment to specific number of points, ie. only groups of points having 2^N elements (N is a positive integer) can be processed by FFT.

It has been suggested different solutions to circumvert these problems, but basically only few different size groups of points are allowed. This means that a huge number of varying length signal segments cannot be analyzed directly by FFT. The only known method to manage arbitrary number of points is the actual Discrete Fourier Transform, which is unpractical because of the much greater number of calculations required compared to FFT.

The basic problems with spectral estimations are, however, intrinsic. First of all, power spectrum is not unique. There is an unlimited number of different signals that can produce exactly the same power spectrum. Secondly, varying amounts of errors are always introduced to spectral estimations due to the finite number of temporal points and also due to different windowing functions used. Thirdly, the Fourier spectrum implies sinusoidal structural model for its target, which is rarely the case in physiological signals. These three factors to large extent can be credited to great amount of unspecificity and insensitivity found in many physiological signal analysis applications using spectral estimators.

Zero crossings methodology, on the other hand, does not account for any other information except the signal polarity. Therefore, any signal behaviour between two consequtive polarity changes will be left unnoticed. Since signal changes are mostly unpredictable in e.g. EMG, huge ammounts of information are ignored by using the ZC ana-

lysis method.

OBJECT OF THE INVENTION

The object of the present invention is to provide a reliable index for determination of muscle fatigue. More specifically, an object is to provide a muscle fatigue measuring method based on a discrete sampling technique, due to the greater amount of flexibility of digital electronics compared to analogue circuitry in signal processing.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an apparatus according to the present invention for measuring muscle fatigue
Fig. 2 shows a decision flowchart of the control logic unit of Fig. 1.
Fig. 3 shows a typical EMG signal segment;
Fig. 4 shows data from an analysed signal according to Fig. 3;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The inventive system approach to provide a more reliable index for quantification of muscle fatigue is shown in Fig 1. This system model is based on a discrete approach instead of a continuous one, due to greater amount of flexibility of digital electronics compared to analogue circuitry in signal processing.

The input signal x(t), which is the actual EMG signal derived from electrodes, is sampled and held stable by a S/H unit 1. The sampled value of $x_i=x(t)|_{t=ti}$ is then fed into four separate system units: accumulator A1, accumulator B1, delay circuit 2 and the positive input of a sub-

traction unit S. Both delay circuit 2 and subtraction unit S are receiving each of the sampled values x_i; but input values to accumulators A1 and B1 are selectively written to these units. Whether or not a particular value x_i is written to either one of these accumulators is decided by the control logic circuit 3, as will be explained in connection with Fig. 2.

Each value of the difference Δx_i of two consequtive values x_i and x_{i-1} is written to accumulator C. The output signal of accumulator C is fed to a squaring unit Q and a multiplier unit P for further processing, which will be explained later.

Generally, the cumulative output signals of the accumulators are hereinafter referred to by a sigma character accompanied by an appropriate subindex, i.e. the output signal of accumulator C is denoted Σ_c. The output of accumulator C is further processed to produce both the square and cube values of Σ_c. These will constitute a weighing function for the output values, in order to emphasize larger changes in the signal. Accumulators A2 and B2 will perform the neccessary scaling for this procedure, as they receive as an input signal a squared value of the output Σ_c of accumulator C. It is obvious that other kinds of weighing functions can be applied. Any writing operation to these accumulators is supervised by the control logic circuit 3.

All five accumulators are reset to zero from time to time by the Control Logic, which derives the reset criteria from one input signal the Δx_i.

After that a number of x_i samples have been received, the accrued values at the accumulator outputs are processed by two divider units D1 and E1. As certain criteria (explained later) in the control logic 3 becomes valid, the control logic signals SET_q, SET_p, $WRITE_{a2}$ or $WRITE_{b2}$ as well as SET_{d1} or SET_{e1} activate the corresponding divider

units resulting in new divider output values (quotients) Γ'_d or Γ'_e, respectively. An example of how this values are calculated, we have

$$\Gamma'_e = (\Sigma_c)^3/\Sigma_{b1} \quad (4)$$

This value is immediately written to a pertinent mean estimator unit F or G. For example, the mean estimation process may simply consist of taking the arithmetic mean, i.e. average, of a sequence of input values Γ'_d or Γ'_e:

$$\Gamma'_{g_k} = \frac{1}{M}\sum_{0}^{M-1}\Gamma'_{e_j}, \text{ where } k = 0,1,2,... \quad (5)$$

Another model for the mean estimator would be to compute the median values.

Finally, for each new pair of (Γ'_f,Γ'_g), the control logic issues the SET_{d2} and SET_{e2} signals in order to activate second divider units D2 and E2. This will result in the following output values from D2 and E2:

$$\Gamma_f = \Gamma'_f/\Sigma_{a2}$$
$$\Gamma_g = \Gamma'_g/\Sigma_{b2} \quad (6)$$

After this, a SET_h command will be issued in order to activate the multiplier unit H. The output of this unit constitutes the actual analysis result in the form of a time series:

$$R_{\gamma_k} = \Gamma_{f_k} \cdot \Gamma_{g_k}, \text{ where } k = 0,1,2,... \quad (7)$$

The values of R_γ tend to decrease as muscle fatigue increases. Examples on this phenomenon are shown later in the text.

Referring now to Figures 1 and 2, a detailed description of the operation of control logic unit 3 is given.

There is only one input to the unit: Δx_i. At an initial stage as sampling is to be started, FLAG will be set according to the difference of the first two values available, i.e. $x_1 - x_0$. If the difference proves to be zero, then the next possible difference will be tested: $x_2 - x_1$. This testing of differences will be continued until a nonzero difference is detected, in which case FLAG will be set to TRUE, if the difference is positive, and to FALSE if the difference is negative.

In Figure 2, a continuous process is shown where the i^{th} Δx value Δx_i is processed, whereby the initial FLAG value has been set earlier. In this continuous process, Δx_i is first checked for positive values. If this value appears positive, then FLAG is tested. If it is TRUE, it means that the signal is still growing in value, and only two actions will follow: the current value of x_i will be written to accumulator A1 and the current value of Δx_i will be written to accumulator C.

If FLAG turns out to be FALSE, a series of actions will follow. This is a critical point of the inventive method, because now a change in the signal direction has occured, which means that the derivative of the input signal has changed its sign. In this specific case, the signal has now started to decrease in value instead of growing. This activates the control unit in a number of different ways, resulting in the calculation of new values to be presented at the outputs of the various calculation means, as will be explained in the following.

Depending on which way the change has become actual, whether it has been altered from growing to decreasing or vica versa, a different series of control actions will be realized. If Δx_i is positive, then the FLAG, having been

false, will be immediately set to TRUE and the value x_i is written to accumulator A1. Immediately following this, a SET_q signal is issued, followed by a SET_p signal, allowing the squaring unit Q and the multiplier unit P to produce the square and cube, respectively, of the accumulator C output signal. Next the square value is written to accumulator B2 and a SET_{e1} signal is issued in order to activate the divider unit E1. Now a new value of Γ'_e can be read at the output of E1, which value is written to the mean estimator G by a $WRITE_g$ procedure. This is followed by a $RESET_{b1}$ signal to clear accumulator B1 and prepare it for the next accumulative process.

The control logic unit 3 includes counter means to synchronise the two mean estimators F and G. This can be done in several ways, for example the counter can be used to count a fixed time period, for which one analysis result would be produced or by incrementing the corresponding counter by one every time a new value is written to a mean estimator. Now e.g. in the first case the FULL value of the counter would indicate how many samples (N) are to be acquired, before a new value of R_γ would be estimated.

As the counter reaches the FULL condition, it will be reset to its initial value, and SET_{d2} and SET_{e2} commands will be issued to produce a pair of values (Γ_f,Γ_g) at the outputs of divider units D2 and E2. These values will be multiplied by multiplying unit H after the SET_h command has been issued. The final output R_γ will now contain information about fatigue status of the muscle being analysed.

After the completion of one estimation and accumulation process cycle as described above, mean estimators F and G will be reset by signals $RESET_f$ and $RESET_g$, respectively. Accumulators A2, B2 and C will be reset by the respective signals $RESET_{a2}$, $RESET_{b2}$ and $RESET_c$. These actions will reset the contents of the mean estimators and accumulators to zero and commence a new mean estimation and accu-

mulation process with no values written to these units at this point.

The case when $\Delta x_i = 0$ will also result in writing the value to accumulator C and, depending on the FLAG status, to either of accumulators A1 or B1.

As can be seen from Fig. 2, there is a symmetric flow of events for the two cases $\Delta x_i > 0$ and $\Delta x_i < 0$. Therefore, the explanation of the control flow in the latter case is analogous to the first one.

After the control logic 3 has performed all neccessary functions, it will start waiting for the next value Δx_{i+1}, which is provided by the sample&hold unit 1 of figure 1.

Referring now to Figures 3 and 4, an EMG (electromyography) signal segment shown in Fig. 3 can be analysed in the following manner:

Between a starting point T1 and an end point T2, the signal has been subdivided into equal length periods of time (ΔT). According to Fig. 4, the first analysis subsegment has been chosen to be 327 ms, which equals 654 sampled values of EMG. The starting point T1 has been set to T1=1.241 s, at which time onset of EMG activity occurs. The end point has been set to T2=9.948 s, at which time there is a rapid diminishing intensity of the EMG signal.

Each subsegment (period) has been analysed to yield two distinct signal descriptors: conventional MF (Median Frequency) and the new descriptor derived by the method accordding to the present invention, the R_γ. Analysis of the consecutive periods yields two separate discrete time series of these two descriptors. The two series are then submitted to least squares linear fit analysis producing an estimate for the slope of each series together with the correlation coefficient. Table 1 and figure 4 exhibits Slope A for the Rγ series and Slope B for the MF series. Both series have been normalised relative to 100. The cor-

responding correlation coefficients as percentages are listed by Correl. A and Correl. B.

	Period/s	Slope A	Slope B	Corr. A	Corr. B
T1 = 1.241 s	0.327	-64.40	-40.60	-80.00	-66.60
T2 = 9.948 s	0.381	-65.40	-42.30	-84.90	-60.50
	0.435	-60.20	-32.90	-74.70	-55.50
	0.489	-61.60	-52.40	-85.50	-65.70
	0.543	-60.20	-36.90	-85.10	-77.20
	0.597	-59.70	-38.40	-86.90	-83.50
	0.651	-57.50	-36.50	-87.90	-77.10
	0.705	-57.60	-35.80	-90.40	-71.10
	0.759	-55.90	-32.10	-93.30	-68.10
	0.813	-54.70	-34.30	-90.90	-71.60
	0.867	-52.40	-32.40	-95.40	-73.60
	0.921	-58.10	-29.30	-97.30	-71.70
	0.975	-54.30	-32.40	-90.90	-66.90
	1.029	-56.50	-32.20	-95.70	-88.90
Median	-57.85	-35.05	-89.15	-71.35	
Average	-58.46	-36.32	-88.49	-71.29	
Average dev		± 2.96	± 4.17	± 4.92	± 6.37
Stand. dev		± 3.73	± 5.87	± 6.29	± 8.69

Table 1

The slope is an estimate of the intensity of the muscle fatiguing process. The steeper the slope the more fatigue is evident in the muscle concerned. If the muscle is subjected to rehabilitation then - provided the treatment proves effective - successive measurements during the treatment phase should produce increasing slope values.

The signal has been registered through standard surface electrodes from *musculus flexor carpi ulnaris* during maximal isometric contraction. This experiment was chosen

to be most favourable to conventional fatigue analysis methodology, and particularly in this case to MF analysis. It is well known that as muscular fatigue increases, MF of the muscle EMG signal decreases almost in a linear fashion.

Normally only one value for the period length is applied, but in this example the period has been given several values to overcome any statistical bias attached to one value periods. From Figure 4 it is clear that as the period length is increased, the estimate of the slopes tends to decrease in both cases. This is probably due to stronger averaging effect in longer periods. Also interestingly, correlation coefficients approach 100% as the period length is increased.

The graphs in Figure 4 (Fatigue 1) show that the MF change is clearly more insensitive to the fatiguing phenomenon than the R_y variation (absolute value of the normalised slope) and, furthermore, the MF graph displays more statistical fluctuations as a function of different analysis period lengths. The latter can be partly contributed to the fact that as period lengths are changed, the FFT algorithms are not always able to utilise all subsegment data values as one single group. The new and inventive methodology has no such limitations, and the R_y slope behaves statistically very smoothly with increasing period lengths.

The correlation coefficient for the MF technique depicts also intense variability with different subsegment lengths. Statistically this carries severe implications for a methodological source of errors in estimating muscle fatigue. As for the method according to the present invention, correlation coefficients form a well behaving, almost monotonic function, which again demonstrates its high degree of statistical stability. The correlation coefficients are also higher for the R_y slopes than for the MF ones.

These differences in statistics can also be verified numerically by the overall statistics of the four series in Table 1.

Relative average deviation of the MF slope is 11.5 %, relative standard error is 4.3 % - for the corresponding correlation coefficient these figures are 9.0 % and 3.3 %. For the R_γ method these values turn out to be: relative average deviation of the slope: 5.1 %, relative standard error 1.7 %. Similarly for the correlation coefficient: relative average deviation 5.6 % and relative standard error 1.9 %.

The MF technique produces in the case of the slope uncertainties more than twice greater than those inherent in the method according to the present invention, and correlation coefficient variability for the MF technique appears almost twice as great as in the R_γ case.

This multivalue period analysis is highly suitable for the new inventive methodology, because all subsegment data samples can always be included in the analysis process. This approach is also more reliable than the one value case; analysis dependencies on period length can be effectively eliminated.

Finally, a fixed period length was chosen to allow the MF algorithms to exploit all subsegment samples (period with 1024 data values.) This number of samples was chosen because for this particular setup, MF seemed to produce good correlation. The two methods were now compared by scanning through all subsegments ten times. Each time a new scan was performed, the starting point T1 was slightly shifted forward by 52 ms, but the subsegment length remained the same. In practice, as far as muscle fatigue is concerned, all the scans were analysing the same overall time segment T1 ... T2. The achieved results, together with differences in percentage betweeen the two methods are shown in table 2:

Slope A	Mean: -58.1	Standard error: 1,4%	
Slope B	Mean: -38.3	Standard error: 2,5%	(+78%)
Corr. coeff. A	Mean: -88.1	Standard error: 0.6%	
Corr. coeff. B	Mean: -82.3	Standard error: 1.5%	(+250%)

Table 2

Again, the same pattern of the differences in sensitivity to fatigue and its correlation coefficient as well as the degree of statistical uncertainties can be distinguished.

It is obvious to one skilled in the art that the present invention is not confined to the examples described above, but that various embodiments of the invention may vary within the scope of the attaced claims.

Claims:

1. A method for measuring muscle fatigue, in which electromyographic (EMG) signals measured from a muscle are used to determine the fatigue level of the muscle, the method comprising the steps of:

- receiving an EMG input signal x(t) from electrodes attached to the muscle to be analyzed;

- sampling said input signal to a sequence of discrete signal values x_i;

- calculating the difference Δx_i between several pairs of successive sample values x_i and x_{i-1};

- depending on the sign of the calculated difference Δx_i, adding cumulatively the sampled values x_i in a first or second accumulator means (A1, B1), and said difference values Δx_i in a third accumulator means (C);

- obtaining separate sequences of quotients between the values representative of the output from said third accumulator means and values representative of the outputs from said first and second accumulator means, respectively;

- obtaining for each of said sequences a single quotient having a weighted value representative of a number of said quotients;

- multiplying the obtained weighted values with each other in order to obtain an index indicative of fatigue during said time period in said muscle.

2. Method according to claim 1, wherein the cumulative addition of the sampled values x_i to said first, second and third accumulator means is done in a cyclic fashion for a number of sample values, after which the accumulator sums are read and the accumulators are reset.

3. Method according to claim 1 or 2, wherein the statistical analysis of the quotients is done in a cyclic fashion with predetermined number of quotients, the analysis being performed after at least one sequence con-

taining a predetermined number of quotients have been provided, whereafter the resulting value is read and new quotient sequences are generated.

4. Method according to claim 1, 2 or 3, wherein the single weighted quotient value for each of said sequences is obtained by calculating the arithmetic mean of the quotients.

5. Method according to claim 1, 2 or 3, wherein the single weighted quotient value for each of said sequences is obtained by calculating the median value of the quotients.

6. Method according to any of the preceding claims, including the steps of further processing the output of accumulator C to produce the square and cube values of its output, in order to provide a scaled emphasis function for the output values (Σ_c).

7. Method according to claim 6, including the steps of further dividing the weighted quotient values with a second value representative of the square of the output from said third accumulator means; and

multiplying the obtained values with each other in order to obtain an index indicative of fatigue during said time period in said muscle.

8. Apparatus for measuring muscle fatigue, in which electromyographic (EMG) signals from a muscle are measured to determine the fatigue level of the muscle, the apparatus comprising:

- input means (1) adapted to receive an EMG input signal x(t) from electrodes attached to the muscle to be analyzed and to sample said input signal to form a sequence of discrete signal values x_i;

- difference calculating means (S) for computing the difference Δx_i between several pairs of successive sample values x_i and x_{i-1};

- control logic means (3) for determining the sign

of said difference Δx_i and for providing the signals necessary for controlling the EMG measuring apparatus;

- accumulator means (A1, B1, C) adapted to selectively receive, depending on the sign of the calculated difference Δx_i, sampled values x_i and said difference values Δx_i;

- dividing means (D1, E1) for computing separate sequences of quotients between values representative of the output from said third accumulator means and values representative of the output from one of said first and second accumulator means, respectively;

- statistical analysing means (F,G) for obtaining for each of said sequences a single weighted quotient value representative of a number of said quotients;

- multiplying means (H) for multiplying the obtained weighted values with each other in order to obtain an index indicative of fatigue during said time period in said muscle.

9. Apparatus according to claim 8, wherein each of the said accumulator means includes a reset input terminal in order to receive an reset signal when a predetermined number of sample values x_i have been cumulatively added and calculated upon.

10. Apparatus according to claim 8 or 9, wherein the statistical analysing means (F,G) includes reset input terminals in order to receive a reset signal when said predetermined number of said quotients on each sequence of quotients have been statistically calculated upon.

11. Apparatus according to claim 8, 9, or 10, wherein the statistical analysing means (F,G) comprises means for calculating the arithmetic mean of the quotients.

12. Apparatus according to claim 8, 9 or 10, wherein the statistical analysing means (F,G) comprises means for calculating the median value of the quotients.

13. Apparatus according to any of the preceding

claims, including processing means (Q, P) to produce the square and cube values of the output of accumulator C, in order to provide an emphasize function for the output values (Σ_c), and further accumulator means (A2, B2) in order to perform the neccessary scaling for the emphasize function.

14. Apparatus according to claim 13, the apparatus further including second dividing means (D2, E2) for dividing the weighted quotient values with a second value representative of the square of the output from said third accumulator means.

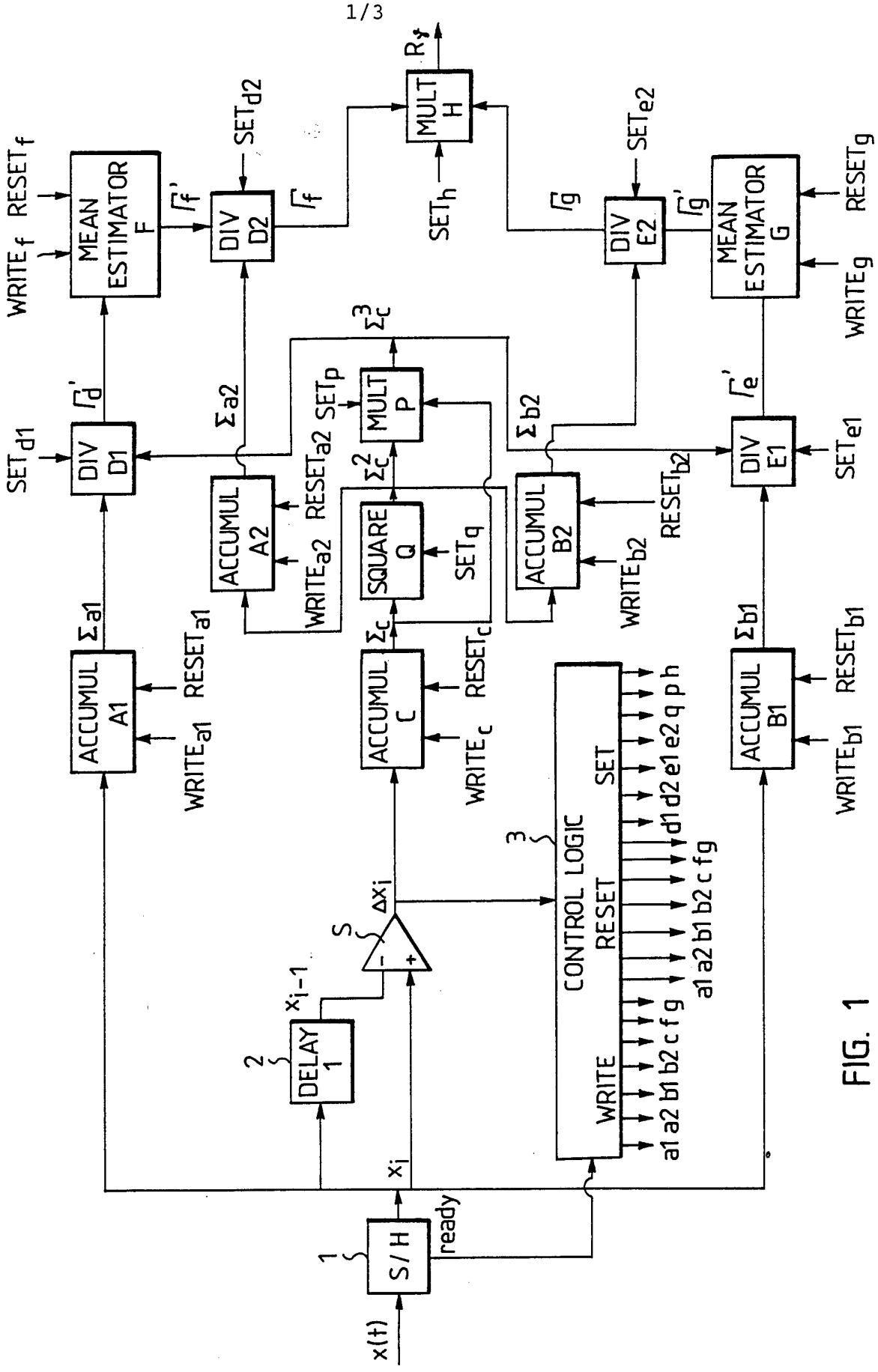
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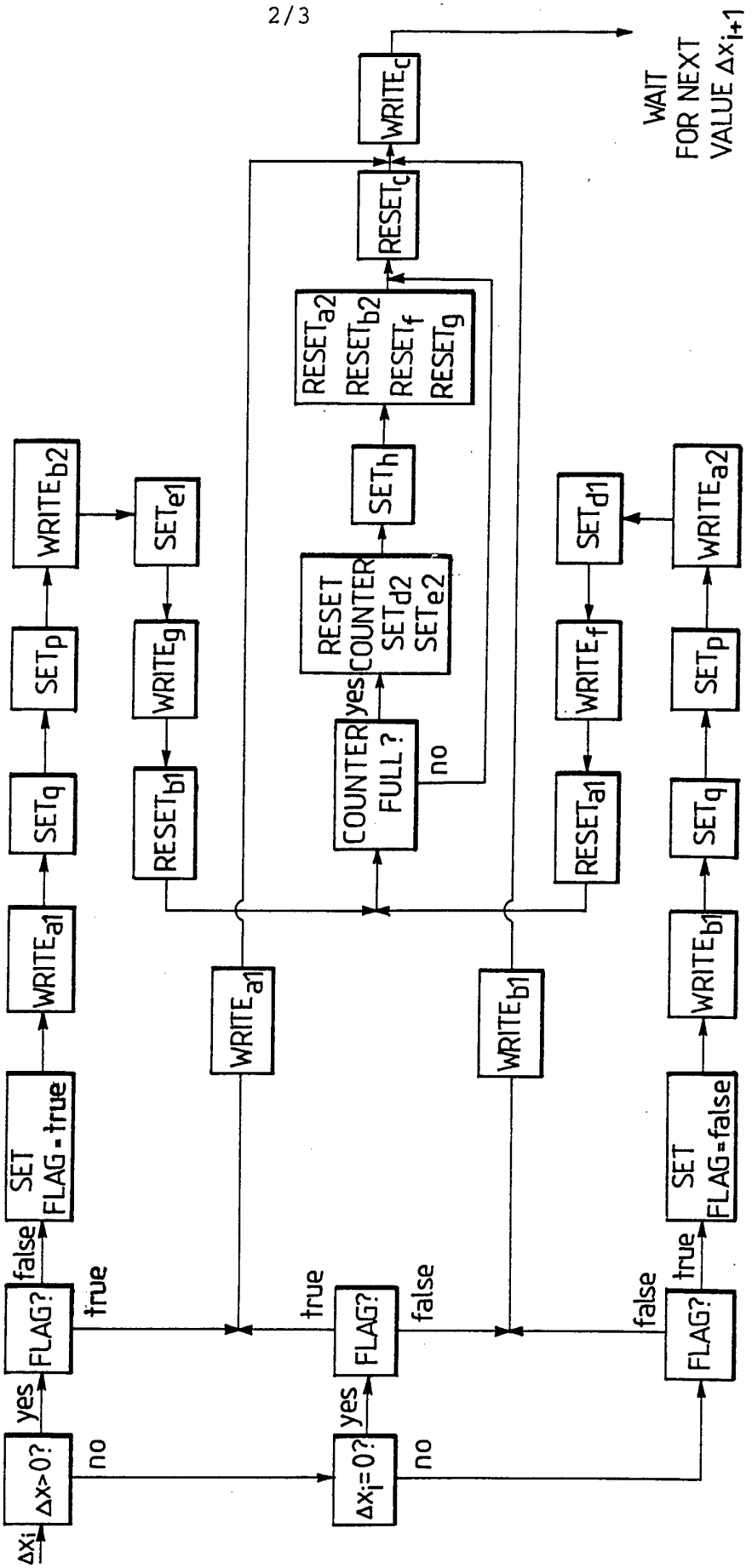
FIG. 1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false
true
SET FLAG=true
WRITEa1
SETq
SETp
WRITEb2
SETe1
WRITEg
RESETb1
WRITEa1
Δxi=0?
yes
no
FLAG?
true
false
COUNTER FULL?
yes
no
RESET COUNTER SETd2 SETe2
SETh
RESETa2 RESETb2 RESETf RESETg
RESETc
WRITEc
WAIT FOR NEXT VALUE Δxi+1
WRITEb1
FLAG?
false
true
SET FLAG=false
WRITEb1
SETq
SETp
WRITEa2
SETd1
WRITEf
RESETa1

FIG. 2

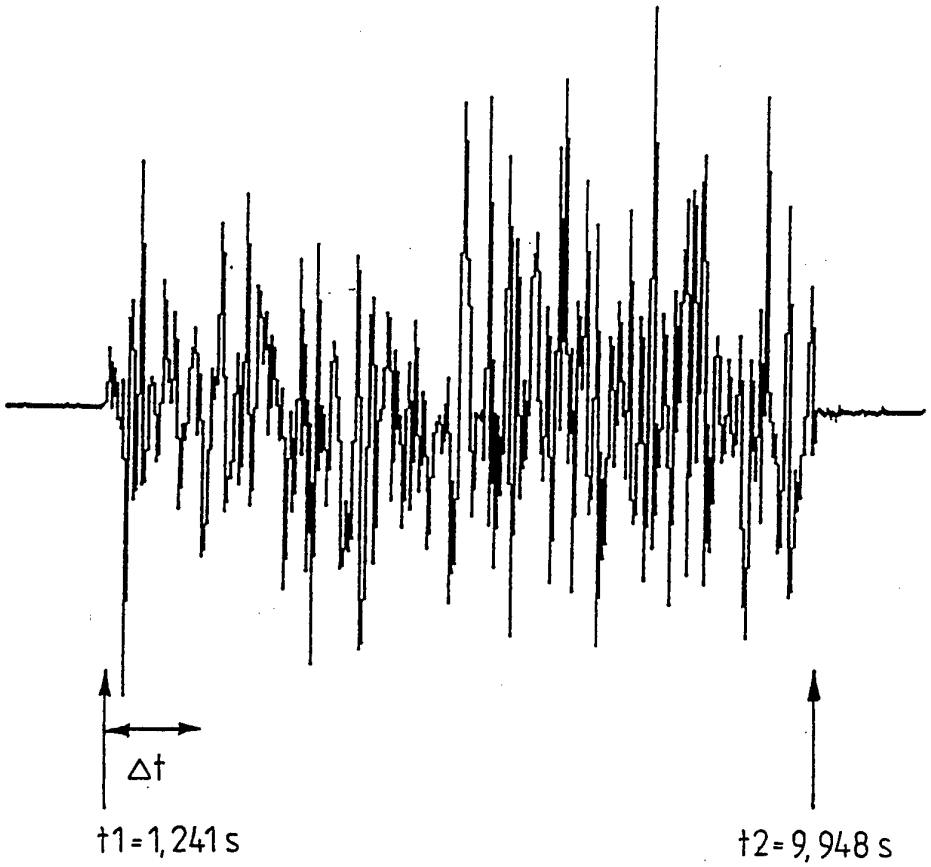
Δt
t1=1,241 s
t2=9,948 s

FIG. 3

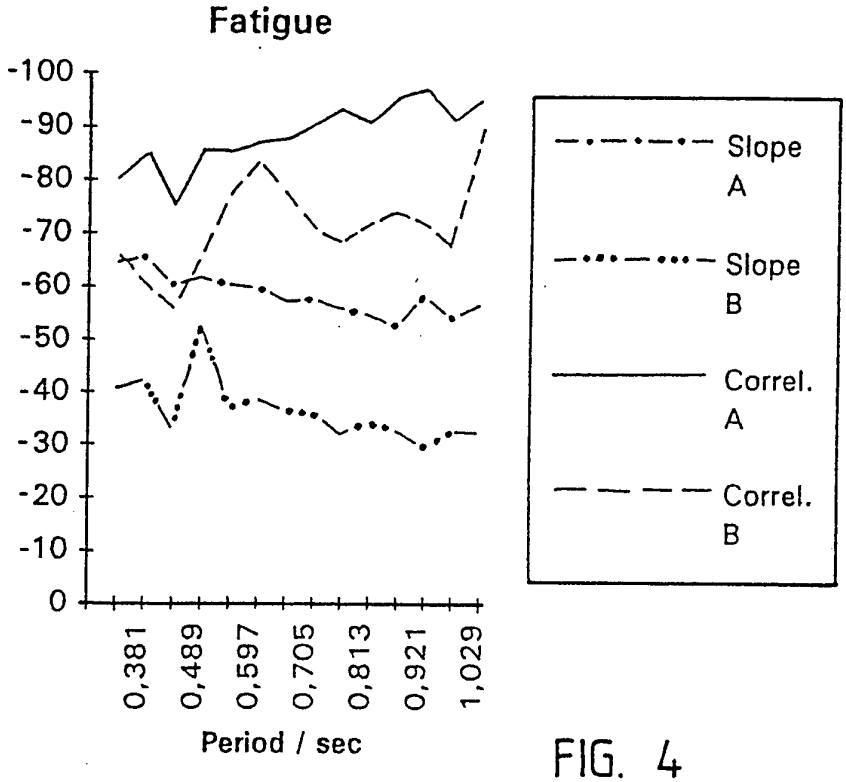
Fatigue
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
0,381
0,489
0,597
0,705
0,813
0,921
1,029
Period / sec
Slope A
Slope B
Correl. A
Correl. B

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 94/00339

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: A61B 5/0488
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)

IPC6: A61B

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

SE,DK,FI,NO classes as above

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

WPI, CLAIMS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE, A1, 3441151 (SIEMS, WOLFGANG), 4 July 1985 (04.07.85), page 5, line 22 - page 7, line 11, see the figures --	1-14
A	WO, A1, 9101683 (BIOLIN AB), 21 February 1991 (21.02.91), page 1 - page 2, see the figures --	1-14
A	US, A, 5092343 (ROBERT SPITZER ET AL), 3 March 1992 (03.03.92), abstract --	1-14
A	US, A, 4823804 (MARQUIS GHISLAINE ET AL), 25 April 1989 (25.04.89), abstract --	1-14

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 November 1994	28 -11- 1994
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Anders Axberger Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 94/00339

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, A, 4213467 (FOSTER B. STULEN ET AL), 22 July 1980 (22.07.80), abstract -- --------	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/10/94

International application No.
PCT/FI 94/00339

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		CA-A- 2064227	01/02/91
		EP-A- 0485428	20/05/92
		JP-T- 4507207	17/12/92
		SE-B,C- 464557	13/05/91
		SE-A- 8902626	01/02/91
		US-A- 5318039	07/06/94
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		JP-A- 2005925	10/01/90
		EP-A- 0433626	26/06/91
		JP-A- 3207342	10/09/91
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		EP-A,B- 0264329	20/04/88
		SE-T3- 0264329	
		FR-A,B- 2605210	22/04/88
		JP-A- 63164940	08/07/88
US-A- 4213467	22/07/80	NONE	