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(54) Method for operating a clothes drying appliance and clothes drying appliance

(57) The method is used for operating a clothes drying appliance (1), wherein a moisture content of the clothes (6) is determined by measuring a current running through the clothes (6) and wherein an AC voltage signal is applied to the clothes (6) (S3). The clothes drying appliance (1) is adapted to perform the method according to any of the preceding claims. The clothes drying appliance (1) may comprise at least an AC voltage generator (3) generating an AC voltage, at least one electrode (5) being connected to output ports of the AC voltage generator (3), the at least one electrode (5) being coverable by the clothes (6); and a logic (2) functionally connected to the at least one electrode (5) for determining a conductance representative of a moisture content of the clothes (6) from a measured AC current between the electrodes (5).

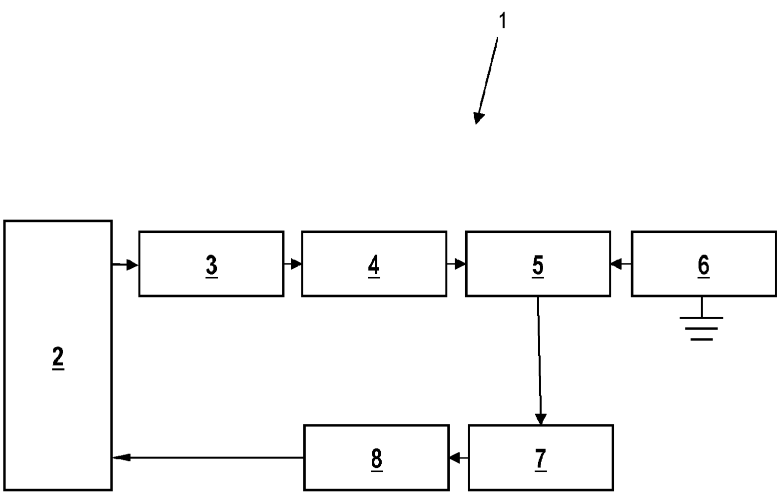

Fig.1

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Description

[0001] The invention relates to a method for operating a clothes drying appliance, wherein moisture content of the clothes or laundry is determined by measuring a current running through the clothes. The invention also relates to a clothes drying appliance being adapted to perform the method.

[0002] Tumble dryers comprise a rotatable drum to contain clothes. To dry moist clothes, the drum is rotated and heated, e.g. by circulating warm air over the clothes. In many tumble dryers, a desired or target moisture content at the end of a drying process or drying cycle can be selected by a user. To achieve the target moisture content, the tumble dryer monitors the moisture content of the clothes and terminates the drying cycle if the target moisture content has been reached. To monitor the moisture content, some tumble dryers use a current sensor that comprises two electrodes within the drum wherein the electrodes are regularly covered by the clothes. A DC voltage is applied to the electrodes. The value of the resulting current through the clothes is related to the moisture content. The moister the clothes are the greater is the current. The tumble dryer can use this current value to estimate the moisture content and to control the drying cycle accordingly. However, the use of a current sensor has the disadvantage that the electrodes are subject to clothes electrolysis that deteriorates the electrode material and accelerates aging of the electrodes. Further, the current sensor exhibits adverse spatial polarization effects. Also, the computational effort is rather high. And generally there is a desire for a more accurate estimation of the moisture content to achieve better and more consistent drying results.

[0003] It is the object of the following invention to provide a possibility to estimate a moisture content of clothes in a clothes drying appliance (e.g. clothes dryer or combined washing machine and clothes dryer) that reduces or eliminates the disadvantages of the prior art and may in particular show an improved life expectancy, reduces polarization effects, is relatively simple to implement (in particular needs only a low computational effort), and/or shows an improved accuracy.

[0004] The object is achieved according to the features of the independent claims. Preferred embodiments can be derived, inter alia, from the dependent claims as well as from the subsequent disclosure.

[0005] The object is achieved by a method for operating a clothes drying appliance, wherein an moisture content of the clothes (as such or by using a representative quantity) is determined by measuring a current running through the clothes wherein an AC voltage signal is applied to the clothes (instead of the DC voltage signal applied up to now).

[0006] The use of the AC voltage signal greatly reduces electrolysis of the electrodes by the constant changes of direction of the current running between the electrodes for improved durability or life expectancy. Spatial polarization effects are mostly eliminated. The use of the AC voltage allows for non-complicated computations, as will be explained further below. And also, an accuracy of the estimated moisture content is greatly improved by up to 40% in comparison to contemporarily implemented estimation methods. The current measurement is also a measurement of the clothes' electrical conductance.

[0007] It is an embodiment that the AC voltage signal (also called the 'carrier' or 'carrier signal') comprises a frequency of at least about 350 Hz, preferably of at least about 400 Hz, preferably of about 400 Hz. This frequency or frequency range is high enough to prevent electrolysis. The AC voltage signal may comprise a frequency of not more than about 450 Hz to 500 Hz; this upper limit is low enough to neglect a capacitance of the clothes.

[0008] It is another embodiment that the AC voltage signal comprises an amplitude of about 5 Volts for easy implementation and ease of use in or with common electronic circuits that often use the same voltage level Vpp = 5 V.

[0009] It is yet another embodiment that the AC voltage signal is DC filtered (a possible DC portion is eliminated) to enhance accuracy of the measurement.

[0010] It is even another embodiment that an envelope signal of consecutive samples is generated from the measured alternating current. The samples may in particular comprise a local peak of the measured current within a certain sample time. A local peak may be detected by a peak detector (hardware AM demodulator) or by a peak detection software, or by a demodulation in general terms. A local peak represents the occasion in which, for the sample time, humid clothes best cover the electrodes and give a relatively best approximation of the actual moisture content. This effect in particular occurs for tumble dryers because, in a tumble dryer, the clothes are perpetually tumbled and thus fall onto the electrodes and disengage themselves again from the electrodes after a certain progress of revolution of the drum.

[0011] The samples (including the peaks) may preferably be sampled within a predetermined sample time to achieve a well-defined time relation. The sample time may in particular be determined such that the known Nyquist criterion is satisfied. For example, the sample time may be two times or more shorter than the time between clothes hitting the electrodes. In other words, the sample frequency may particularly be two times or more the expected frequency of the laundry or clothes hitting the electrodes. This limits a systematic error margin.

[0012] It is yet another embodiment that a maximum value of n consecutive samples is extracted or determined from the envelope signal. n is a positive number, e.g. 64, 128 or 256. This embodiment uses the effect that, in a tumble dryer, because of the perpetual tumbling, the electrodes are sometimes only partly or lightly covered (which results in a low current not representing the true moisture content of the clothes) and sometime well covered (representing the true moisture content of the clothes well). The extraction of the maximum value achieves that only a best approximation of the real moisture content of the clothes from the group of n samples is used for further computation. This enhances accuracy and gives a particularly robust measurement.

[0013] It is a further embodiment that a series of maximum values is generated during a drying cycle. By this, an even more accurate computation of the moisture content is possible by using compositions of two or more maximum values. Also, curve fits can be used. The series may in particular come from continuous extraction of maximum values from a consecutive series of n consecutive samples.

[0014] It is also an embodiment that the series of the maximum values is passed through a logarithmic filter to give a series of filtered values. The filtered value is a particular useful and accurate representative of a moisture content of the clothes. The logarithmic filter converts a basically logarithmic relation between the moisture content and the time into a linear relationship. The linear relationship or straight line is easier to use for determining the occurrence of a certain incident, e.g. determining when the target moisture content has been reached.

[0015] It is a particular embodiment that the filter uses a relation comprising:

$$y(m) = y(m-1) + \log(a, x(m)-y(m-1)), \text{ wherein} \qquad (1)$$

y(m) is an m-th filtered value, y(m-1) is the previous filtered value, a is a parametric log base and x(m) is an m-th maximum value (of n samples) received from the filter. The integer m may be called a series index or series number and preferably has a defined relation to the time t at which the maximum value has been sampled. Relation (1) has been found to give a particularly good compromise between easy computation and good accuracy.

[0016] In particular, the moisture content G(m) (as a physical quantity) may be derived from y(m) by, e.g., G(m) = f(y (m)) or G(t) = f(y(t)). f(x) is a function that transforms a filtered value y (y(m) or y(t)) into a value of the moisture content G and that may be determined e.g. by experiments. The function f may be stored e.g. by means of a characteristic line and/or in a look-up table.

[0017] The object is also achieved by a clothes drying appliance, wherein the clothes drying appliance is adapted to perform the method as described above.

[0018] It is an embodiment and also achieves the object as such that the clothes drying appliance comprises at least

- an AC voltage generator generating an AC voltage,
- at least one electrode being connected to output ports of the AC voltage generator, the at least one electrode being coverable by the clothes; and
- a logic functionally connected to the at least one electrode for determining a representative or representative quantity of a moisture content of the clothes from a measured AC current between the electrodes.

[0019] It is another embodiment that a DC voltage cut-off means is connected between the AC voltage generator and the at least one electrode. This eliminates a possible DC portion of the carrier signal and enhances an accuracy of the humidity determination.

[0020] It is yet another embodiment that a current probe is connected between the at least one electrode and the logic.

[0021] It is even another embodiment that a peak detector is connected between the at least one electrode and the logic. The peak detector which may be implemented in hardware or software can determine the maximum values of the AC current measurement samples.

[0022] For a precise measurement while using cost-effective electrodes, the electrodes may be inserted or arranged in a bearing-shield of the dryer, in particular a lowest section of the bearing shield. The electrodes may be coated by a non-metallic material, e.g. a plastic. The electrodes may be moulded into the bearing shield, e.g. overmoulded by the bearings shield's plastic material.

[0023] In the following description which in particular refers to the figures of the attached drawings, a preferred embodiment of the invention is schematically described in greater detail.

Fig.1 shows a block diagram of a possible implementation of a moisture content detection of a clothes drying appliance;
Fig.2 shows process steps to determine a moisture content of clothes to be dried in a clothes drying appliance;
Fig.3 shows a diagram depicting one possible result from the process of fig.2.

[0024] Fig.1 sketches a possible implementation of a moisture content detection of a clothes drying appliance represented by a tumble dryer 1. Fig.2 shows process steps to detect a moisture content of clothes to be dried in a clothes drying appliance. A possible concrete embodiment is now described referring to both figures.

[0025] The tumble dryer 1 comprises a logic in form of a controller 2, e.g. a micro-controller, for controlling operation of the tumble dryer 1, in particular a drying cycle. The controller 2 inter alia controls operation of an AC voltage generator 3.

[0026] The voltage generator 3 generates an AC voltage signal (step S1) of a frequency of about 400 Hz. This frequency has the advantage that it is high enough to prevent electrolysis but is low enough to neglect a capacitance of clothes 6. The AC voltage is about 5 Volts which corresponds an operation voltage Vpp of the controller 2 and is thus particularly easy to generate.

[0027] On its output side the AC voltage generator 3 is coupled to a DC cut-off means 4 (or DC filter). By the DC cut-off means 4 the AC voltage signal from the AC voltage generator 3 is DC filtered (step S2) to remove any DC portion that could deteriorate the accuracy.

[0028] The AC voltage signal may, in particular be a square (or quasi-sine) wave which is particularly suitable for creating a temporarily constant voltage level for easier analysis or interpretation. However, also other waveforms may be used.

[0029] The output side of the DC cut-off means 4 is coupled to two electrodes 5 that are part of a current probe and that are located on a lower apex of a bearing shield of the tumble dryer 1. Thus, a DC-filtered AC voltage signal is applied to the clothes 6 by the electrodes 5 (step S3). The electrodes 5 are regularly covered by different clothes 6 (laundry) tumbled within a rotatable drum of the tumble dryer 1. If the clothes 6 cover the electrodes 5, a current flows through the clothes 6 between the electrodes 5 thanks to the water (moisture) contained in the clothes 6. The moister the clothes 6 are the higher is the current. In other words, the carrier signal's AC current is heavily modulated by the laundry's conductance: when the laundry has temporarily good contact with the electrodes 5, the current is high. This current is detected or sensed by the current probe.

[0030] The two electrodes 5 are functionally coupled to a current-to-voltage (CV) converter 7 for easier computation. The current probe may be omitted, and the electrodes 5 may directly be connected to the CV converter 7. The CV converter 7 is coupled to a peak detector 8. The peak detector 8 may be implemented in hardware (e.g. in a respective integrated circuit) or in software (e.g. within the controller 2).

[0031] The peak detector 8 detects a peak of the current (esp. of the absolute value of the current) over a predetermined period of time, the sample time, for consecutive sample times (step S4). The peak or sample represents the occasion in which humid clothes best cover the electrodes over the sample time. They give a relatively best approximation of the real moisture content within the sample time. Thus, the peak detector 8 detects a string or chain of (local, over the sample time) peaks or samples. This string of peaks forms a respective envelope signal (step S5). The envelope signal is a representative of the spatially temporary conductance of the clothes 6.

[0032] The envelope is or the samples or peaks are sampled frequently enough to satisfy the known Nyquist criterion. In other words, the sample time is so short that the Nyquist criterion is satisfied. In particular, the sample frequency may be two times or more than the expected frequency of the laundry or clothes 6 hitting the electrodes 5. This limits a sample error margin.

[0033] The peak detector 8 is connected to the controller 2 (e.g. via an analog-to-digital converter (ADC) which may be part of the controller 2) which computes the string of samples. It is a first computational step (step S6) to determine, from the envelope signal, a maximum value of n consecutive samples or peaks with n being a positive number. The determination or extraction of the maximum value achieves that only a best approximation of the real moisture content of the clothes from a group of n peaks is used for further computation for enhanced accuracy.

[0034] Over the measurement time, a series of maximum values is generated (step S7) that is passed through a logarithmic filter to give a series of filtered values (step S8). The logarithmic filter converts a basically logarithmic relation between the moisture content and the time into a linear relationship. The linear relationship or straight line is easier to use for determining the occurrence of a certain incident, e.g. determining when a predetermined target moisture content has been reached. Generally, other filters may also be used.

[0035] In the shown embodiment the filter uses a relation comprising the relation

$$y(m) = y(m-1) + \log(a, x(m)-y(m-1)),$$

wherein y(m) is an m-th filtered value, y(m-1) is the previous filtered value, a is a parametric log base and x(m) is an m-th maximum value received from the filter. This relation has been found to give a particularly good compromise between easy computation and good accuracy.

[0036] The filtered values y(m) (and thus also the string of filtered values y(m)) may be directly used as representative values of the moisture content of the clothes 6 to control a drying cycle of the tumble dryer 1. The filtered values y(m) may also be translated into (physical) values of the moisture content G of the clothes 6, e.g. by using a experimentally of computationally predetermined characteristic curve or relation. For example, the filtered values y(m) may be compared to a target value yend for reaching a target moisture content Gend at the end of a drying cycle, and the drying cycle may be stopped if this target value yend is reached or exceeded.

[0037] Fig.3 shows a diagram depicting one possible string of filtered values y(m) over time t. By having passed through the logarithmic filter, the values y(m) substantially form a straight line or curve C1 that is pointed downward. Each of the values y(m) corresponds to a value G(m) of the moisture content G or moisture content of the clothes. This correspondence can generally described by the function G(m) = f(y(m)) or G(t) = f(y(t)). If y is equal to the target value yend, the target moisture content Gend has been reached. This may be determined by the fact that one of the filtered values y(m) exceeds (i.e., is smaller than) the target value yend and/or by a filtered value y(m) is within a pre-determined margin around the target value yend.

[0038] Of course, the invention is not limited to the embodiment as described above.

List of Reference Signs

[0039]

1	tumble dryer
2	controller
3	AC voltage generator
4	DC cut-off means
5	electrode
6	clothes
7	current-to-voltage converter
8	peak detector
C1	curve
tend	time to terminate drying cycle
y(m)	filtered value for series number m
yend	value of filtered value corresponding to tend

Claims

1. A method for operating a clothes drying appliance (1), wherein a moisture content (G) of the clothes (6) is determined by measuring a current running through the clothes (6) and
wherein an AC voltage signal is applied to the clothes (6) (S3).

2. The method according to claim 1, wherein the AC voltage signal comprises a frequency of at least about 350 Hz, preferably of at least about 400 Hz, preferably of about 400 Hz.

3. The method according to any of the preceding claims, wherein the AC voltage signal comprises an amplitude of about 5 Volts.

4. The method according to any of the preceding claims, wherein an envelope signal of consecutive samples is generated from the measured alternating current (S4, S5).

5. The method according to claim 4, wherein the envelope signal comprises consecutive peak values extracted from the measured alternating current over a corresponding sample time (S4).

6. The method according to any of the claims 4 or 5, wherein a maximum value of n consecutive samples is extracted from the envelope signal (S6).

7. The method according to any of the claims 5 to 6, wherein a series of maximum values is generated (S7).

8. The method according to claim 7, wherein the series of the maximum values is passed through a logarithmic filter to give a series of filtered values (y) (S8).

9. The method according to claim 8, wherein the filter uses a relation comprising:

$y(m)=y(m-1) + \log(a, x(m)-y(m-1))$, wherein y(m) is an m-th filtered value, y(m-1) is the previous filtered value, a is a parametric log base and x(m) is an m-th maximum value received from the filter.

10. A clothes drying appliance (1), wherein the clothes drying appliance is adapted to perform the method according to any of the preceding claims.

11. The clothes drying appliance (1), in particular according to claim 10, wherein the clothes drying appliance (1) comprises at least

- an AC voltage generator (3) generating an AC voltage,
- at least one electrode (5) being connected to output ports of the AC voltage generator (3), the at least one electrode (5) being coverable by the clothes (6); and
- a logic (2) functionally connected to the at least one electrode (5) for determining a representative of a moisture content of the clothes (6) from a measured AC current between the electrodes (5).

12. The clothes drying appliance (1) according to claim 11, wherein a DC voltage cut-off means (4) is connected between the AC voltage generator (3) and the at least one electrode (5).

13. The clothes drying appliance (1) according to any of the claims 11 to 12, wherein a current probe is connected between the at least one electrode (5) and the logic (2).

14. The clothes drying appliance (1) according to any of the claims 11 to 13, wherein a peak detector (8) is connected between the at least one electrode (5) and the logic (2).

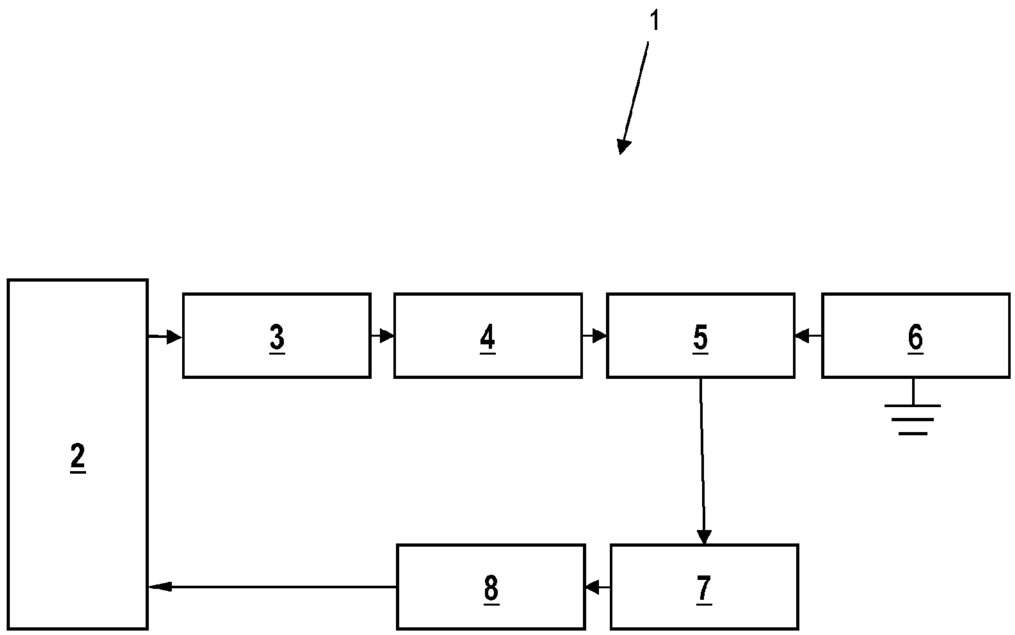

Fig.1

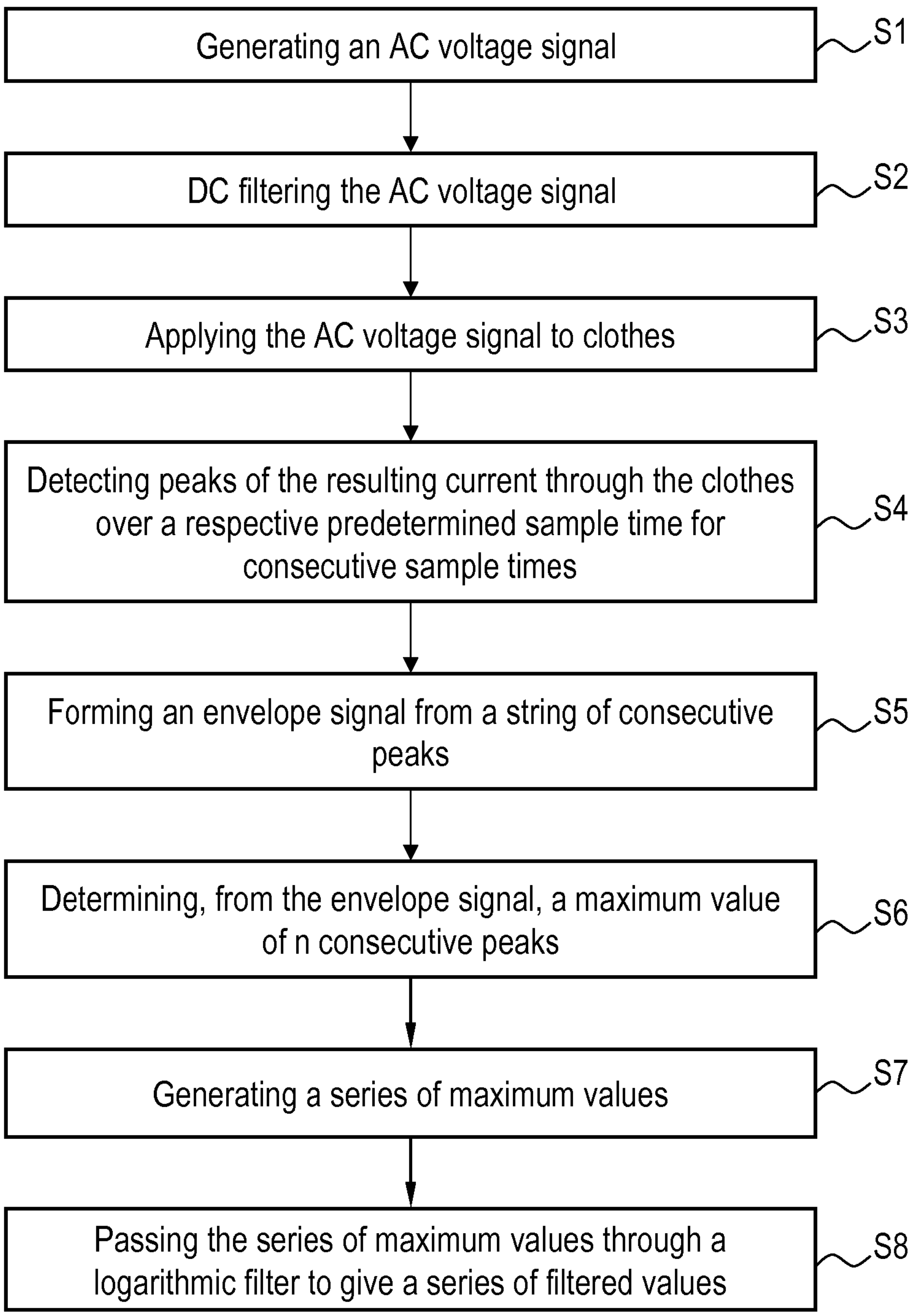
Generating an AC voltage signal
S1
DC filtering the AC voltage signal
S2
Applying the AC voltage signal to clothes
S3
Detecting peaks of the resulting current through the clothes over a respective predetermined sample time for consecutive sample times
S4
Forming an envelope signal from a string of consecutive peaks
S5
Determining, from the envelope signal, a maximum value of n consecutive peaks
S6
Generating a series of maximum values
S7
Passing the series of maximum values through a logarithmic filter to give a series of filtered values
S8

Fig.2

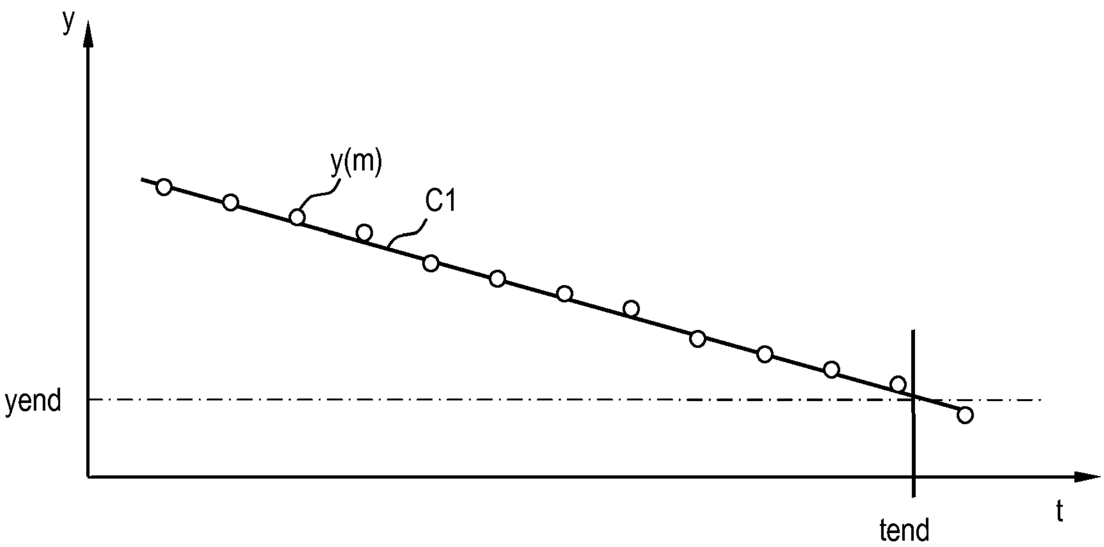

Fig.3

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EUROPEAN SEARCH REPORT

Application Number
EP 10 16 9428

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2009/064143 A2 (LG ELECTRONICS INC [KR]; KIM JONG SEOK [KR]; PARK DAE YUN [KR]; KIM DO) 22 May 2009 (2009-05-22) * paragraph [0079] - paragraph [0081]; figures * -----	1,10	INV. D06F58/28
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X	EP 1 443 139 A1 (E G O CONTROL SYSTEMS GMBH & C [DE]) 4 August 2004 (2004-08-04) * paragraph [0012] - paragraph [0025]; figures * -----	1,10,11	

TECHNICAL FIELDS SEARCHED (IPC)
D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	12 January 2011	Diaz y Diaz-Caneja

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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