METHOD AND DEVICE OF DETERMINATION OF AN INPUT SIGNAL WHICH CHANGES IN TIME

BACKGROUND OF THE INVENTION

Sensors convert nonelectrical physical or chemical quantities into electrical signals. The behavior of semiconductor sensor devices is modeled, under a series of assumptions, by a system of nonlinear partial differential equations and associated boundary and input value conditions. For such sensors, it is essential to solve numerically at least some of the equations in order to obtain a meaningful result describing environmental conditions encountered by the sensor. Mechanical sensors also suffer from some of the same issues relating to nonlinearity and associated boundary and initial value considerations.

When the desired result is determined by the integration of sensor output over time, errors of bias scale, and nonlinearity occur. Mathematical algorithms are used to improve the accuracy of the result by correcting for such errors of bias, scale and nonlinearity.

The present invention relates to methods and devices of determination of an input signal which changes in time as well as of its integral value.

Methods are known of the above mentioned general type and disclosed for example in Inventor's Certificates of the USSR 1,453,418 and 1,541,635. In accordance with the method and device disclosed in these references, integration is performed to a given value of the integration result. This objective is presented for example in inertia systems of targeting, for turning off an engine when a rocket reaches a desired speed V_r. The input signal in this case is an acceleration which is measured by accelerometer, and its inaccuracies are a main source of error of the system as a whole. The device includes a convertor **1** for a frequency of pulse sequence, a frequency multiplier **2**, an integrator or pulse counter **3**, a source of reference signals **4**, keys **5** and a control device **7**. A code corresponding to a desired value of speed is introduced into the pulse counter by integration of reference signals (accelerations) during a time corresponding time interval. The values of the reference signals can be obtained by turning a sensitivity axis of the accelerometer relative to a local vertical. Then, during measurements of the input signal which is the acceleration during a flight, an inverse integration is performed. In other words, the pulses from the convertor, multiplied many times by the frequency multiplier are deducted in the counter from the code obtained during the time of direct integration when the counter was operating for addition of the reference signals. A system of equations was used to determine the reference signals and time intervals. The nature of change of the input signal was approximately known beforehand, and therefore an initial moment of the input signal was calculated. Zeroing of the pulse counter is a signal that the speed reached the desired value. The above described method has a high accuracy. However, it has some disadvantages, namely the fact that the high accuracy is guaranteed in only one point and not along the whole scale of speed changes. This values must be known in order to determine of the location of a rocket. The known method and device are not always technically implementable since it is necessary that one reference signal is greater and the other is smaller than an average value of the input signal. However, the acceleration can reach a few g while on the ground during giving of the reference signals not always there is a standard of acceleration more than 1 g.

SUMMARY OF THE INVENTION

Accordingly, it is an object of present invention to provide a method and device which eliminates the disadvantages of the prior art.

In keeping with these objects and with others which will become apparent hereinafter, one feature of present invention resides, briefly stated, in a method of determination of an input signal changing in time, in which conversions which were performed for a final point in accordance with a known algorithm disclosed in the prior art, is also performed for final point t_n for intermediate t_1, t_2, t_k in accordance with a modified algorithm, so that it is possible to use not reference signals which are required by change curve of a changing acceleration, but reference signals which are available or in other words can be less than 1 g. The desired movement parameters are determined during the flight, and therefore a deviation of the acceleration curve from an expected acceleration curve does not reduce the accuracy.

In accordance with another feature of the present invention the device is provided with means for performing the above mentioned conversions for intermediate points as well.

The novel features which are considered as characteristic for the present invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing a device for determination of an input signal which changes in time in accordance with known method;

FIG. **2** shows a linear increase in input signals and an adjustment in the reference signals using the known method;

FIG. **3** graphically shows a changing speed over time where:

curve **1**—actual speed

curve **2**—reading of speed without correction

curve **3**—reading of the speed using the known method, where the reference signals are introduced for the moment in time (t_n);

curve **4**—reading of speed for the new method, where the reference signals are introduced for the intermediate moments in time ($t_1, t_2 \ldots t_n$)

FIG. **4** is a view showing a device for the determination of an input signal which changes in time in accordance with the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

In accordance with the present invention, the determination of an input signal which changes in time is performed with corresponding conversions for not only a final point, but also for intermediate points. For this purpose, a device includes a multi-position switch **1** through which an input signal x(t) and reference signal Xl, X**2**, . . . are supplied to several elements connected in series, in particular a convertor of analog into frequency **2**, a key **3**, a counter-integrator **4**. The device further has a register unit of reference signals **5**, a memory unit **6**, and arithmetic-logical unit **7**, a register of expected integral value of the input signal **8** and a digital comparetor **9**.

Using the example of calculating the desired speed of a rocket prior to turning off the engine, the device operates in the following manner.

Before the beginning of measurements of an input signal, frequencies $f_1, f_2 \ldots$ of the convertor **2** which correspond to the reference signals $X_1, X_2, \ldots$ are determined. Then the arithmetic-logical device determines corresponding reading of accelerations

$$y_i = \frac{f_i - f_o}{\beta_1},$$

where f_0 is a frequency of pulses of the convertor at a zero input signal;

β_1 is a coefficient of conversion of scale factor of the convertor **2**. The scale factor is determined as

$$B_1 = \frac{D_1}{D},$$

where D_1 and D_2 are determined as follows:

$$D = \begin{vmatrix} X_1 & X_1^2 & \ldots & X_1^n \\ X_2 & X_2^2 & \ldots & X_2^n \\ \vdots & \vdots & \ddots & \vdots \\ X_n & X_n^2 & \ldots & X_n^n \end{vmatrix} D_1 = \begin{vmatrix} f_1 - f_0 & X_1^2 & \ldots & X_1^n \\ f_2 - f_0 & X_2^2 & \ldots & X_2^n \\ \vdots & \vdots & \ddots & \vdots \\ f_n - f_0 & X_n^2 & \ldots & X_n^n \end{vmatrix}$$

Also, coefficients of decomposition d_i of a function X=P(Y) of reverse characteristic of the input/out of the convertor **2** are determined and introduced into the memory unit **6**. The values are determined by solving the following system of linear equations

$$X_i = \sum_{j=1}^{n} d_i \cdot Y_i^j$$

This system of equation is solved through the determinators

$$d_i = \frac{D_i}{D_d}$$

where

$$D_d = \begin{vmatrix} Y_1 & Y_1^2 & Y_1^3 & \ldots & Y_1^n \\ Y_2 & Y_2^2 & Y_2^3 & \ldots & Y_1^n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Y_n & Y_n^2 & Y_n^3 & \ldots & Y_n^n \end{vmatrix}$$

$$D_j = \begin{vmatrix} Y_1 & Y_1^2 & \ldots & Y_1^{j-1} & X_1 & Y_1^{j+1} & \ldots & Y_1^n \\ Y_2 & Y_2^2 & \ldots & Y_2^{j-1} & X_2 & Y_2^{j+1} & \ldots & Y_2^n \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \ddots & \vdots \\ Y_n & Y_n^2 & \ldots & Y_n^{j+1} & X_n & Y_n^{j+1} & \ldots & Y_n^n \end{vmatrix}$$

At the beginning of the measurements, the acceleration x(t) is supplied to the input of the convertor **2** and its pulse are counted by the counter **4**. Periodically, from cycle to cycle, the code N_k^1 which is written in the pulse counter **4** where K is a number of cycle is written into the memory unit **6**. The arithmetic-logical unit determines the difference $N_k = N_k^1 - N_o$, where N_o is a code corresponding to the value of the zero reference signal. By dividing $N_k - N_{k-1}$ by β_1 the value ΔW—is determined which is an increment of speed value. After this the arithmetic unit calculates the values ΔW^2, ΔW^3 and adds them with the results of the previous calculations stored in the memory unit **6**. Therefore, the initial moments of indication Y of the input signal are determined:

$$M_1[y] = \frac{1}{t}\sum_{1}^{n} \Delta W_k; \quad M_2[y] = \frac{1}{t}\sum_{1}^{n} \Delta W_k^2; \ldots$$

Therefore, knowing the expected initial moments of input signal $M_1[y]$, $M_2[y]$, . . . are known, and the arithmetic logical unit calculates and rights in the memory unit **6** the expected initial moments of the input signal

$$M_1[x]=d_1M_1[y]+d_2M_2[y]+d_3M_3[y]+ \ldots$$

$$M_2[x]=d_1{}^2M_2[y]+\mathbf{2}d_1d_2M_3[y]+\mathbf{2}d_1d_3M_3[y]+ \ldots$$

$$M_3[x]=d_1{}^3M_3[y]+\mathbf{3}d_1{}^2d_2M_4[y]+\mathbf{3}d_1{}^2d_3M_5[y]+ \ldots$$

$$M_n[x]=d_1{}^nM_n[y]+nd_1{}^{n-1}d_2M_{n+1}[y]+nd_1{}^{n-1}d_3M_{n+2}[y]+$$

Since this and subsequent calculations require time, it is not possible to obtain the measured values of speed exactly at the time t=T. However, it is necessary for example in the case when upon reaching of the given speed a command for turning off of the rocket engine is given. Therefore, knowing the speed and its increment in "k" and some subsequent cycles, expected values in a subsequent "k+1" cycle are determined by extrapolation.

Knowing the initial moments $M_i[x]$, from the linear system of equation

$$\sum_{i=1}^{n} T_i \cdot X_i^m = T \cdot M_m[x]$$

where m=0,1,2 . . . n−1 and T is an expected time of measurements, T_i is determined by determinators

$$T_i = \frac{\Delta_i}{\Delta} \cdot T$$

$$\Delta = \begin{vmatrix} 1 & 1 & \ldots & 1 \\ X_1 & X_2 & \ldots & X_n \\ X_1^2 & X_2^2 & \ldots & X_n \\ X_1^n & X_2^n & \ldots & X_n^n \end{vmatrix}$$

$$\Delta_i = \begin{vmatrix} 1 & 1 & \ldots & 1 & 1 & 1 & \ldots & 1 \\ X_1 & X_2 & \ldots & X & M_1[x] & X_{i+1} & \ldots & X_n \\ X_1^2 & X_2^2 & \ldots & X_{i-1}^2 & M_2[x] & X_{i+1}^2 & \ldots & X_n^2 \\ X_1^n & X_2^n & \ldots & X_{i-1}^n & M_n[x] & X_{i+1}^n & \ldots & X_n^n \end{vmatrix}$$

By calculating the value of T_i, it is possible to find the value of speed expected in the time T

$$V(T) = \sum_{i=1}^{n} T_i \cdot X_i$$