

SIGNAL PROCESSING APPARATUS AND

DISPLACEMENT DETECTING APPARATUS USING THE SAME

BACKGROUND OF THE INVENTION5 Field of the Invention

This invention relates to a signal processing apparatus for generating an interpolation signal of resolution higher than the period of a periodic signal and a position detecting apparatus using the same, and
 10 more particularly to a signal interpolation apparatus using sine and cosine wave signals generated in conformity with displacement from an encoder or the like to obtain resolution higher than the period thereof, in other words, shorter than the fundamental
 15 period, and can be well applied particularly in the field of precise position measurement and precise position control.

Related Background Art

An example of the conventional art is shown in
 20 Figure 1 of the accompanying drawings. In Figure 1, sine and cosine wave signals generated in conformity with displacement from an encoder or the like are converted into a rectangular wave of a frequency higher than the fundamental period of the sine wave signal by
 25 the use of a phase digitizer 21 for quantizing the sine and cosine wave signals in conformity with the phase angles thereof. From this signal, a count up pulse and

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a count down pulse are produced by an up/down pulse output circuit 22, and these are integrated by an up/down counter circuit 23, whereby a positional signal is outputted. As the phase digitizer 21, use can be
 5 made of one having a construction as shown, for example, in Figure 2 of the accompanying drawings.

As another example of the prior art, the construction described in Japanese Laid-Open Patent Application No. 54-19773 is shown in Figure 3 of the
 10 accompanying drawings. In Figure 3, sine and cosine signals are first introduced as digital values into a microprocessor 34 by an A/D converter 31, the ratio between the values is found and the inverse tangent value thereof is calculated, and an interpolation
 15 process for finding the phase angle of the sine wave is carried out. Also, in parallel with this process, the sine and cosine signals are compared with 0V by a comparator 32 and are thereby converted into a rectangular wave, whereafter as in Figure 1, a count up
 20 pulse and a count down pulse are produced by an up/down pulse output circuit 33, and these are integrated by an up/down counter circuit 35, and the fundamental wave frequency of the sine wave signal is counted. These are synthesized by a microprocessor 34 to thereby
 25 obtain positional information.

In the conventional art shown in Figure 1, when particularly the interpolation number is great and



highly accurate position detection is to be effected,
the circuit scale of the phase digitizer becomes great
in proportion to the interpolation number. For
example, in the construction of Figure 2, the same
5 number of comparators as the interpolation number
becomes necessary and particularly, it is not realistic
to digitize to 1/100 or smaller. Even if this problem
is solved at all, the maximum response frequency of the
up/down counter in the post stage of the phase
10 digitizer is limited and therefore, it becomes
impossible to highly accurately find the position of an
object which is moving at a high speed.

The example of the prior art shown in Figure 3
intends to solve the above-noted problem to a certain
15 degree, and an interpolation portion and a fundamental
wave frequency counting portion are separated from each
other to thereby provide parallel constructions,
whereby even if the interpolation number is great, the
circuit construction can be made small and moreover,
20 the position of an object moving at a high speed can be
detected highly accurately.

In the construction of Figure 3, however, the A/D
converting portion and the phase digitizing portion
operate in parallel and therefore, their operations
25 must be executed completely in synchronism with each
other, and even when only slight shift in time has
occurred, there has been the possibility that mismatch



occurs to positioned information obtained from each portion. In such case, there is the possibility that positional information momentarily having a great error is outputted and for example, in a case where a servo system is constructed by the use of the detected positional information, momentarily great disturbance is applied to the servo system, and this has resulted in the possibility that a fatal problem such as the collision of a moving object arises. Further, when the sine wave signal has noise, a similar problem arises and it has been impossible to obviate this.

Also, it is ideal that the sine and cosine wave signals obtained from the encoder or the like have equal amplitudes, but the amplitudes often fluctuate depending on position. Particularly when highly accurate detection is necessary, such amplitude fluctuation makes accurate interpolation calculation impossible, for example, in a portion for finding inverse tangent and therefore, in the aforescribed cited example, there is proposed a method of correcting this in a software-like fashion by the microprocessor 34. However, particularly, amplitude correction generally involves multiplying and dividing processes and therefore, the load of the microprocessor applied thereto is great, and for example, when the same processor is used for the control calculation of the



servo system, this becomes an overhead and it becomes impossible to secure the control period short. It is possible to prepare a table or the like and curtail the amount of multiplication and division, but in such
 5 case, the greater is the interpolation number, the larger becomes the capacity of the table, and it becomes impossible to effectively utilize a memory.

SUMMARY OF THE INVENTION

10 In view of the above-noted disadvantage peculiar to the conventional art, it is an object of the present invention to provide a highly reliable signal processing apparatus, a position detecting apparatus and a driving device which can make a circuit
 15 construction small even if the interpolation number is great, and which can detect a periodic signal highly accurately and can further prevent the occurrence of an error resulting from the influences of the mismatch, noise, etc. of information.

20 It is a further object of the present invention to provide an apparatus which can easily correct any amplitude fluctuation without increasing the load of a processor or the like.

It is still a further object of the present
 25 invention to provide an apparatus which can confirm that the operation of a phase digitizer is normal.

One form of the signal processing apparatus of the



present invention for achieving the above objects is a
signal processing apparatus for processing first and
second periodic analog signals having the same period
and having a fixed phase relation therebetween,
5 characterized by digitizing means for converting the
first and second periodic analog signals into first and
second digital signals in conformity with the
respective amplitudes thereof, signal generating means
responsive to the first and second periodic analog
10 signals to generate a signal having a period shorter
than the period of the first periodic analog signal,
means for outputting the periodicity of the first
periodic analog signal and first phase information of
the first periodic analog signal from the signal from
15 the signal generating means and processing means for
producing second phase information of the first
periodic analog signal from the first and second
digital signals from the digitizing means, and
correcting the periodicity from the output means on the
20 basis of the first phase information and the second
phase information.

A preferred form of the resolution of the first
phase information is characterized in that it is lower
than that of the second phase information.

25 A preferred form of said processing means is
characterized by means for comparing the first phase
information and said second phase information with each

other.

A preferred form of said processing means is characterized by means for synthesizing said corrected periodicity and said second phase information.

5 Further, a preferred form of said signal processing apparatus is characterized by means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said first and second digital signals.

10 One form of the displacement detecting apparatus of the present invention is an apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object, having the same period and
15 having a fixed phase relation therebetween, characterized by:

digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective
20 amplitudes thereof, signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal, means for outputting the periodicity of the first periodic analog
25 signal and first phase information of first periodic analog signal from the signal from the signal generating means and processing means having means for



producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from said output means on the basis of the first phase information and the second phase information, and means for synthesizing said corrected periodicity and the second phase information and outputting the displacement information of an object.

10 A preferred form of the resolution of the first phase information is characterized in that it is lower than that of the second phase information.

 A preferred form of said processing means is characterized by means for comparing said first phase
15 information and the second phase information with each other.

 Further, a preferred form of the displacement detecting apparatus is characterized by means for adjusting the amplitudes of the first and second
20 periodic analog signals on the basis of said first and second digital signals.

 A preferred form of the processing means is characterized by means for detecting the monotonicity of the first phase information sequentially inputted.

25 The signal processing apparatus of the present invention and a displacement detecting apparatus using the same will hereinafter be described in detail with



respect to some embodiments thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Figure 1 is an illustration of an example of the prior art.

Figure 2 is an illustration of an example of the prior art.

Figure 3 is an illustration of an example of the prior art.

10 Figure 4 shows a first embodiment of the present invention.

Figure 5 is a chart illustrating the first embodiment of the present invention.

15 Figure 6 is a diagram illustrating a second embodiment of the present invention.

Figure 7 is a diagram illustrating a third embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 A first embodiment of the present invention is shown in Figure 4. In Figure 4, the reference numeral 1 designates an A/D converter with high resolution for converting an analog signal obtained from an encoder 5 and receiving as an input an analog signal varying in a
25 sine and cosine wave fashion for the displacement of an object into a digital signal. The A/D converter 1 is of resolution of 12 bits and attaches importance to



accuracy and resolution, and operates at a relatively low speed and does not respond to an input signal of a high frequency. The reference numeral 2 denotes a phase digitizer which, like the A/D converter 1, receives as inputs sine and cosine wave analog signals obtained from the encoder 5, but attaches importance to a high speed and is of low resolution. The phase digitizer 2 is of resolution of 3 bits, and the period of the output signal thereof is shorter than the period of the signal inputted thereto. The reference numeral 3 designates a high speed signal processing portion which has the output of the phase digitizer 2 as an input and outputs the periodicity of the sine wave signal, i.e., the number of the fundamental waves of the sine wave, and a logical signal which becomes 1 within a range of 0° to 180° of the phase of the sine wave and becomes 0 within a range of 180° to 360° . The reference numeral 4 denotes a signal processing portion for receiving the outputs of the A/D converter 1 and the high speed signal processing portion 3 and effecting the signal processing of producing final positional information. A digital signal processor (DSP) is used as the signal processing portion 4 to realize high speed processing. Also, an incremental type encoder is used as the encoder 5 which outputs sine and cosine waves in conformity with position.

The procedure of these operations will hereinafter



be described in succession.

The sine and cosine wave signals outputted from the encoder 5 are first inputted to the A/D converter 1 and are outputted as digital values SINX and COSX of 12 bits each. At the same time, these sine and cosine wave signals are inputted to the phase digitizer 2, which thus outputs digital data M of 3 bits which become 0 when the phase angle of the sine wave signal is 0 and which increases by 1 during each 1/8 of the period of the sine wave signal. That is, 360° of one period is divided into eight areas, and phase data digitized in the order of 0, 1, 2 counter-clockwisely from the first quadrant are allotted thereto. The high speed signal processing portion 3 receives this output M, and integrates +1 when M varies from 7 to 0, and integrates -1 when M varies from 0 to 7, and outputs the periodicity N of the obtained sine wave signal. At the same time, it outputs a logical signal PH which becomes 1 when M is within a range of 0 to 3, and becomes 0 when M is within a range of 4 to 7.

Such a construction in which the portion for counting the periodicity of the fundamental wave is endowed with redundancy to thereby obviate wrong counting caused by pulse noise or the like is a feature of the present invention.

In the DSP 4, by the use of SINX, COSX, N and PH obtained by the above-described procedure, positional



information is produced by a procedure shown in the flow chart of Figure 5. That, the phase angle ϕ of the sine wave signal is first calculated from SINX and COSX. This can be obtained by calculating the ratio

5 between the two values, and referring to an inverse tangent table prepared in advance by the use of the obtained value. Next, if ϕ exists in a range of 180° to 360° and moreover the logical signal PH from the high speed signal processing portion 3 is 0, that is,

10 indicates that it is 180° to 360° , it is judged that mismatch has occurred between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2. That is, the judgment standard is always considered to be the A/D converter 1 side and it

15 can be judged that the value N which ought to increase by 1 in the high speed signal processing portion 3 is not yet actually incremented and accordingly, in order to eliminate this mismatch, the correcting process of increasing N by 1 to thereby provide $N' = N + 1$ is

20 carried out within the DSP 4. If conversely to this case, ϕ exists in a range of 180° to 360° and moreover the logical signal PH from the high speed signal processing portion 3 is 1, that is, indicates that it is from 0° to 180° , it is judged that 1 more has been

25 integrated in the high speed signal processing portion, and N is subtracted by 1 to thereby provide $N' = N - 1$.



When these two conditions do not apply, there is no mismatch between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2 and therefore, the correction as described above is not necessary and $N' = N$ is provided. Thereafter, the obtained N' and the phase angle ϕ can be added to thereby obtain final positional information.

By providing the correcting means as described above, there can be constructed a highly accurate position detecting apparatus in which the mismatch between the data obtained from the signal processing portions provided in parallel can be prevented to thereby eliminate any momentary detection error and which is stable and moreover can cope with high speed motion.

A second embodiment of the present invention is shown in Figure 6. This embodiment is one which a multiplication type D/A converter 6 for correcting the amplitudes of the signals from the encoder 5 is added to the first embodiment shown in Figure 4.

This embodiment is similar in the basic processing procedure to the first embodiment, but in this embodiment, by the utilization of the fact that the digital data obtained from the A/D converter 1 are always introduced into the DSP 4, the maximum values and minimum values of the A/D converted data $SINX$ and



COSX of the sine and cosine wave signals are held within the DSP 4. Further, each time the signals from the encoder 5 are A/D-converted, these maximum values and minimum values are successively renewed to thereby hold optimum maximum and minimum values at all times. The amplitudes of the sine wave and cosine wave signals are then calculated and a correction signal is outputted to the multiplication type D/A converter 6 so that they become equal to each other, whereby the data are set and the correction of the amplitudes of the signals from the encoder 5 is effected.

By providing such gain correcting means, any error included in the phase angle data ϕ due to the unbalance of the gain can be eliminated to thereby enhance the linearity thereof particularly when the calculation for finding the inverse tangent shown in the flow chart of Figure 5 is effected. The signals from the encoder 5 can also be set to as great as possible amplitudes in the A/D converter 1 and phase digitizer 2 in conformity with their maximum input voltages and therefore, the influence of a quantization error occurring when the signals from the encoder 5 become small can be minimized. When the input voltage widths of the A/D converter 1 and phase digitizer 2 differ from each other, multiplication type D/A converters can be prepared discretely or the signals can be suitably attenuated after they have passed through the D/A



converter 6.

Further, a digital filter is prepared within the DSP 4 and high frequency noise which may be included in the signals from the encoder 5 is attenuated to a sufficiently negligible level by filter calculation. Since the digital filter processing by software is possible, there can be provided a filter having a desired cut-off/phase characteristic, such as an FIR filter of linear phase.

In the above-described embodiment, a phase digitizer of at least 1 bit is used with the portion for counting the periodicity of the fundamental wave to give redundancy, thereby improving resistance to disturbance. Also, provision is made of a variable gain amplifier positively utilizing the phase information obtained in the phase digitizer portion to effect correction or error detection when the information obtained on the interpolation side and the periodicity of the fundamental wave are synthesized, and further correcting the amplitudes of the sine and cosine wave signals.

As a third embodiment of the present invention, there is shown the construction of Figure 7 in which an electromagnetic motor 7 and a motor driver 8 are added as an actuator to the construction of Figure 6 to thereby provide a positioning servo system. The angle of the motor is highly accurately detected by the



procedure shown in the above-described embodiment to thereby construct such a control system that this coincides with a desired target position. Control calculation constituting an appropriate compensator on the basis of the detected angle data is effected within the DSP 4 and a current reference value to the motor obtained as a result is given to the motor driver 8, whereby the highly accurate positioning of the motor becomes possible.

At this time, the redundancy realized by the phase digitizer 2 is utilized more positively. That is, a logical signal ERR which becomes U as long as the phase-digitized value M increases by 1 each or decreases by 1 each and which becomes 1 when M varies to 2 or greater at a time, that is, when the monotonicity of M becomes null is generated by the high speed signal processing portion and is introduced into the DSP 4. When the logical signal ERR has become 1, it is judged that some sudden disturbance has been inputted from a mechanical system, and for example, the output current of the driver 8 is rendered 0 to thereby once stop the servo operation, thus informing the operator that abnormality has happened. Thereby, a problem that the servo system is destroyed by an abnormal operation due to a great detection error, disturbance or the like can be obviated, and a highly reliable servo system can be constructed.





11 22 33 44 55 66 77 88 99 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The above-described embodiments are thereby to be considered in all

5 respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be
10 embraced therein.

This specification discloses a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween and having digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.



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WHAT IS CLAIMED IS:

1. A signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation

5 therebetween, comprising:

digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof;

10 signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal;

means for outputting the periodicity of said first periodic analog signal and first phase information of said first periodic analog signal from the signal from said signal generating means; and

15 processing means for producing second phase information of said first periodic analog signal from said first and second digital signals from said digitizing means, and correcting the periodicity from said output means on the basis of said first phase information and said second phase information.

25 2. The apparatus of Claim 1, wherein the resolution of said first phase information is lower than that of said second phase information.



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periodic analog signal;

means for outputting the periodicity of said first
periodic analog signal and first phase information of
said first periodic analog signal from the signal from
5 said signal generating means; and

processing means having means for producing second
phase information of said first periodic analog signal
from said first and second digital signals from said
digitizing means, and correcting the periodicity from
10 said output means on the basis of said first phase
information and said second phase information, and
means for synthesizing said corrected periodicity and
said second phase information and outputting the
displacement information of the object.

15

7. The apparatus of Claim 6, wherein the
resolution of said first phase information is lower
than that of said second phase information.

20

8. The apparatus of Claim 6, wherein said
processing means has means for comparing said first
phase information and said second phase information
with each other.

25

9. The apparatus of Claim 6, further comprising
means for adjusting the amplitudes of said first and
second periodic analog signals on the basis of said





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first and second digital signals.

10. The apparatus of Claim 6, wherein said processing means has means for detecting the
5 monotonicity of said first phase information sequentially inputted.



ABSTRACT OF THE DISCLOSURE

This specification discloses a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween and having digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.





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FIG. 1

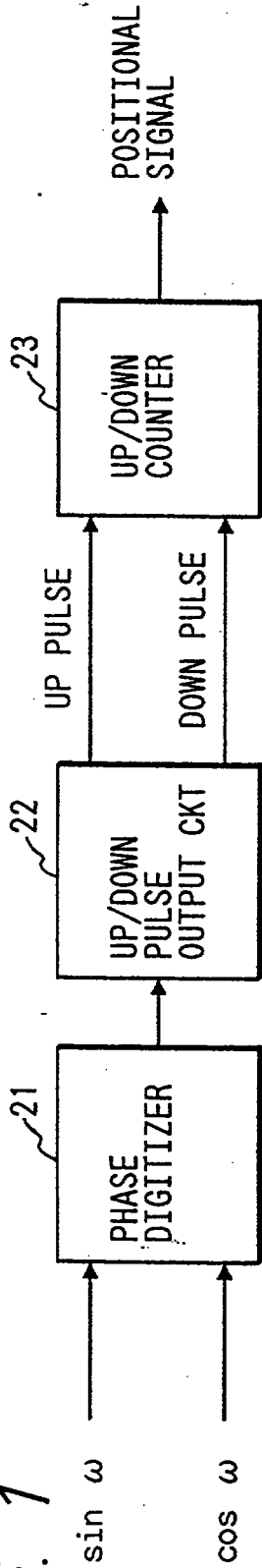
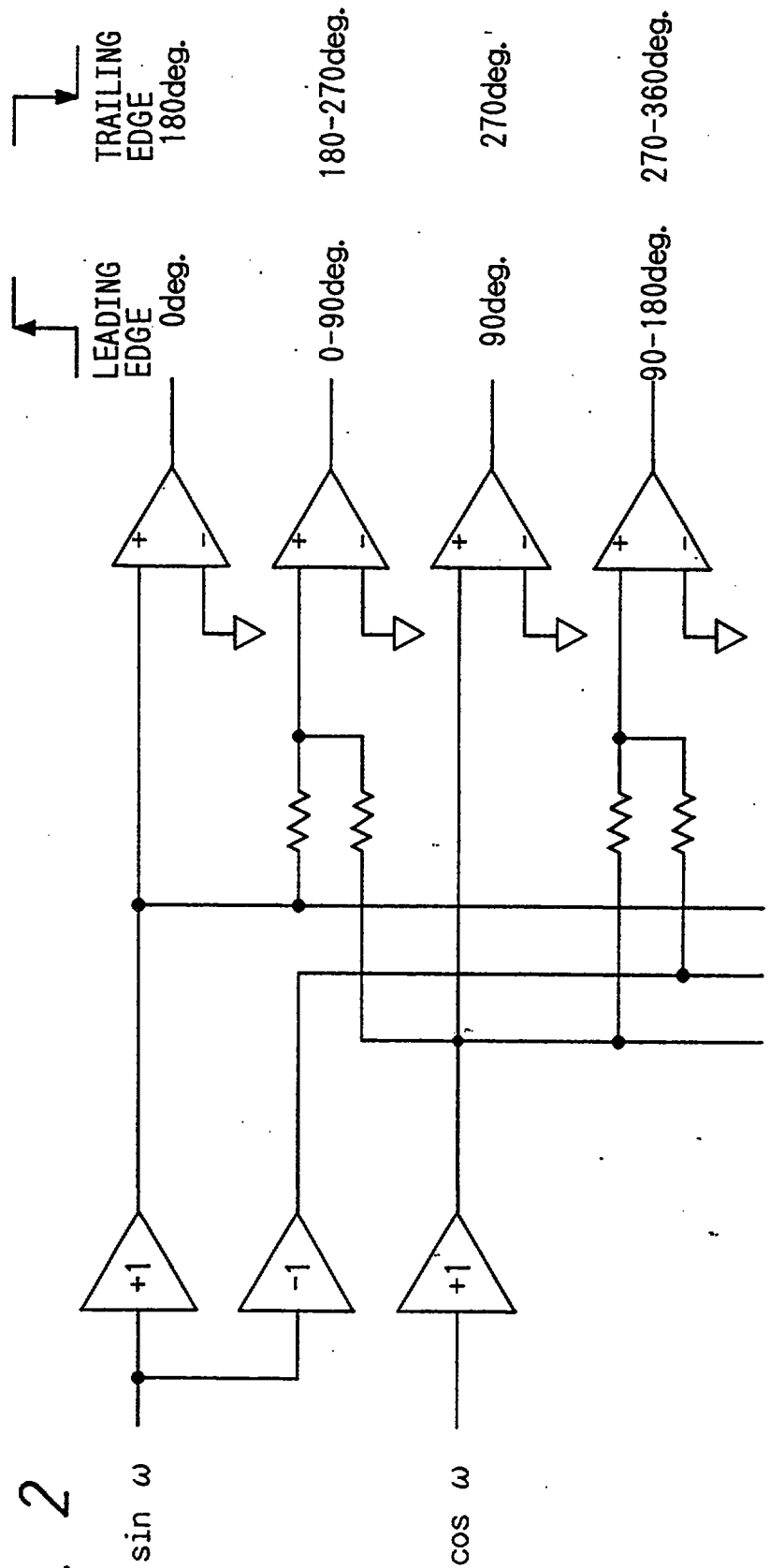


FIG. 2



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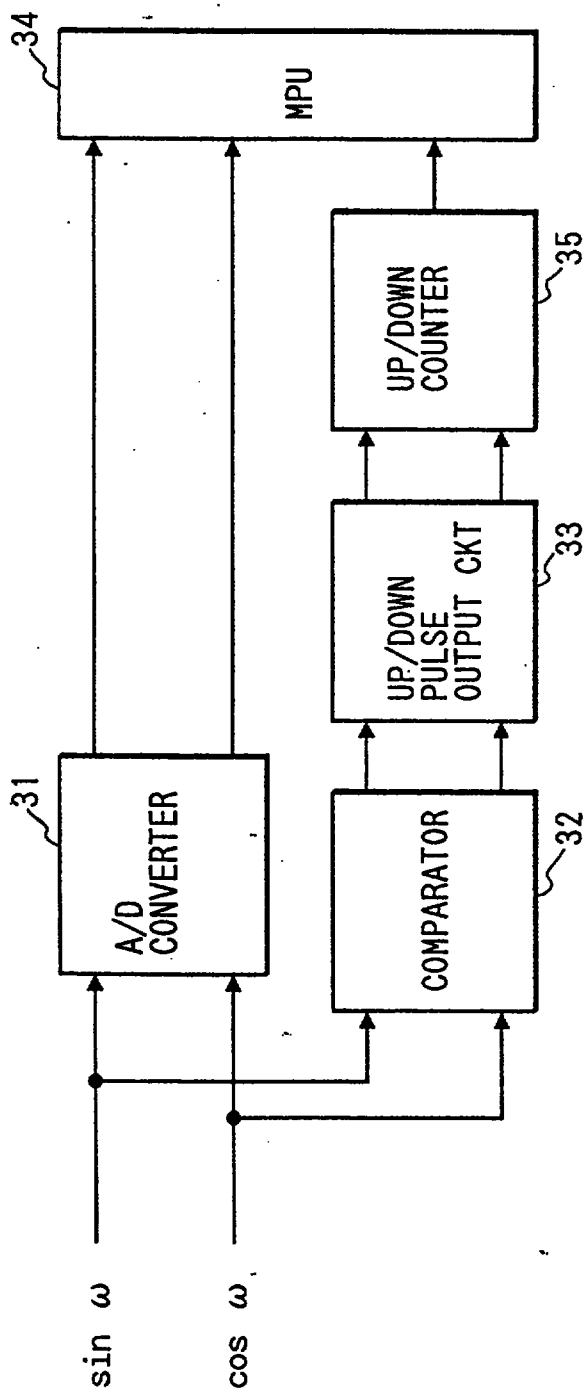


FIG. 3

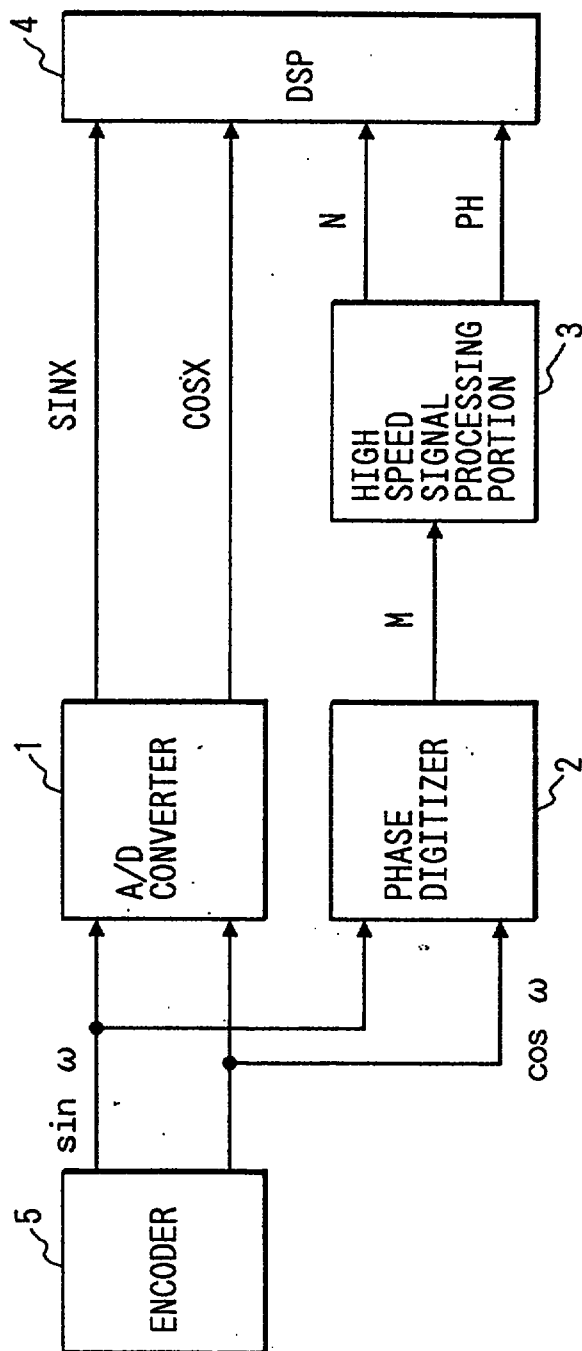


FIG. 4



FIG. 5

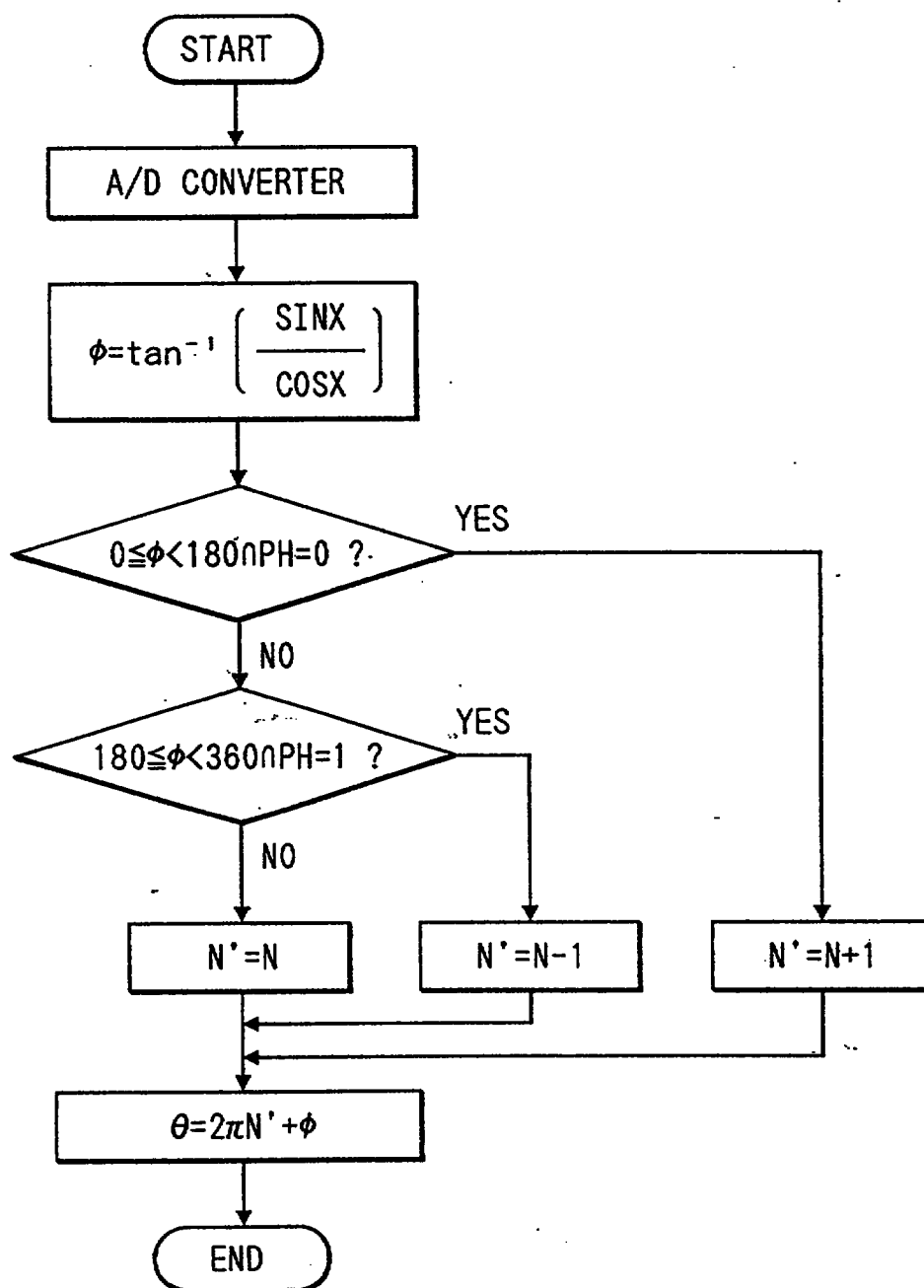


FIG. 6

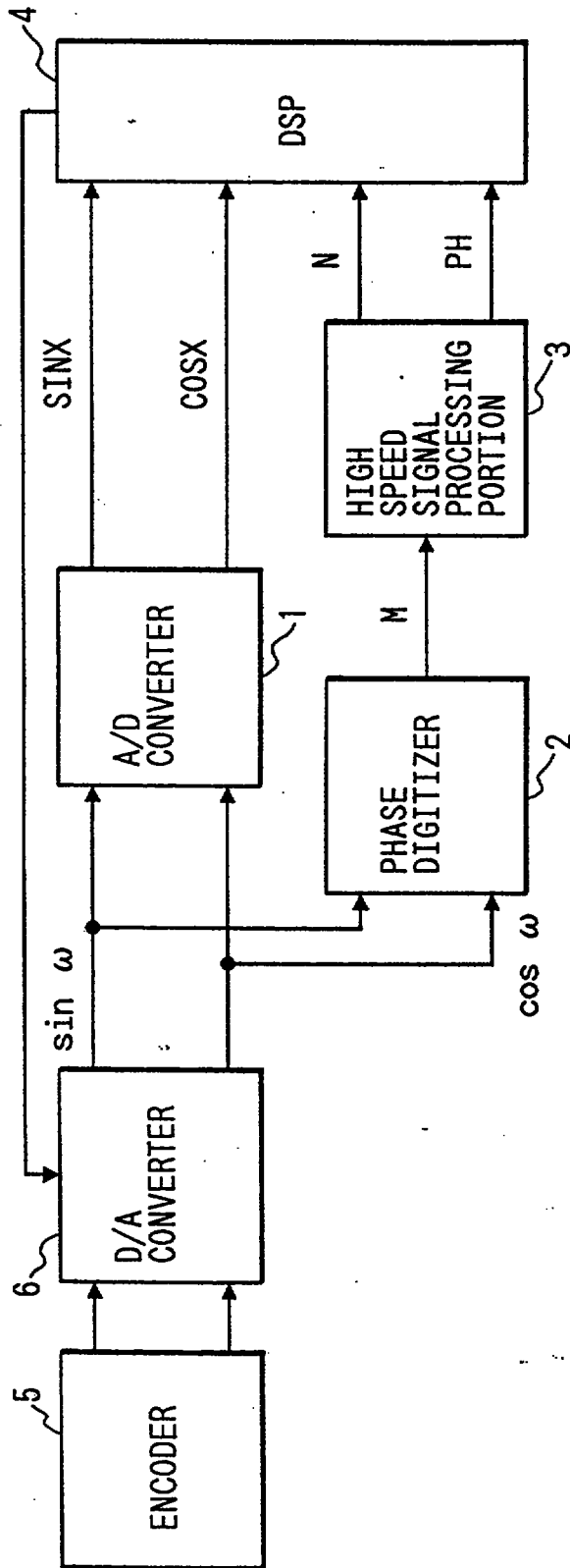
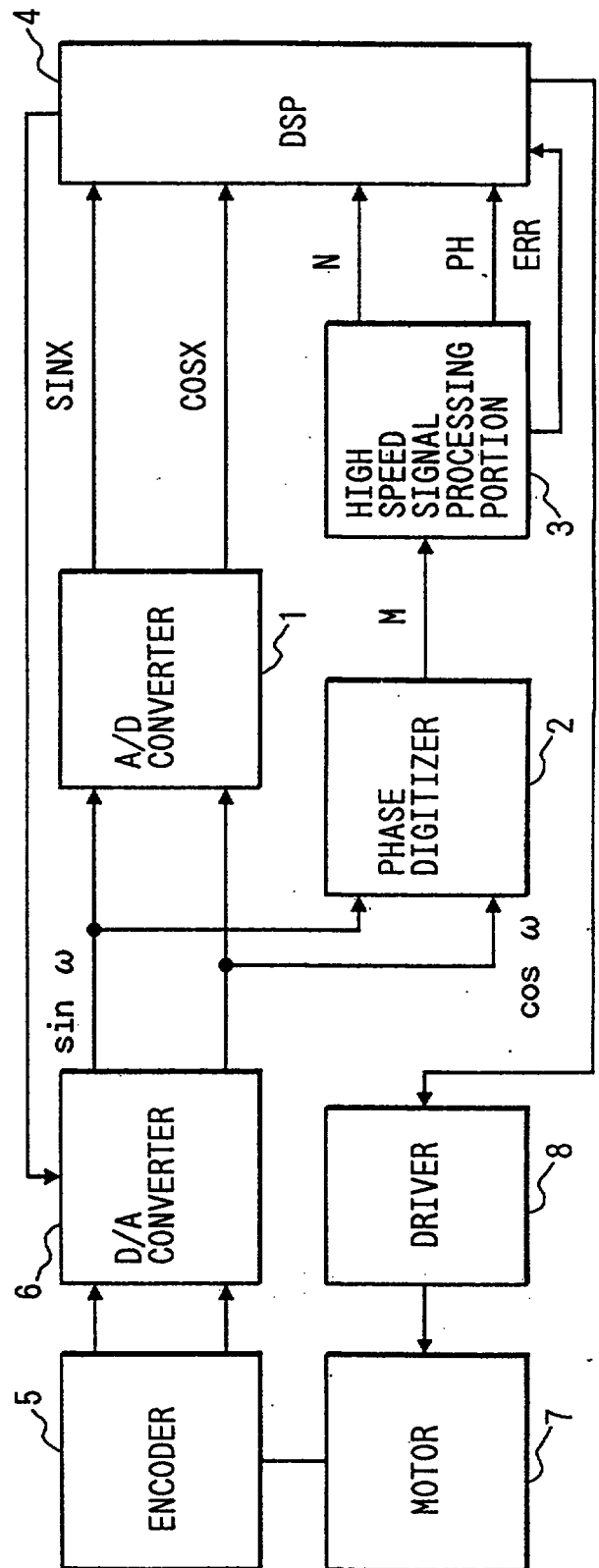


FIG. 7



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SIGNAL PROCESSING APPARATUS AND

DISPLACEMENT DETECTING APPARATUS USING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a signal processing apparatus for generating an interpolation signal of resolution higher than the period of a periodic signal and a position detecting apparatus using the same, and more particularly to a signal interpolation apparatus using sine and cosine wave signals generated in conformity with displacement from an encoder or the like to obtain resolution higher than the period thereof, in other words, shorter than the fundamental period, and can be well applied particularly in the field of precise position measurement and precise position control.

Related Background Art

An example of the conventional art is shown in Figure 1 of the accompanying drawings. In Figure 1, sine and cosine wave signals generated in conformity with displacement from an encoder or the like are converted into a rectangular wave of a frequency higher than the fundamental period of the sine wave signal by the use of a phase digitizer 21 for quantizing the sine and cosine wave signals in conformity with the phase angles thereof. From this signal, a count up pulse and

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a count down pulse are produced by an up/down pulse output circuit 22, and these are integrated by an up/down counter circuit 23, whereby a positional signal is outputted. As the phase digitizer 21, use can be made of one having a construction as shown, for example, in Figure 2 of the accompanying drawings.

As another example of the prior art, the construction described in Japanese Laid-Open Patent Application No. 54-19773 is shown in Figure 3 of the accompanying drawings. In Figure 3, sine and cosine signals are first introduced as digital values into a microprocessor 34 by an A/D converter 31, the ratio between the values is found and the inverse tangent value thereof is calculated, and an interpolation process for finding the phase angle of the sine wave is carried out. Also, in parallel with this process, the sine and cosine signals are compared with 0V by a comparator 32 and are thereby converted into a rectangular wave, whereafter as in Figure 1, a count up pulse and a count down pulse are produced by an up/down pulse output circuit 33, and these are integrated by an up/down counter circuit 35, and the fundamental wave frequency of the sine wave signal is counted. These are synthesized by a microprocessor 34 to thereby obtain positional information.

In the conventional art shown in Figure 1, when particularly the interpolation number is great and

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highly accurate position detection is to be effected, the circuit scale of the phase digitizer becomes great in proportion to the interpolation number. For example, in the construction of Figure 2, the same number of comparators as the interpolation number becomes necessary and particularly, it is not realistic to digitize to 1/100 or smaller. Even if this problem is solved at all, the maximum response frequency of the up/down counter in the post stage of the phase digitizer is limited and therefore, it becomes impossible to highly accurately find the position of an object which is moving at a high speed.

The example of the prior art shown in Figure 3 intends to solve the above-noted problem to a certain degree, and an interpolation portion and a fundamental wave frequency counting portion are separated from each other to thereby provide parallel constructions, whereby even if the interpolation number is great, the circuit construction can be made small and moreover, the position of an object moving at a high speed can be detected highly accurately.

In the construction of Figure 3, however, the A/D converting portion and the phase digitizing portion operate in parallel and therefore, their operations must be executed completely in synchronism with each other, and even when only slight shift in time has occurred, there has been the possibility that mismatch



occurs to positioned information obtained from each portion. In such case, there is the possibility that positional information momentarily having a great error is outputted and for example, in a case where a servo system is constructed by the use of the detected positional information, momentarily great disturbance is applied to the servo system, and this has resulted in the possibility that a fatal problem such as the collision of a moving object arises. Further, when the sine wave signal has noise, a similar problem arises and it has been impossible to obviate this.

Also, it is ideal that the sine and cosine wave signals obtained from the encoder or the like have equal amplitudes, but the amplitudes often fluctuate depending on position. Particularly when highly accurate detection is necessary, such amplitude fluctuation makes accurate interpolation calculation impossible, for example, in a portion for finding inverse tangent and therefore, in the aforescribed cited example, there is proposed a method of correcting this in a software-like fashion by the microprocessor 34. However, particularly, amplitude correction generally involves multiplying and dividing processes and therefore, the load of the microprocessor applied thereto is great, and for example, when the same processor is used for the control calculation of the

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servo system, this becomes an overhead and it becomes impossible to secure the control period short. It is possible to prepare a table or the like and curtail the amount of multiplication and division, but in such case, the greater is the interpolation number, the larger becomes the capacity of the table, and it becomes impossible to effectively utilize a memory.

SUMMARY OF THE INVENTION

In view of the above-noted disadvantage peculiar to the conventional art, it is an object of the present invention to provide a highly reliable signal processing apparatus, a position detecting apparatus and a driving device which can make a circuit construction small even if the interpolation number is great, and which can detect a periodic signal highly accurately and can further prevent the occurrence of an error resulting from the influences of the mismatch, noise, etc. of information.

It is a further object of the present invention to provide an apparatus which can easily correct any amplitude fluctuation without increasing the load of a processor or the like.

It is still a further object of the present invention to provide an apparatus which can confirm that the operation of a phase digitizer is normal.

One form of the signal processing apparatus of the



present invention for achieving the above objects is a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween, characterized by digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.

A preferred form of the resolution of the first phase information is characterized in that it is lower than that of the second phase information.

A preferred form of said processing means is characterized by means for comparing the first phase information and said second phase information with each

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other.

A preferred form of said processing means is characterized by means for synthesizing said corrected periodicity and said second phase information.

Further, a preferred form of said signal processing apparatus is characterized by means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said first and second digital signals.

One form of the displacement detecting apparatus of the present invention is an apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object, having the same period and having a fixed phase relation therebetween, characterized by:

digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of first periodic analog signal from the signal from the signal generating means and processing means having means for

producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from said output means on the basis of the first phase information and the second phase information, and means for synthesizing said corrected periodicity and the second phase information and outputting the displacement information of an object.

A preferred form of the resolution of the first phase information is characterized in that it is lower than that of the second phase information.

A preferred form of said processing means is characterized by means for comparing said first phase information and the second phase information with each other.

Further, a preferred form of the displacement detecting apparatus is characterized by means for adjusting the amplitudes of the first and second periodic analog signals on the basis of said first and second digital signals.

A preferred form of the processing means is characterized by means for detecting the monotonicity of the first phase information sequentially inputted.

The signal processing apparatus of the present invention and a displacement detecting apparatus using the same will hereinafter be described in detail with

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respect to some embodiments thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of an example of the prior art.

Figure 2 is an illustration of an example of the prior art.

Figure 3 is an illustration of an example of the prior art.

Figure 4 shows a first embodiment of the present invention.

Figure 5 is a chart illustrating the first embodiment of the present invention.

Figure 6 is a diagram illustrating a second embodiment of the present invention.

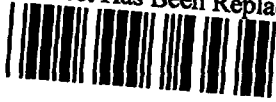
Figure 7 is a diagram illustrating a third embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention is shown in Figure 4. In Figure 4, the reference numeral 1 designates an A/D converter with high resolution for converting an analog signal obtained from an encoder 5 and receiving as an input an analog signal varying in a sine and cosine wave fashion for the displacement of an object into a digital signal. The A/D converter 1 is of resolution of 12 bits and attaches importance to

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accuracy and resolution, and operates at a relatively low speed and does not respond to an input signal of a high frequency. The reference numeral 2 denotes a phase digitizer which, like the A/D converter 1, receives as inputs sine and cosine wave analog signals obtained from the encoder 5, but attaches importance to a high speed and is of low resolution. The phase digitizer 2 is of resolution of 3 bits, and the period of the output signal thereof is shorter than the period of the signal inputted thereto. The reference numeral 3 designates a high speed signal processing portion which has the output of the phase digitizer 2 as an input and outputs the periodicity of the sine wave signal, i.e., the number of the fundamental waves of the sine wave, and a logical signal which becomes 1 within a range of 0° to 180° of the phase of the sine wave and becomes 0 within a range of 180° to 360° . The reference numeral 4 denotes a signal processing portion for receiving the outputs of the A/D converter 1 and the high speed signal processing portion 3 and effecting the signal processing of producing final positional information. A digital signal processor (DSP) is used as the signal processing portion 4 to realize high speed processing. Also, an incremental type encoder is used as the encoder 5 which outputs sine and cosine waves in conformity with position.

The procedure of these operations will hereinafter

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be described in succession.

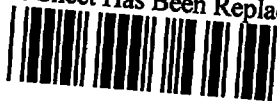
The sine and cosine wave signals outputted from the encoder 5 are first inputted to the A/D converter 1 and are outputted as digital values SINX and COSX of 12 bits each. At the same time, these sine and cosine wave signals are inputted to the phase digitizer 2, which thus outputs digital data M of 3 bits which become 0 when the phase angle of the sine wave signal is 0 and which increases by 1 during each $1/8$ of the period of the sine wave signal. That is, 360° of one period is divided into eight areas, and phase data digitized in the order of 0, 1, 2 counter-clockwisely from the first quadrant are allotted thereto. The high speed signal processing portion 3 receives this output M, and integrates +1 when M varies from 7 to 0, and integrates -1 when M varies from 0 to 7, and outputs the periodicity N of the obtained sine wave signal. At the same time, it outputs a logical signal PH which becomes 1 when M is within a range of 0 to 3, and becomes 0 when M is within a range of 4 to 7.

Such a construction in which the portion for counting the periodicity of the fundamental wave is endowed with redundancy to thereby obviate wrong counting caused by pulse noise or the like is a feature of the present invention.

In the DSP 4, by the use of SINX, COSX, N and PH obtained by the above-described procedure, positional

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information is produced by a procedure shown in the flow chart of Figure 5. That, the phase angle ϕ of the sine wave signal is first calculated from SINX and COSX. This can be obtained by calculating the ratio between the two values, and referring to an inverse tangent table prepared in advance by the use of the obtained value. Next, if ϕ exists in a range of 180° to 360° and moreover the logical signal PH from the high speed signal processing portion 3 is 0, that is, indicates that it is 180° to 360° , it is judged that mismatch has occurred between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2. That is, the judgment standard is always considered to be the A/D converter 1 side and it can be judged that the value N which ought to increase by 1 in the high speed signal processing portion 3 is not yet actually incremented and accordingly, in order to eliminate this mismatch, the correcting process of increasing N by 1 to thereby provide $N' = N + 1$ is carried out within the DSP 4. If conversely to this case, ϕ exists in a range of 180° to 360° and moreover the logical signal PH from the high speed signal processing portion 3 is 1, that is, indicates that it is from 0° to 180° , it is judged that 1 more has been integrated in the high speed signal processing portion, and N is subtracted by 1 to thereby provide $N' = N - 1$.

When these two conditions do not apply, there is no mismatch between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2 and therefore, the correction as described above is not necessary and $N' = N$ is provided. Thereafter, the obtained N' and the phase angle ϕ can be added to thereby obtain final positional information.

By providing the correcting means as described above, there can be constructed a highly accurate position detecting apparatus in which the mismatch between the data obtained from the signal processing portions provided in parallel can be prevented to thereby eliminate any momentary detection error and which is stable and moreover can cope with high speed motion.

A second embodiment of the present invention is shown in Figure 6. This embodiment is one which a multiplication type D/A converter 6 for correcting the amplitudes of the signals from the encoder 5 is added to the first embodiment shown in Figure 4.

This embodiment is similar in the basic processing procedure to the first embodiment, but in this embodiment, by the utilization of the fact that the digital data obtained from the A/D converter 1 are always introduced into the DSP 4, the maximum values and minimum values of the A/D converted data $SINX$ and



COSX of the sine and cosine wave signals are held within the DSP 4. Further, each time the signals from the encoder 5 are A/D-converted, these maximum values and minimum values are successively renewed to thereby hold optimum maximum and minimum values at all times. The amplitudes of the sine wave and cosine wave signals are then calculated and a correction signal is outputted to the multiplication type D/A converter 6 so that they become equal to each other, whereby the data are set and the correction of the amplitudes of the signals from the encoder 5 is effected.

By providing such gain correcting means, any error included in the phase angle data ϕ due to the unbalance of the gain can be eliminated to thereby enhance the linearity thereof particularly when the calculation for finding the inverse tangent shown in the flow chart of Figure 5 is effected. The signals from the encoder 5 can also be set to as great as possible amplitudes in the A/D converter 1 and phase digitizer 2 in conformity with their maximum input voltages and therefore, the influence of a quantization error occurring when the signals from the encoder 5 become small can be minimized. When the input voltage widths of the A/D converter 1 and phase digitizer 2 differ from each other, multiplication type D/A converters can be prepared discretely or the signals can be suitably attenuated after they have passed through the D/A



converter 6.

Further, a digital filter is prepared within the DSP 4 and high frequency noise which may be included in the signals from the encoder 5 is attenuated to a sufficiently negligible level by filter calculation. Since the digital filter processing by software is possible, there can be provided a filter having a desired cut-off/phase characteristic, such as an FIR filter of linear phase.

In the above-described embodiment, a phase digitizer of at least 1 bit is used with the portion for counting the periodicity of the fundamental wave to give redundancy, thereby improving resistance to disturbance. Also, provision is made of a variable gain amplifier positively utilizing the phase information obtained in the phase digitizer portion to effect correction or error detection when the information obtained on the interpolation side and the periodicity of the fundamental wave are synthesized, and further correcting the amplitudes of the sine and cosine wave signals.

As a third embodiment of the present invention, there is shown the construction of Figure 7 in which an electromagnetic motor 7 and a motor driver 8 are added as an actuator to the construction of Figure 6 to thereby provide a positioning servo system. The angle of the motor is highly accurately detected by the



procedure shown in the above-described embodiment to thereby construct such a control system that this coincides with a desired target position. Control calculation constituting an appropriate compensator on the basis of the detected angle data is effected within the DSP 4 and a current reference value to the motor obtained as a result is given to the motor driver 8, whereby the highly accurate positioning of the motor becomes possible.

At this time, the redundancy realized by the phase digitizer 2 is utilized more positively. That is, a logical signal ERR which becomes U as long as the phase-digitized value M increases by 1 each or decreases by 1 each and which becomes 1 when M varies to 2 or greater at a time, that is, when the monotonicity of M becomes null is generated by the high speed signal processing portion and is introduced into the DSP 4. When the logical signal ERR has become 1, it is judged that some sudden disturbance has been inputted from a mechanical system, and for example, the output current of the driver 8 is rendered 0 to thereby once stop the servo operation, thus informing the operator that abnormality has happened. Thereby, a problem that the servo system is destroyed by an abnormal operation due to a great detection error, disturbance or the like can be obviated, and a highly reliable servo system can be constructed.

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The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The above-described embodiments are thereby to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

This specification discloses a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween and having digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.

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WHAT IS CLAIMED IS:

1. A signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween, comprising:

digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof;

signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first periodic analog signal;

means for outputting the periodicity of said first periodic analog signal and first phase information of said first periodic analog signal from the signal from said signal generating means; and

processing means for producing second phase information of said first periodic analog signal from said first and second digital signals from said digitizing means, and correcting the periodicity from said output means on the basis of said first phase information and said second phase information.

2. The apparatus of Claim 1, wherein the resolution of said first phase information is lower than that of said second phase information.



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3. The apparatus of Claim 1, wherein said processing means has means for comparing said first phase information and said second phase information with each other.

4. The apparatus of Claim 1, wherein said processing means has means for synthesizing said corrected periodicity and said second phase information.

5. The apparatus of Claim 1, further comprising means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said first and second digital signals.

6. An apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object, having the same period and having a fixed phase relation therebetween, having:

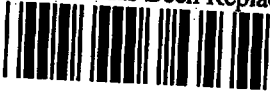
digitizing means for converting said first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof;

signal generating means responsive to said first and second periodic analog signals to generate a signal having a period shorter than the period of said first

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periodic analog signal;

means for outputting the periodicity of said first periodic analog signal and first phase information of said first periodic analog signal from the signal from said signal generating means; and

processing means having means for producing second phase information of said first periodic analog signal from said first and second digital signals from said digitizing means, and correcting the periodicity from said output means on the basis of said first phase information and said second phase information, and means for synthesizing said corrected periodicity and said second phase information and outputting the displacement information of the object.

7. The apparatus of Claim 6, wherein the resolution of said first phase information is lower than that of said second phase information.

8. The apparatus of Claim 6, wherein said processing means has means for comparing said first phase information and said second phase information with each other.

9. The apparatus of Claim 6, further comprising means for adjusting the amplitudes of said first and second periodic analog signals on the basis of said

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first and second digital signals.

10. The apparatus of Claim 6, wherein said processing means has means for detecting the monotonicity of said first phase information sequentially inputted.



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SIGNAL PROCESSING APPARATUS AND DISPLACEMENT
DETECTING APPARATUS USING THE SAME

ABSTRACT OF THE DISCLOSURE

This specification discloses a signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relation therebetween and having digitizing means for converting the first and second periodic analog signals into first and second digital signals in conformity with the respective amplitudes thereof, signal generating means responsive to the first and second periodic analog signals to generate a signal having a period shorter than the period of the first periodic analog signal, means for outputting the periodicity of the first periodic analog signal and first phase information of the first periodic analog signal from the signal from the signal generating means and processing means for producing second phase information of the first periodic analog signal from the first and second digital signals from the digitizing means, and correcting the periodicity from the output means on the basis of the first phase information and the second phase information.

FIGURE 4

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FIG. 1

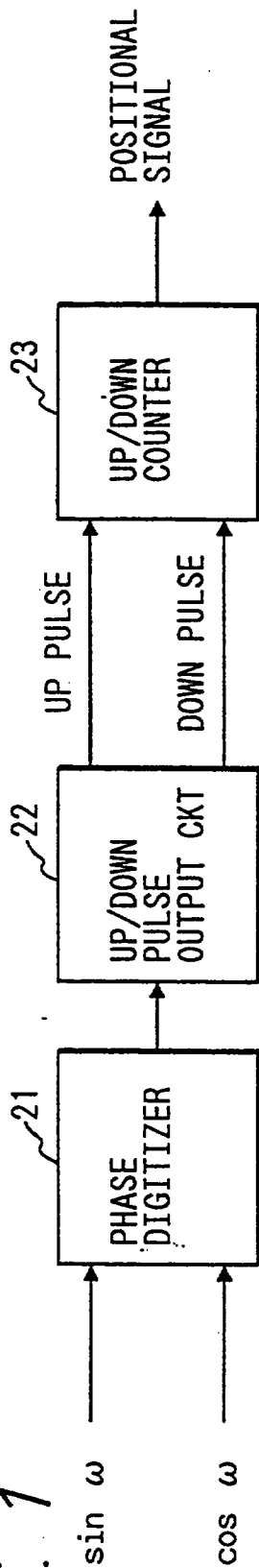
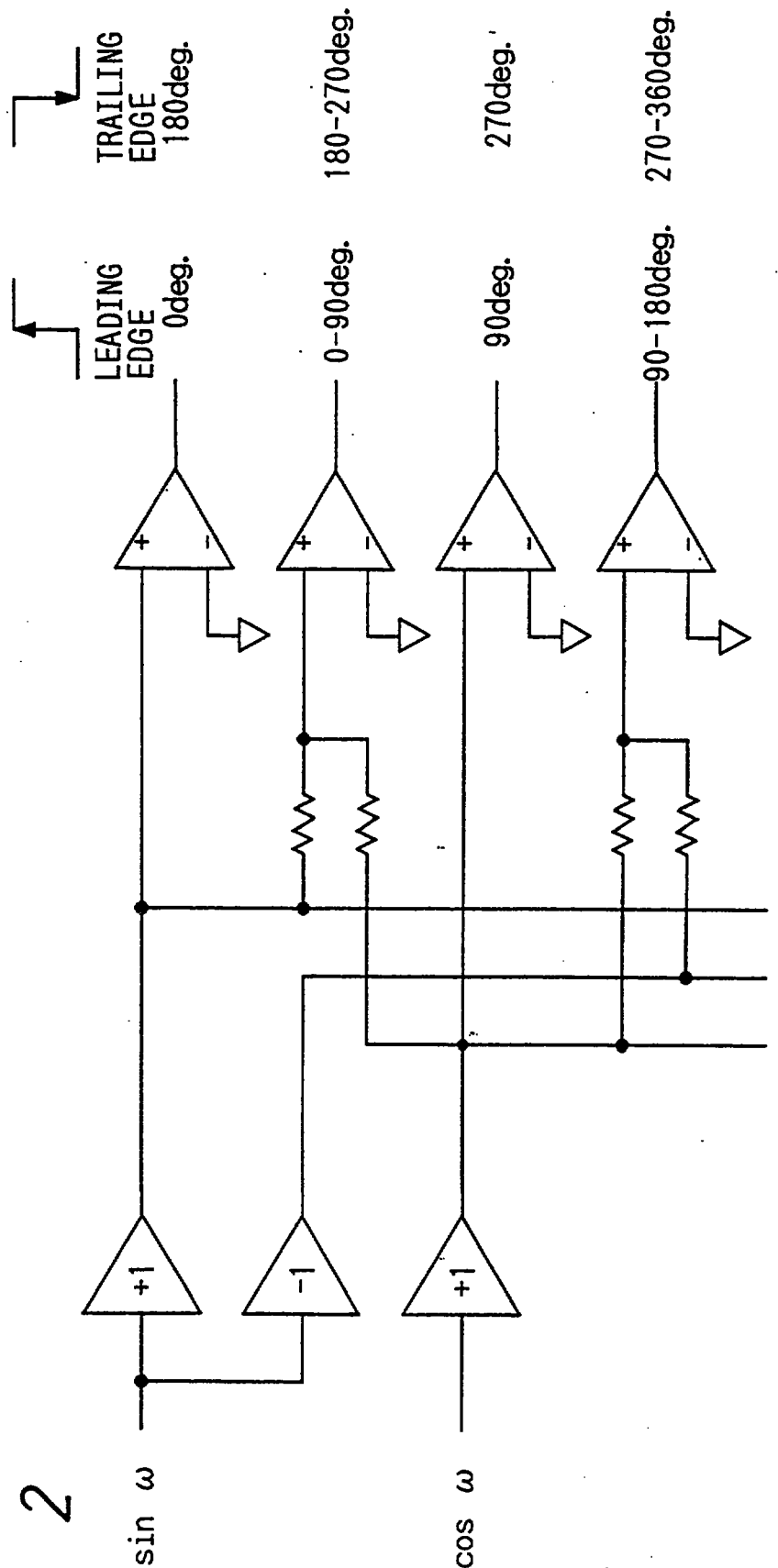


FIG. 2



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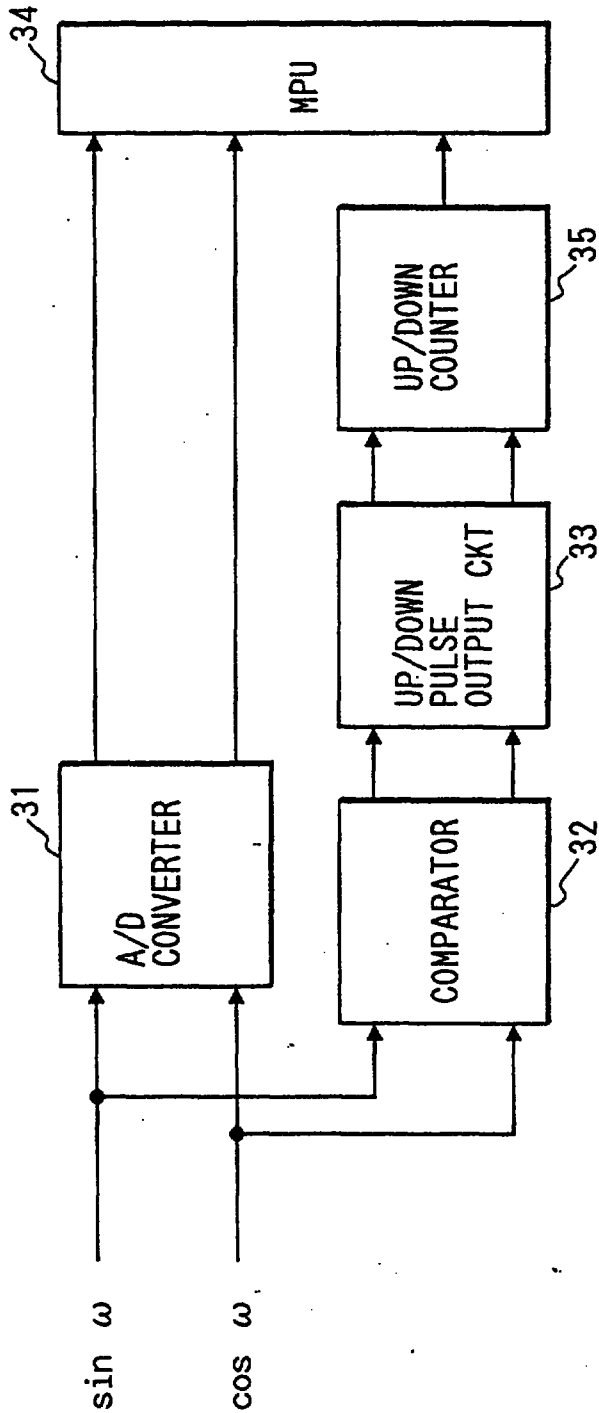


FIG. 3

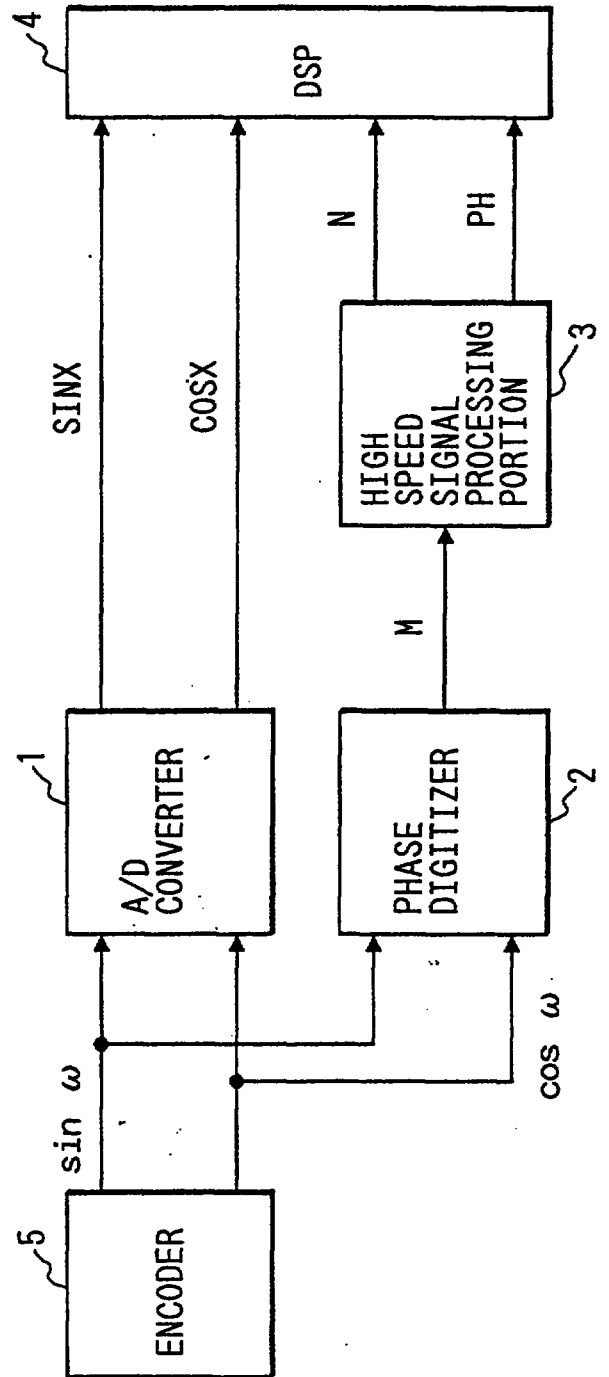
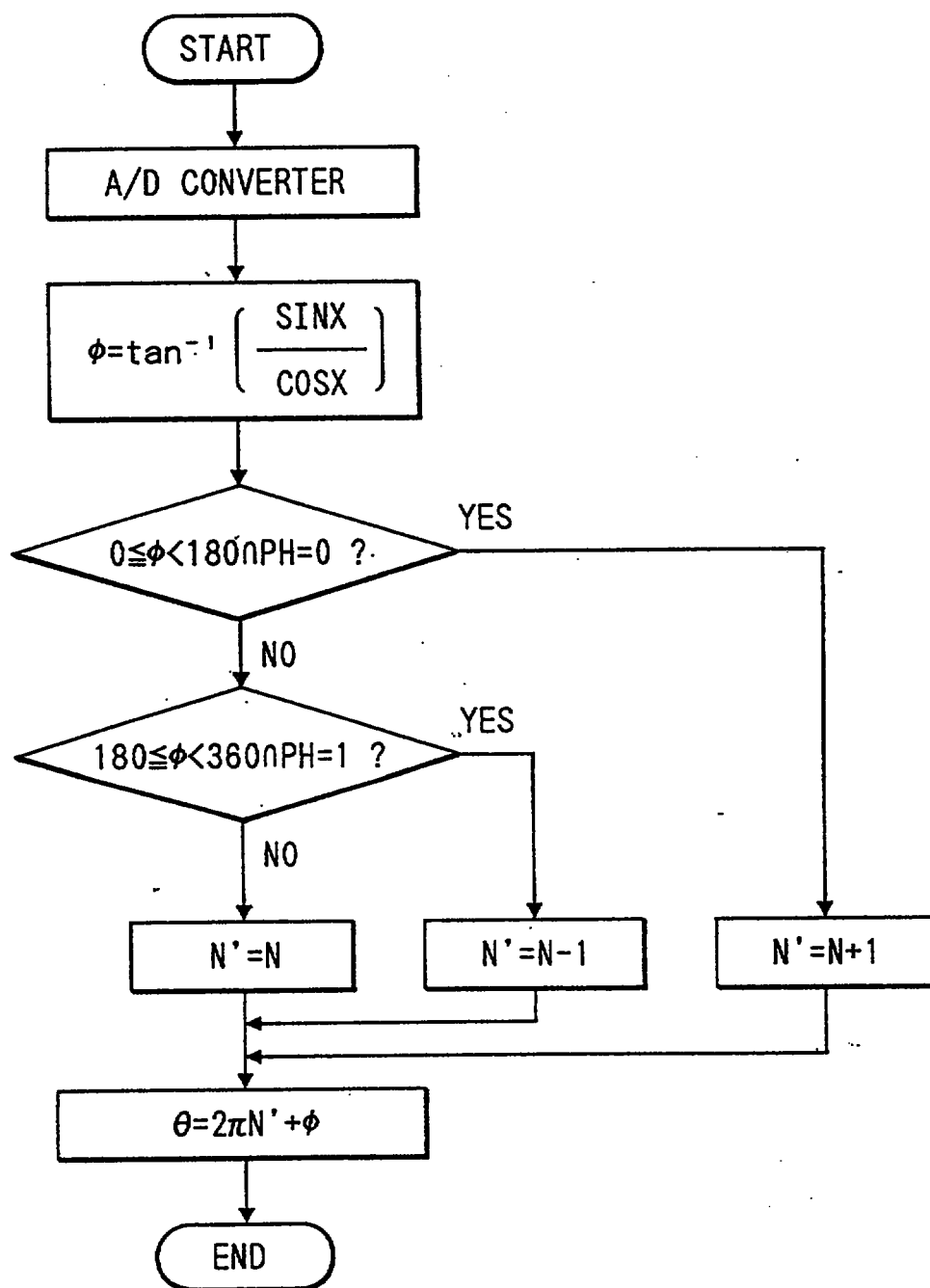


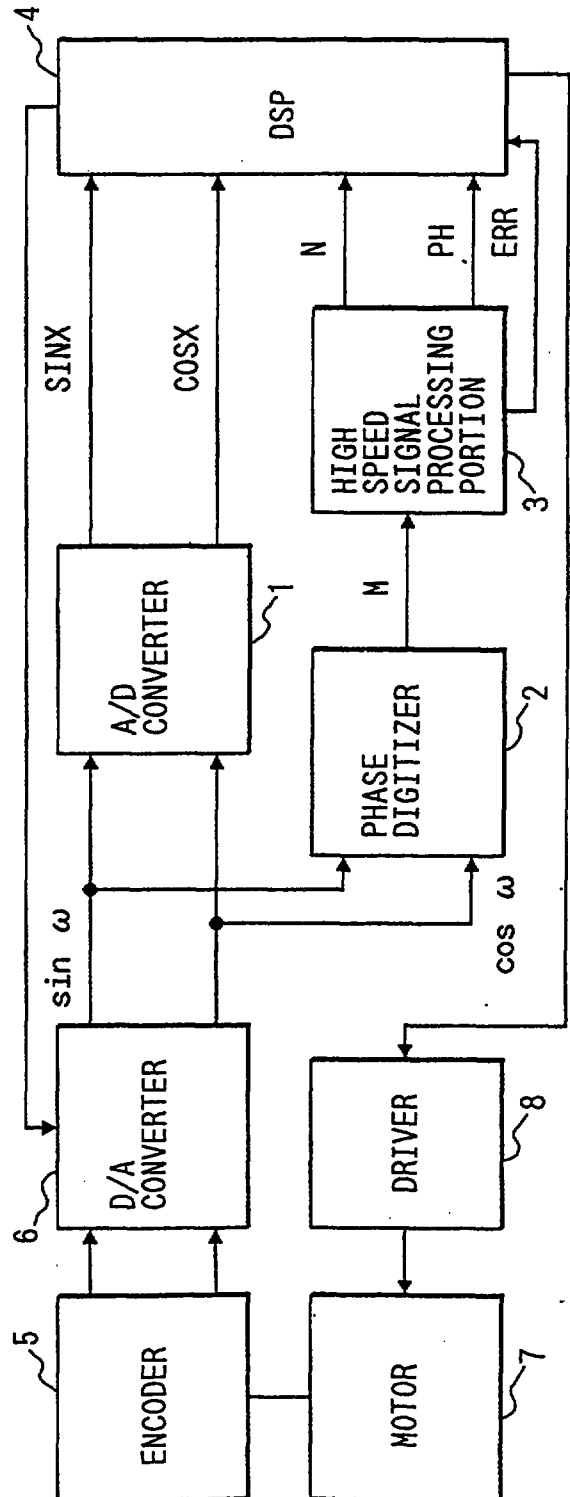
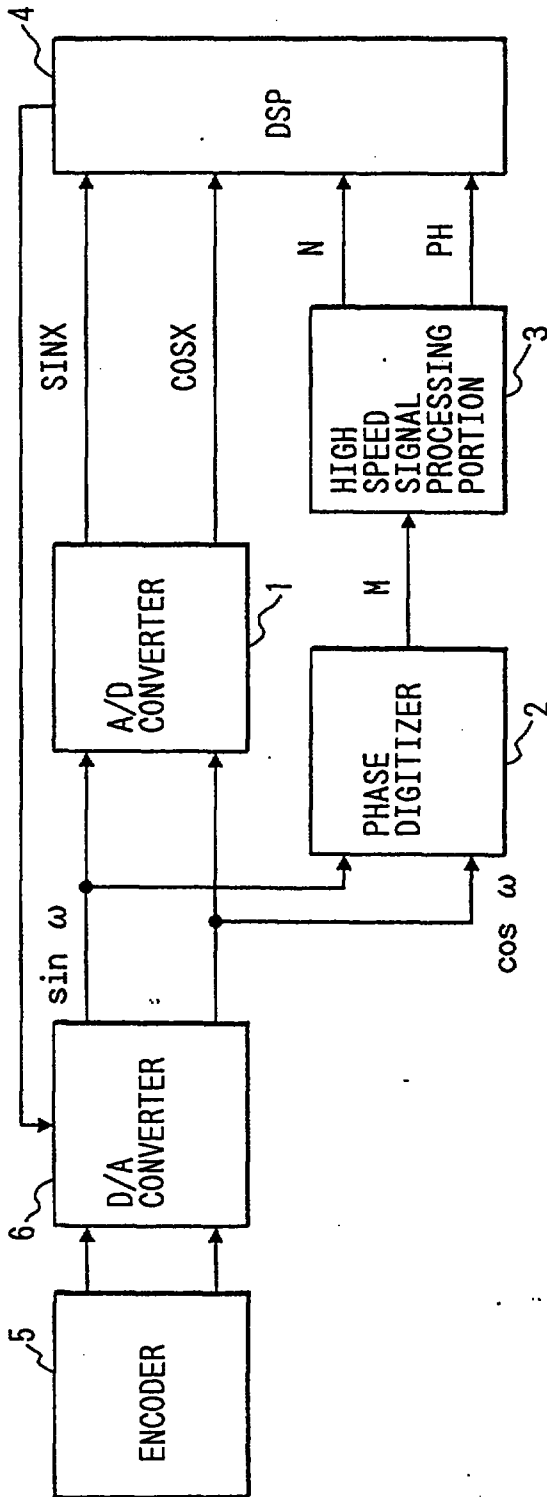
FIG. 4

FIG. 5



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SIGNAL PROCESSING APPARATUS AND

DISPLACEMENT DETECTING APPARATUS USING THE SAME

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a signal processing apparatus for generating an interpolation signal having a resolution higher than the period of a periodic signal and a position detecting apparatus using the same, and more particularly to a signal interpolation apparatus using sine and cosine wave signals generated in accordance with the displacement by an encoder or the like to obtain a resolution higher than the period thereof, in other words, shorter than the fundamental period. This apparatus can be used in the fields of precise position measurement and precise position control.

Related Background Art

An example of the conventional art is shown in Figure 1, of the accompanying drawings. In Figure 1, sine and cosine wave signals generated in accordance with displacement by an encoder or the like are converted into a rectangular wave having a frequency higher than the fundamental frequency of the sine wave signal by the use of a phase digitizer 21 for quantizing the sine and cosine wave signals in accordance with the phase angles thereof. From this signal, a count up pulse and

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a count down pulse are produced by an up/down pulse output circuit 22, and these are integrated by an up/down counter circuit 23, whereby a position signal is outputted. As for the phase digitizer 21, use can be made of one having a construction as shown, for example, in Figure 2 of the accompanying drawings.

As another example of the prior art, the construction described in Japanese Laid-Open Patent Application No. 54-19773 is shown in Figure 3 of the accompanying drawings. In Figure 3, sine and cosine signals are converted into digital values by an A/D converter 31 and input into a microprocessor 34, wherein the ratio between the values is found and the inverse tangent value thereof is calculated, and an interpolation process for finding the phase angle of the sine wave is carried out. Also, in parallel with this process, the sine and cosine signals are compared with OV by a comparator 32 and are thereby converted into a rectangular wave. Thereafter, as in Figure 1, a count up pulse and a count down pulse are produced by an up/down pulse output circuit 33. These are integrated by an up/down counter circuit 35, and the fundamental frequency of the sine wave signal is counted, which is synthesized by a microprocessor 34 to obtain positional information.

In the conventional art shown in Figure 1, when the interpolation number is great and

highly accurate position detection is required, the circuit scale of the phase digitizer increases in proportion to the interpolation number. For example, in the construction of figure 2, the same number of comparators as the interpolation number becomes necessary and particularly, it is not realistic to digitize to 1/100 or smaller. Even if this problem is solved, the maximum response frequency of the up/down counter in the post stage of the phase digitizer is limited and therefore, it becomes impossible to detect highly accurately the position of an object which is moving at a high speed.

The example of the prior art shown in Figure 3 intends to solve the above-noted problem to a certain degree, and the interpolation portion and the fundamental frequency counting portion are separated from each other to provide parallel construction, whereby even if the interpolation number is great, the circuit construction can be made small and moreover, the position of an object moving at a high speed can be detected highly accurately.

In the construction of Figure 3, however, the A/D converting portion and the phase digitizing portion operate in parallel and therefore, their operations must be executed completely in synchronism with each other, and even when only slight shift in time has occurred. There is a possibility that mismatch

occurs between positional information obtained from each portion. In such case, there is the possibility that positional information momentarily having a great error is outputted. For example, in a case where a servo system is constructed to use the detected positional information and a momentarily great disturbance is applied to the servo system, there is a possibility that a fatal problem such as the collision of a moving object. Further, when the sine wave signal has noise, a similar problem arises and it has been impossible to obviate this.

Also, It is ideal that the sine and cosine wave signals obtained from the encoder or the like have equal amplitudes, but their amplitudes often fluctuate depending on position. Particularly when highly accurate detection is necessary, such amplitude fluctuate makes accurate interpolation calculation impossible, for example, in a portion for finding the inverse tangent. Therefore, in the aforedescribed example, there is proposed a method of correcting this in a software-like fashion by the microprocessor 34, However, amplitude correction generally involves multiplying and dividing processes and therefore, the load of the microprocessor is high. If the same processor is used for the control calculation of the

servo system, this high load becomes overhead and it becomes impossible to secure a short control period. It is possible to prepare a look up table or the like and curtail the amount of multiplication and division, but in such case, the greater the interpolation number is, the larger the look up table, and it becomes difficult to store the table in memory effectively.

SUMMARY OF THE INVENTION

In view of the above-noted disadvantage peculiar to the conventional art, it is an object of the present invention to provide a highly reliable signal processing apparatus, a position detecting apparatus and a driving device which can make a circuit construction small even if the interpolation number is great, and which can detect a periodic signal highly accurately and can further prevent the occurrence of an error resulting from the influences of the mismatch, noise, etc. of information.

It is a further object of the invention to provide an apparatus which can easily correct any amplitude fluctuation without increasing the load of a processor or the like.

It is still a further object of the present invention to provide an apparatus which can confirm that the operation of a phase digitizer is normal.

One form of the signal processing apparatus of the

respect to some embodiments thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of an example of the prior art.

Figure 2 is an illustration of an example of the prior art.

Figure 3 is an illustration of an example of the prior art.

Figure 4 shows a first embodiments of the present invention.

Figure 5 is a chart illustrating the first embodiment of the present invention.

Figure 6 is a diagram illustrating a second embodiment of the present invention.

Figure 7 is a diagram illustrating a third embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention is shown in Figure 4. In Figure 4, the reference numeral 1 designates an A/D converter with high resolution for converting into a digital signal, an analog signal obtained from an encoder 5 signal varying in a sine and cosine wave fashion in accordance with the displacement of an object. The A/D converter 1 has a resolution of 12 bits, i.e., attaches importance to

accuracy resolution, operates at a relatively low speed and does not respond to an input signal of a high frequency. The reference numeral 2 denotes a phase digitizer which, like the A/D converter 1, receives as inputs sine and cosine wave analog signals obtained from the encoder 5, but operates at a high speed and is of low resolution. The phase digitizer 2 has a resolution of 3 bits, and the period of the output signal thereof is shorter than the period of the signal inputted thereto. The reference numeral 3 designates a high speed signal processing portion which has the output of the phase digitizer 2 as an input and outputs the periodicity N of the sine wave signal, i.e., the number of the fundamental waves of the sine wave, and a logical signal PH which is 1 within a range of 0° to 180° of the phase of the sine wave and is 0 within a range of 180° to 360° . The reference numeral 4 denotes a signal processing portion for receiving the outputs of the A/D converter 1 and the high speed signal processing portion 3 and effecting the signal processing of producing final positional information. A digital signal processor (DSP) is used as the signal processing portion 4 to realize high speed processing. Also an incremental type encoder is used as the encoder 5 which outputs sine and cosine waves in accordance with position.

The procedure of these operations will hereinafter

be described in succession.

The sine and cosine wave signals outputted from the encoder 5 are first inputted to the A/D converter 1 and are outputted as digital values SINX and COSX of 12 bits each. At the same time, these sine and cosine wave signals are inputted to the phase digitizer 2, which outputs digital data M of 3 bits. M is 0 when the phase angle of the sine wave signal is 0 and increases by 1 during each 1/8 of the period of the sine wave signal. That is, 360° of one period is divided into eight phase segments, and phase data is digitized in the order of 0, 1, 2 counter-clockwise from the first quadrant. The high speed signal processing portion 3 receives this output increments N by 1" when M changes from 7 to 0, and outputs the periodicity N of the obtained sine wave signal. At the same time, it outputs a logical signal PH which becomes 1 when M is 0, 1, 2, or 3, and is 0 when M is 4, 5, 6 or 7.

The portion for counting the periodicity of the fundamental wave generates redundant data N and PH obviate wrong counting caused by pulse noise or the like as follows.

In the DSP 4, by the use of SINX, COSX, N and PH obtained by the above-described procedure, positional

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information is produced by a procedure shown in the flow chart of Figure 5. The phase angle ϕ of the sine wave signal is first calculated from SINX and COSX. The phase angle is obtained by calculating the ratio of SINX to COSX, and applying that ratio to an inverse tangent look up table prepared in advance. Next, if ϕ is computed to be in range of 0° to 180° and the logical signal PH from the high speed signal processing portion 3 is 0, indicating the phase angle to be between 180° to 360° , DSP 4 determines that a mismatch has occurred between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2. The phase angle computed from the digital signals output from the A/D converter 1 is always considered to be the correct phase angle. In this case, the value N should have increased by 1, since the sine wave passed through 0° as indicated by the phase angle computed from the digital values output from the A/D converter, but did not because of an error. Accordingly, in order to eliminate this error, a correcting process of increasing N by 1 to provide $N' = N + 1$ is carried out by the DSP 4. If conversely, ϕ is computed to be in a range of 180° to 360° and processing portion 3 is 1, indicating the phase angle to be between 0° and 180° , DSP 4 determines that N has been incorrectly incremented by 1 too many is from 0° to 180° , it is judged that 1 more has been in the high speed signal processing portion, and N is corrected by subtracting by 1 to thereby provide $N' = N - 1$.

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When these two conditions do not apply, ie, the phase angle computed from the digital signals of the A/D converter correctly matches PH, there is no mismatch between the data obtained from the A/D converter 1 and the data obtained by way of the phase digitizer 2 and therefore, the correction as described above is not necessary and $N' = N$.

Thereafter, corrected periodicity N' , multiplied by 2π , and the phase angle ϕ are added to thereby obtain final positional information.

By providing the correcting means as described above, there can be constructed a highly accurate position detecting apparatus in which the mismatch between the data obtained from the signal processing portions provided in parallel can be prevented to thereby eliminate any momentary detection error and which is stable and moreover can cope with high speed motion.

A second embodiment of the present invention is shown in Figure 6. This embodiment is one which a multiplication type D/A converter 6 for correcting the amplitudes of the signals from the encoder 5 is added to the first embodiment shown in Figure 4.

This embodiment is similar in the basic processing procedure to the first embodiment, but in this embodiment, by the utilization of the fact that the digital data obtained from the A/D converter 1 are always introduced into the DSP 4, the maximum values and minimum values of the A/D converted data $SINX$ and

COSX of the sine and cosine wave signals are held within the DSP 4. Further, each time the signals from the encoder 5 are A/D-converter, these maximum values and minimum values are successively renewed to thereby hold optimum maximum and minimum values at all times. The amplitudes of the sine wave and cosine wave signals are then calculated and a correction signal is outputted to the multiplication type D/A converter 6 and applied to the sine wave and cosine wave signals so that they become equal to each other, and thus, the correction of the amplitudes of the signals from the encoder 5 is effected.

By providing such gain correcting means, any error included in the phase angle data ϕ due to the imbalance of the gain can be eliminated to thereby enhance the linearity thereof particularly when the calculation for finding the inverse tangent shown in the flow chart of Figure 5 is effected. The signals from the encoder 5 can also be set to the maximum possible amplitudes in the A/D converter 1 and phase digitizer 2 in conformity with their maximum input voltages and therefore, the influence of a quantization error occurring when the signals from the encoder 5 are small can be minimized. When the input voltage widths of the A/D converter 1 and phase digitizer 2 differ from each other, multiplication type D/A converters can be prepared discretely or the signals can be suitably attenuated after they have passed through the D/A.

converter 6.

Further, a digital filter may be implemented within the DSP 4 and high frequency noise which may be included in the signals from the encoder 5 is attenuated to a sufficiently negligible level by filter calculation. Since the digital filter processing by software is possible, there can be provided a filter having a desired cut-off/phase characteristic, such as an FIR filter of linear phase.

In the above-described embodiment, a phase digitizer of at least 1 bit is used with the portion for counting the periodicity of the fundamental wave to give redundancy, thereby improving resistance to disturbance. Also, provision is made of a variable gain amplifier positively utilizing the phase information obtained in the phase digitizer portion to affect correction or error detection when the information obtained on the interpolation side and the periodicity of the fundamental are synthesized, and for further correcting the amplitudes of the sine and cosine wave signals.

As a third embodiment of the present invention, there is shown the construction of Figure 7 in which an electromagnetic motor 7 and a motor driver 8 are added as an actuator to the construction of Figure 6 to thereby provide a positioning servo system. The angle of the motor is highly accurately detected by the



procedure shown in the above-described embodiment to thereby construct such a control system that this angle coincides with a desired target position. Control calculation constituting an appropriate compensator on the basis of the detected angle data is effected within the DSP 4 and a current reference value to the motor obtained as a result is given to the motor driver 8, whereby the highly accurate positioning of the motor becomes possible.

At this time, the redundancy in the phase angle PH realized by the phase digitizer 2 is utilized more positively. That is, a logical signal ERR is 0 as long as the phase-digitized value M increases by 1 each time interval and which becomes 1 when M varies by 2 or greater in the time interval, that is, when the monotonicity of M becomes null, is generated by the high speed signal processing portion and is introduced into the DSP 4. When the logical signal ERR has become 1, it is judged that some sudden disturbance has been inputted from a mechanical system, and for example, the output current of the driver 8 is rendered 0 to thereby stop the servo operation, thus informing the operator that some abnormality has happened. Thereby, a problem that the servo system is destroyed by an abnormal operation due to a great detection error, disturbance or the like can be obviated, and a highly reliable servo system can be constructed.

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CLAIMS

1. (Amended) A signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relationship therebetween, comprising:

digitizing means for converting respective amplitudes of the first and second periodic analog signals into first and second digital signals;

signal generating means for generating a signal from the first periodic analog signal, the generated signal having ~~[a period]~~ an angular resolution that is ~~[shorter]~~ larger than the ~~[period]~~ angular resolution of the first periodic analog signal;

first processing means for generating, from the signal generated by said signal generating means, a third digital signal representing the periodicity of the first periodic analog signal and a first interpolation signal representing a first interpolation value within a period ~~[phase information]~~ of the first periodic analog signal; and

second processing means for producing a second interpolation signal representing a second interpolation value within a period ~~[phase information]~~ of the first periodic analog signal from the first and second digital signals from said digitizing means, wherein the first interpolation signal has a angular resolution lower than a angular resolution of the second interpolation signal, and for changing the third digital signal on the basis of the first interpolation signal and the second interpolation signal ~~[and for correcting the periodicity from said first processing means on the basis of the first phase information and the second phase information]~~.



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3. (Amended) The apparatus of Claim 1, wherein said second processing means changes the third digital signal by comparing [~~compares~~] the first [~~phase information~~] interpolation signal with the second interpolation signal [~~phase information~~].

4. (Amended) The apparatus of Claim 1, wherein said second processing means synthesizes an angular position from the [~~corrected periodicity~~] changed third signal and the second interpolation signal [~~phase information~~].

5. (Amended) The apparatus of Claim 1, further comprising means for adjusting the respective amplitudes of [~~said~~] the first and second periodic analog signals on the basis of [~~said~~] the first and second digital signals.

6. (Amended) An apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object and having the same period and having a fixed phase relationship therebetween, comprising:

digitizing means for converting respective amplitudes of the first and second periodic analog signals into first and second digital signals;

signal generating means for generating a signal from the first periodic analog signal, the generated signal having [~~a period~~] an angular resolution that is [~~shorter~~] larger than the [~~period~~] angular resolution of the first periodic analog signal;





first processing means for generating, from the signal generated by said signal generating means, a third digital signal representing the periodicity of the first periodic analog signal and a first interpolation signal representing a interpolation value within a period [phase information] of the first periodic analog signal; and

second processing means for producing a second interpolation signal representing an interpolation value within a period [phase information] of the first periodic analog signal from the first and second digital signals from said digitizing means, wherein the first interpolation signal has a angular resolution lower than a angular resolution of the second interpolation signal, and for changing the third digital signal on the basis of the first interpolation signal and the second interpolation signal [for correcting the periodicity from said first processing means on the basis of the first phase information and the second phase information], and for synthesizing the displacement of the object from the {corrected periodicity} changed third digital signal and the second interpolation signal [phase information and for outputting the displacement of the object].

7. The apparatus of Claim 6, wherein the resolution of said first phase information is lower than that of said second phase information.

8 (Amended) The apparatus of Claim 6, wherein said second processing means changes the third digital signal by comparing [compares] the first interpolation signal [phase information] with the second interpolation signal [phase information].





9. (Amended) The apparatus of Claim 6, further comprising means for adjusting the respective amplitudes of [said] the first and second periodic analog signals on the basis of [said] the first and second digital signals.

10. (Amended) The apparatus of Claim 6, wherein said first processing means detects a change of the signal generated by said signal generating means [~~the monotonicity of the first phase information which is sequentially inputted~~].

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Date: 28 JUL 1997

SIGNAL PROCESSING APPARATUS AND DISPLACEMENT DETECTING
APPARATUS USING THE SAME

IN THE ABSTRACT :

A signal processing apparatus is provided for processing first and second periodic analog signals having the same period and having a fixed phase relationship therebetween. the apparatus includes an A/D converter for converting respective amplitudes of the first and second periodic analog signals into first and second digital signals. The apparatus also includes a phase digitizer for generating a signal from the first periodic analog signal, the generated signal having a period that is shorter than the claims by replacing the claims with the patented claims.

Figure 4

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first processing means for generating, from the signal generated by said signal generating means, a third digital signal representing the periodicity of the first periodic analog signal and a first interpolation signal representing a interpolation value within a period of the first periodic analog signal; and

second processing means for producing a second interpolation signal representing an interpolation value within a period of the first periodic analog signal from the first and second digital signals from said digitizing means, wherein the first interpolation signal has a angular resolution lower than a angular resolution of the second interpolation signal, and for changing the third digital signal on the basis of the first interpolation signal and the second interpolation signal, and for syntheizing the displacement of the object from the changed third digital signal and the second interpolation signal.

7. The apparatus of claim 6, wherein said second processing means changes the third digital signal by comparing the first interpolation signal with the second interpolation signal.

8. The apparatus of Claim 6, further comprising means for adjusting the respective amplitudes of the first and second periodic analog signals on the basis of the first and second digital signals.

9. The apparatus of Claim 6, wherein said first processing means detects a change of the signal generated by said signal generating means.

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SIGNAL PROCESSING APPARATUS AND DISPLACEMENT DETECTING
APPARATUS USING THE SAME

IN THE ABSTRACT :

A signal processing apparatus is provided for processing first and second periodic analog signals having the same period and having a fixed phase relationship therebetween. the apparatus includes an A/D converter for converting respective amplitudes of the first and second periodic analog signals into first and second digital signals. The apparatus also includes a phase digitizer for generating a signal from the first periodic analog signal, the generated signal having a period that is shorter than the claims by replacing the claims with the patented claims.

Figure 4

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converter 6.

Further, a digital filter may be implemented within the DSP 4 and high frequency noise which may be included in the signals from the encoder 5 is attenuated to a sufficiently negligible level by filter calculation. Since the digital filter processing by software is possible, there can be provided a filter having a desired cut-off/phase characteristic, such as an FIR filter of linear phase.

In the above-described embodiment, a phase digitizer of at least 1 bit is used with the portion for counting the periodicity of the fundamental wave to give redundancy, thereby improving resistance to disturbance. Also, provision is made of a variable gain amplifier positively utilizing the phase information obtained in the phase digitizer portion to affect correction or error detection when the information obtained on the interpolation side and the periodicity of the fundamental wave are synthesized, and for further correcting the amplitudes of the sine and cosine wave signals.

As a third embodiment of the present invention, there is shown the construction of Figure 7 in which an electromagnetic motor 7 and a motor driver 8 are added as an actuator to the construction of Figure 6 to thereby provide a positioning servo system. The angle of the motor is highly accurately detected by the



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CLAIMS :

1. A signal processing apparatus for processing first and second periodic analog signals having the same period and having a fixed phase relationship therebetween, comprising:

digitizing means for converting respective amplitudes of the first and second periodic analog signals into first and second digital signals;

signal generating means for generating a signal from the first periodic analog signal, the generated signal having an angular resolution that is larger than the angular resolution of the first periodic analog signal;

first processing means for generating, from the signal generated by said signal generating means, a third digital signal representing the periodicity of the first periodic analog signal and a first interpolation signal representing a first interpolation value within a period of the first periodic analog signal; and

second processing means for producing a second interpolation signal representing a second interpolation value within a period of the first periodic analog signal from the first and second digital signals from said digitizing means, wherein the first interpolation signal has angular resolution lower than angular resolution of the second interpolation signal, and for changing the third digital signal on the basis of the first interpolation signal and the second interpolation signal.

2. The apparatus of Claim 1, wherein said second processing means changes the third digital signal by comparing the first interpolation signal with the second interpolation signal.



3. The apparatus of Claim 1, wherein said second processing means synthesizes an angular position from the changed third signal and the second interpolation signal.

4. The apparatus of Claim 1, further comprising means for adjusting the respective amplitudes of the first and second periodic analog signals on the basis of the first and second digital signals.

5. An apparatus for detecting the displacement of an object by the use of first and second periodic analog signals generated by the displacement of the object and having the same period and having a fixed phase relationship therebetween, comprising:

digitizing means for converting respective amplitudes of the first and second periodic analog signals into first and second digital signals;

signal generating means for generating a signal from the first periodic analog signal, the generated signal having an angular resolution that is larger than the angular resolution of the first periodic analog signal;

first processing means for generating, from the signal generated by said signal generating means, a third digital signal representing the periodicity of the first periodic analog signal and a first interpolation signal representing an interpolation value within a period of the first periodic analog signal; and

second processing means for producing a second interpolation signal representing an interpolation value within a period of the first periodic analog signal from the first and second digital signals from said digitizing means, wherein the first interpolation signal has a angular resolution lower than a angular resolution of the second interpolation signal, and for changing the third digital signal on the basis of the first interpolation signal and the second interpolation signal, and for synthesizing the displacement of the object from the changed third digital signal and the second interpolation signal.



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6. The apparatus of claim 5, wherein said second processing means changes the third digital signal by comparing the first interpolation signal with the second interpolation signal.

7. The apparatus of Claim 5, further comprising means for adjusting the respective amplitudes of the first and second periodic analog signals on the basis of the first and second digital signals.

8. The apparatus of Claim 5, wherein said first processing means detects a change of the signal generated by said signal generating means.