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Hort

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[54] PHASE CONTROL SYSTEM FOR ROTARY MEANS

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[52] U.S. Cl. 318/314; 318/318

[51] Int. Cl. H02p 5/16

[58] Field of Search 318/312, 318, 313, 327, 318/314, 329, 315

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[57] ABSTRACT

A phase control system for a rotary member is provided which has a device for adjusting the rotation of a rotary member so as to make the rotational speed and rotary phase of the rotary member coincident for a reference frequency signal. The phase control system has a rotational speed control function to lock the rotary phase of the rotary member at the reference frequency signal without especially providing a device which makes the rotational speed of the rotary member coincident with the reference frequency signal.

8 Claims, 37 Drawing Figures

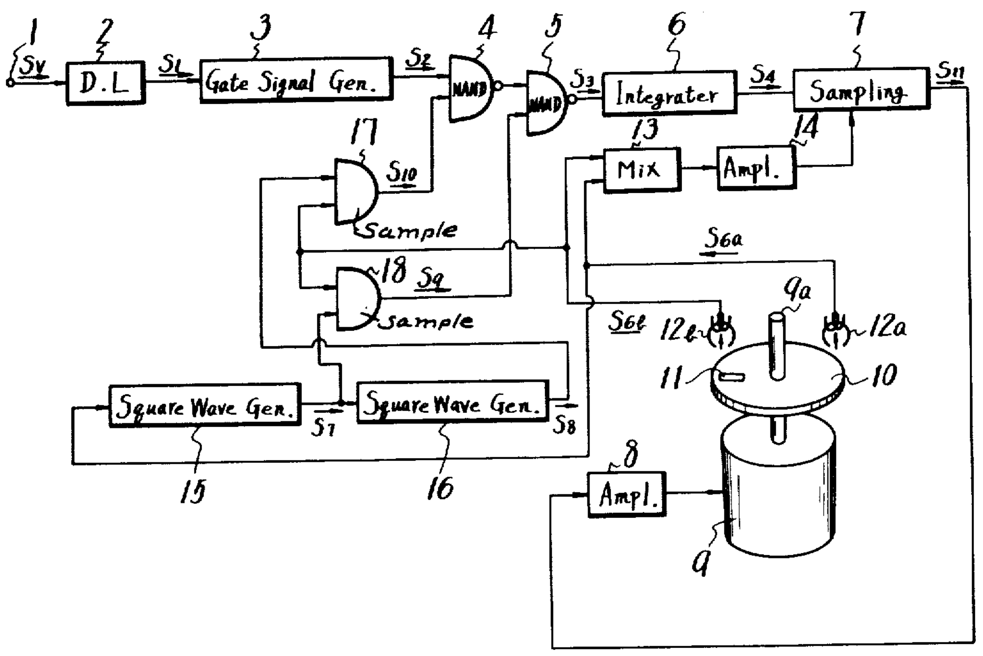

Fig. 1

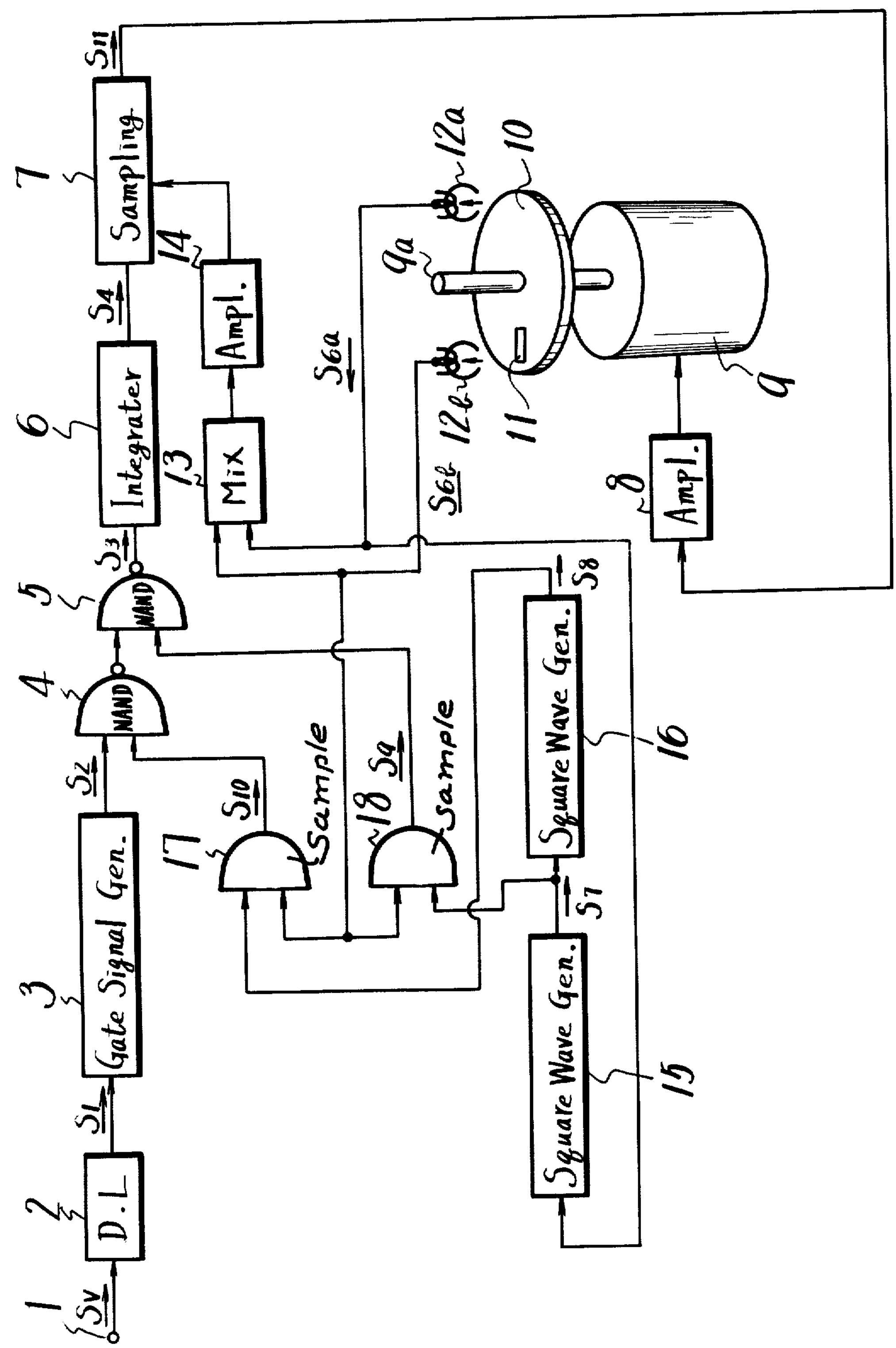
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Fig. 2A

Fig. 2B

Fig. 2C

Fig. 2D

Fig. 2E

Fig. 2F

Fig. 2G

Fig. 2H

Fig. 2I

Fig. 2J

Fig. 2K

Fig. 2L

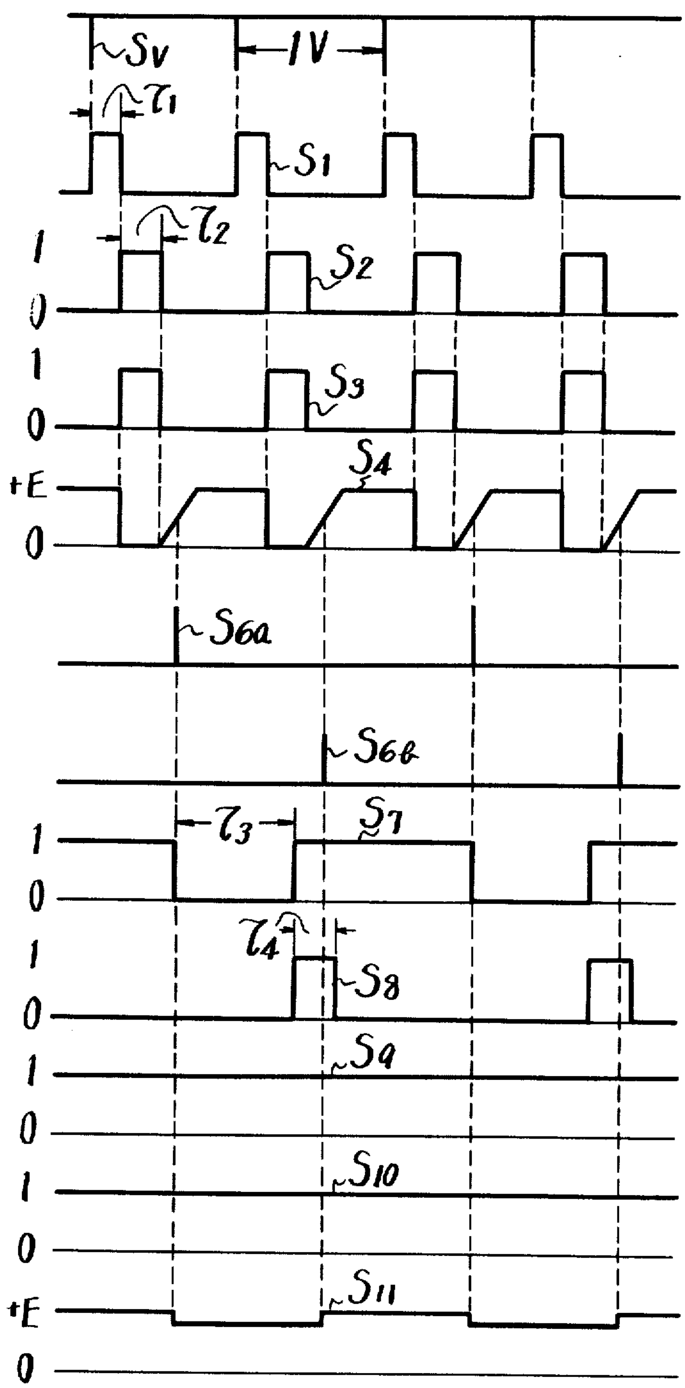


Fig. 3A

Fig. 3B

Fig. 3C

Fig. 3D

Fig. 3E

Fig. 3F

Fig. 3G

Fig. 3H

Fig. 3I

Fig. 3J

Fig. 3K

Fig. 3L

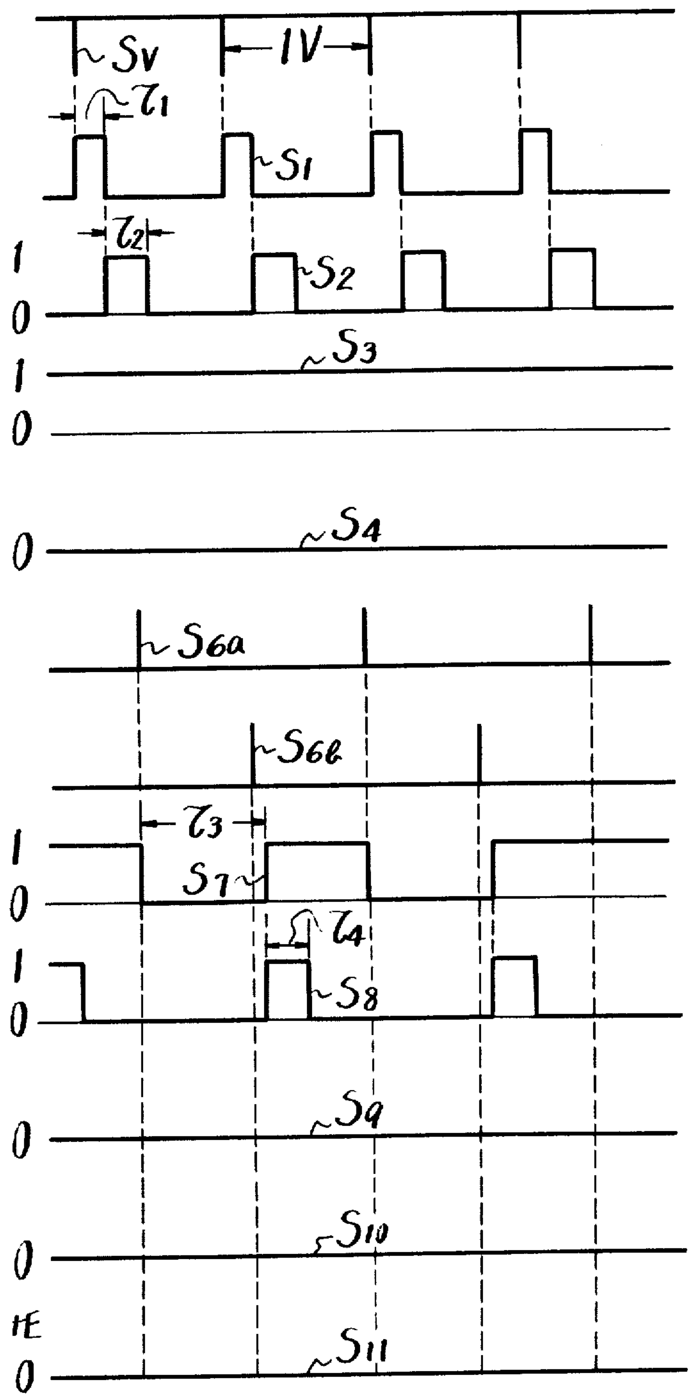
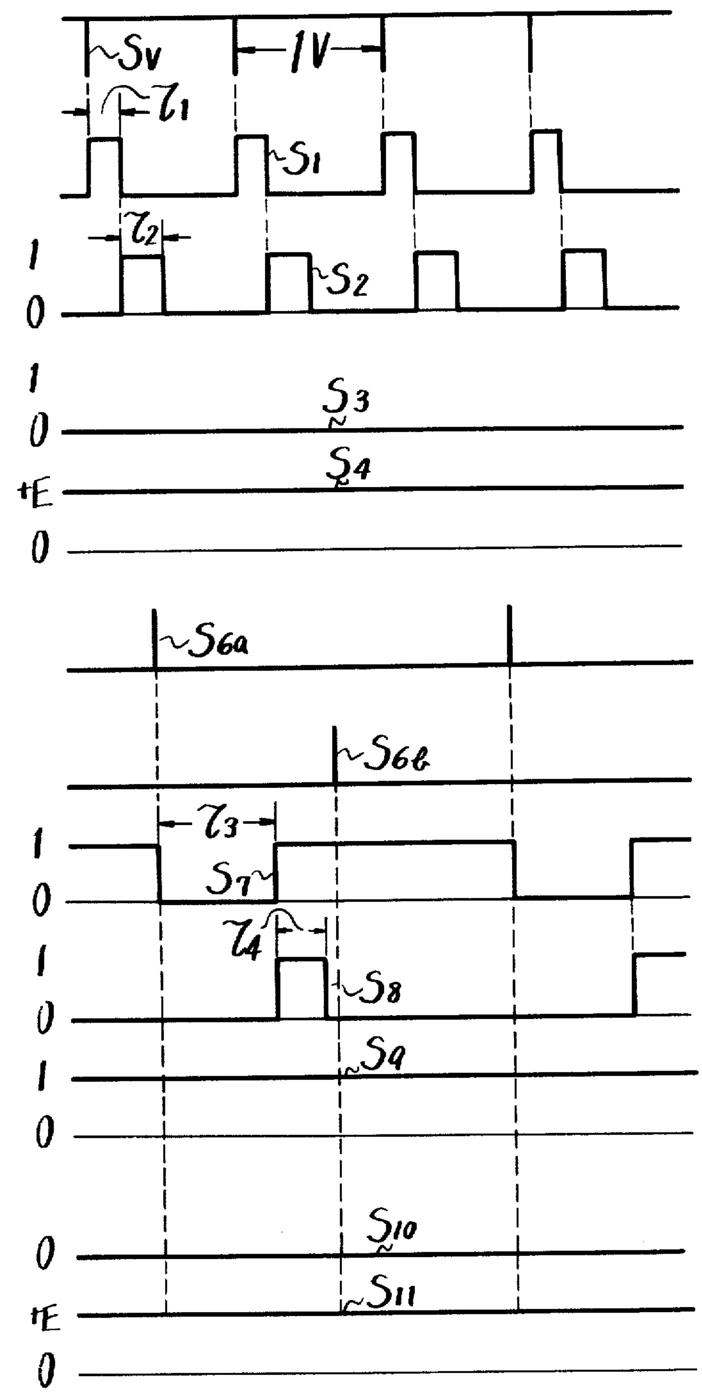


Fig. 4A
Fig. 4B
Fig. 4C
Fig. 4D
Fig. 4E
Fig. 4F
Fig. 4G
Fig. 4H
Fig. 4I
Fig. 4J
Fig. 4K
Fig. 4L



PHASE CONTROL SYSTEM FOR ROTALY MEANS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a phase control system, and more particularly to an improved phase control system for a rotary member.

2. Description of the Prior Art

Up to now, there have been proposed various systems in which a means is provided for controlling the rotary phase of a rotary member to adjust the rotary phase or angular phase of the rotary member and to lock the same at a phase signal. Such systems are used for controlling the rotary phase of a rotary head employed in a video tape recorder, by way of example. In the case where the rotary phase of a rotary member such, for example, as a rotary head is controlled, if the control is achieved by a phase control system only or without providing a speed control system, the rotary member can not be locked at a correct rotary phase in its rotation. In other words, in such cases there is a defect that the rotary member is rotated while being locked at the phase signal but with a rotational speed of *n* times or $1/n$ times (where *n* is 2, 3, . . .) the correct rotational speed. To avoid this, with the prior art system for a rotary member, it is required to provide a rotational speed control means in addition to the phase control system. As a result, the system becomes complicated in construction.

It is necessary that the speed of the rotary member set by the rotational speed control system must be as correct as possible. Otherwise, the rotary member is locked at a speed higher than the correct rotary speed by 2 times or lower than the latter by one-half. As a result of this, it requires much time before the rotary member is locked at the correct speed. By way of example, when a video tape is reproduced by a video tape recorder, the tracking of the rotary head for the signal tracks recorded on the video tape can be hardly done completely.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved phase control system for a rotary member free from the drawbacks encountered in the prior art.

It is another object of the present invention to provide a phase control system for a rotary member which makes it possible to quickly achieve coincidence.

It is a further object of the invention to provide a phase control system for a rotary member by which a rotary member can be rotated with phase-locked condition to a reference synchronizing signal without the provision of a rotational speed control system for rotating the rotary member at a reference rotational speed.

The additional and other objects, features and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a systematic diagram showing an example of the phase control system for a rotary member according to the present invention; and

FIGS. 2A to 2L, 3A to 3L and 4A to 4L, inclusive, are waveform diagrams used for explanation of the example shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the drawing an embodiment of the present invention will be hereinafter described.

In FIG. 1, reference numeral **9** indicates a motor, for example, a DC motor with a rotary shaft **9***a*. Though not shown, a rotary shaft of, for example, a rotary head of a video tape recorder is directly connected to the rotary shaft **9***a*, or the rotary shaft **9***a* itself serves as a tape transporting capstan. Further, a hub portion for supporting a video tape (not shown) is mounted on the free end of rotary shaft **9***a* and hence the rotary shaft **9***a* serves as a sheet rotative shaft for the video tape recorder. A rotary disc **10** is attached to the rotary shaft **9***a* integral therewith which has provided thereon a bar magnet **11** for indicating the phase angle of the rotary shaft **9***a* when it is rotated. A first pulse generator **12***a* and a second pulse generator **12***b* are provided which detect the bar magnet **11** and pick up the rotational speed and angular position of rotary shaft **9***a* when it is rotated. Well-known magnetic heads can be employed as the pulse generators **12***a* and **12***b* in the illustrated embodiment, by way of example, but it may be possible that various detecting means other than magnetic heads are employed as the pulse generator. In this alternative embodiments, it is of course necessary that other elements be used instead of the bar magnet **11** in association with the employed detecting means.

In the embodiment depicted in FIG. **1**, the first and second pulse generators **12***a* and **12***b* are arranged on a chassis (not shown) such that they may oppose the bar magnet **11** on the diameter of the disc **10** symmetrical with respect to the rotary shaft **9***a* or the pulse generators **12***a* and **12***b* are mounted with an angular separation of 180°.

In FIG. **1**, reference numeral **1** indicates an input terminal to which a synchronizing signal such as a vertical synchronizing signal separated from a television signal is applied. The synchronizing signal applied to the input terminal **1** is fed to a time-delay circuit **2** the output signal or time-delayed signal from which is applied to a gate signal generator **3**. Monostable multivibrators, for example, can be used as the time-delay circuit **2** and gate signal generator **3**, respectively. In this case, if necessary, the time interval within which the multivibrators are maintained in unstable state is made to be variable manually, the construction of which is well known and hence its description is omitted. Accordingly, the delay-time by the time-delay circuit **2** and the pulse width of the gate pulse derived from the gate signal generator **3** can be both adjusted manually. A first NAND-circuit **4** is provided with a pair of imput terminals one of which is supplied with the output signal or the gate pulse from the gate pulse generator **3**. A second NAND-circuit **5** is also provided with a pair of input terminals one of which is supplied with the output signal from the first NAND-circuit **4**. A signal integrating circuit such, for example, as a Miller integrator **6** is supplied, at its input terminal, with the output signal of the second NAND-circuit **5** and a sampling-hold gate circuit **7** is supplied, at its input terminal, with the output signal from the Miller integrator **6**. The output signal of the sampling-hold gate circuit **7** is fed through a power amplifier such as a DC amplifier **8** to the motor **9**. Thus, the motor **9** is controlled in its rotational speed or rotational phase in accordance with the DC level of the output signal from the DC amplifier **8**. The integrator circuit **6**, the sampling-hold gate circuit **7**, the amplifier **8** and so on form a servo circuit.

First and second square-wave signal generators **15** and **16** are provided. The input terminal of first square-wave signal generator **15** is connected to the first pulse generator **12***a*, while the input terminal of second square-wave signal generator **16** is connected to the output terminal of first square-wave signal generator **15**. A first sampling circuit **17** is provided with a pair of input terminals which are supplied with the output signal from the second square-wave signal generator **16** and that of the second pulse generator **12***b*, respectively, to produce an AND-output signal. A second sampling circuit **18** is also provided with a pair of input terminals which are supplied with the output signal of the first square-wave signal generator **15** and that of the second pulse generator **12***b* to produce an AND output signal.

In fact, the both sampling circuits **17** and **18** are formed of a circuit in which the output signal from the square-wave generator is sampled with the output pulse from the pulse generator **12***b*, and a circuit in which the sampled output signals are stored. A sampling-hold gate circuit such as a latching circuit and so on can be used as the above circuit. A typical example of a sampling-hold gate circuit which can comprise the sampling circuits **17** and **18** is the sample and hold amplifier, Model A400, manufactured by Digital Equipment Corporation, Maynard, Massachusetts. Alternatively, the sampling circuits each may comprise a latching circuit such as a general-purpose J-K flip-flop circuit, such as Model M207 manufactured by Digital Equipment Corporation. The output terminal of the first sampling circuit **17** is connected to the remaining input terminal of the first NAND-circuit **4**, while the output terminal of second sampling circuit **18** is connected to the remaining input terminal of the second NAND-circuit **5**. A mixer **13** is provided which is supplied with, at its input terminals, the output pulses from the first and second pulse generators **12***a* and **12***b* to produce a composite signal which is applied to the gate signal input terminal of the sampling-hold gate circuit 7 through an amplifier **14**, if necessary.

With the above construction, if the motor **9** is rotated at a speed of 30 r.p.s. during a normal state, by way of example, the first and second pulse generators **12***a* and **12***b* produce pulses of 30Hz corresponding to the first and second rotary positions, respectively. Further, if the vertical synchronizing signal contained in the television signal is used as the synchronizing signal mentioned above, so that its frequency is 60Hz. The output signal from the mixer **13**, which combines the first and second rotary position signals from the first and second pulse generators **12***a* and **12***b*, is a pulse signal of 60Hz when the motor **9** is rotated at the normal speed.

A description will be now given to the operation of the phase control system illustrated in FIG. **1** with reference to FIGS. **2** to **4**.

Through FIGS. **2A**, **3A** and **4A**, symbols S_V represent the vertical synchronizing input synchronizing signal; through FIGS. **2B**, **3B** and **4B** symbols S_1 represent the output signal from the time-delay circuit **2**; through FIGS. **2C**, **3C** and **4C** S_2 the output signal from the gate signal generating circuit **3**; through FIGS. **2D**, **3D** and **4D**, S_3 the output signal from the second NAND-circuit **5**; through FIGS. **2E**, **3E** and **4E**, S_4 the output signal from the integrating circuit **6**; through FIGS. **2F**, **3F** and **4F**, S_{6a} the first rotary position signal from the first pulse generator **12***a;* through FIGS. **2G**, **3G** and **4G**, S_{6b} the second rotary position signal from the second pulse generator **12***b;* through FIGS. **2H**, **3H** and **4H**, S_7 the output signal from the first square-wave signal generator **15**; through FIGS. **2I**, **3I** and **rI**, S_8 the output signal from the second square-wave signal generator **16**; through FIGS. **2J**, **3J** and **4J**, S_9 the output signal from the second sampling circuit **18** through FIGS. **2K**, **3K** and **4K**, S_{10} the output signal from the first sampling circuit **17**; and through **2L**, **3L** and **4L**, S_{11} the output signal from the sampling-hold gate circuit **7**, respectively.

As shown in FIGS. **2C** to **4C**, the output signal S_2 derived from the gate signal generator **3** is delayed in phase from the vertical synchronizing signal S_V by τ_1 and has the time duration of τ_2. The phase delay τ_1 and time duration τ_2 determine the phase difference between the synchronizing signal S_V and the pulses S_{6a} and S_{6b} obtained from the pulse generators **12***a* and **12***b*.

By way of example, when the system of the present invention is employed in a video tape recorder which uses a rotary magnetic head, the recording position of the synchronizing signal S_V in the signal recording track on a video tape is determined by the above phase difference.

Time periods τ_3 and τ_4 of the output signals S_7 and S_8 from the square-wave generators **15** and **16** are determined, in this embodiment, as follows: When the motor **9** is rotated at the correct rotational speed, for example, at the rotational speed of 30 r.p.s., the time periods τ_3 and τ_4 are selected such that the square-wave signal S_8 from the generator **16** may coincide in generating time with the angle phase pulse S_{6b}. In the invention, the first and second square-wave generators **15** and **16** are formed of monostable multivibrators, respectively, so that the monostable multivibrators are respectively adjusted and hence their time intervals, within which the monostable multivibrators are in unstable state, are controlled to make the width or time duration of their output pulses variable and consequently to set the time periods τ_3 and τ_4 suitably.

As shown in FIGS. **2** to **4**, the square-wave signal S_7 falls from "1" to "0" at the first rotary position signal S_{6a}; rises up from 0 to 1 after the time period of τ_3; and falls again from 1 to 0 at the next first rotary position signal S_{6a}, which is repeated. The square-wave signal S_8 rises up from 0 to 1 when the signal S_7 rises up; falls from 1 to 0 after the time period of τ_4; and rises up from 0 to 1 when the signal S_7 rises up next, which is repeated.

The operation will be now described for the case where the motor **9** is rotated phase lock at the synchronizing signal correctly with as shown in FIG. **2**.

In this case, the pulse S_{6b} obtained from the pulse generator 12b, shown in FIG. 2G, coincides in time interval with the square-wave pulse S_8 shown in FIG. 2I, which is in 1 state, so that the output signal S_{10} from the first sampling circuit **17** is held in 1 state as shown in FIG. 2K. Accordingly, the pulse S_2 from the gate signal generator **3**, shown in FIG. 2C, is reversed in phase by the first NAND-circuit **4** and then fed to one input terminal of the second NAND-circuit **5**. While, the first square-wave generator **15** produces as its output terminal the square-wave pulse S_7 which becomes 0 at the time when the pulse S_{6a} is generated as shown in FIG.

2F, and returns to 1 after the time period τ_3 or at the time before the pulse S_{6b} is generated, as shown in FIG. 2H. Accordingly, the second sampling circuit **18** produces the signal S_9 which is held in 1 continuously, as shown in FIG. 2J. As a result, the second NAND-circuit **5** produces the signal S_3, which is same as that S_2 in waveform and phase, as shown in FIG. 2D. The signal S_3 is fed to the integrator **6** in which the signal S_3 is integrated at its "0" interval and inverted in phase. Thus, the integrator **6** produces the trapezoidal-wave signal S_4 which has the ramp portion as shown in FIG. 2E. The trapezoidal-wave signal S_4 is fed to the sampling-hold gate circuit **7** and is sampled with the pulses S_{6a} and S_{6b} at its ramp interval. As a result, the signal S_{11}, which is varied in amplitude in response to the difference between the pulses S_{6a}, S_{6b} and the synchronizing signal S_V as shown in FIG. 2L, is obtained from the sampling-hold gate circuit **7**.

The amplitude of the sampling-hold signal S_{11} becomes high as the phase of signals S_{6a} and S_{6b} is intended to be delayed with respect to the signal S_V, and becomes low as the phase of signals S_{6a} and S_{6b} is intended to lead. Accordingly, after the signal S_{11} is amplified by the amplifier **8**, if desired, it is applied to the motor **9** to rotate the rotary shaft 9a of motor **9** always at the phase lock condition with the signal S_V.

If the load to the rotary shaft 9a of the motor **9** is removed, the rotational speed of motor **9** increases exceeding the possible phase lock condition. The operation of the system according to this invention in such a state will be now described with reference to FIG. **3**.

In FIG. **3**, the signals S_V and S_1 to S_{11} are obtained from the positions of the system same as those described in connection with FIG. **2**.

As the rotational speed of the motor **9** is increased, as mentioned above, the signal S_{6b} from the second pulse generator **12b** is advanced in phase with respect to both the square-wave signals S_7 and S_8 from the square-wave generators **15** and **16**. As a result, the signals S_9 and S_{10} from the sampling circuits **18** and **17** fall to 0 abruptly as shown in FIGS. **3J** and **3K**, respectively and hence the signal S_3 applied to the integrator **6** becomes 1, as shown in FIG. **3D**. The signal S_3 is integrated thereby and its phase is reversed from 1 to 0 therein. Accordingly, even if the output signal S_4 from the integrator **6** is sampled and held in the sampling-hold gate circuit **7**, the output signal S_{11} from the sampling-hold gate circuit **7** is still 0, as shown in FIG. **3L**. Thus, no current is applied to the motor **9**. In practice, however, there is no need to make the current flowing through the motor **9** completely zero, but a small amount of current could flow through the motor **9**. As a result, the rotational speed of the motor **9** is lowered abruptly and hence the motor **9** returns to the rotation state described in connection with FIG. **2**.

The case where the motor **9** is rotated at a speed lower than the predetermined servo rotational speed, as in the starting of the rotation of motor **9**, will be described with reference to FIG. **4**.

In this case, the time period from the generation of pulse S_{6a} to that of pulse S_{6b} becomes longer than the time period $(\tau_3 + \tau_4)$ as shown in FIG. **4**. Accordingly, the signal S_{6b} from the second pulse generator **12b** becomes coincident with the square-wave signal S_7 from the generator **15** in timing and hence the signals S_9 and S_{10} from the sampling circuits **18** and **17** become 1 and 0 as shown in FIGS. **4I** and **4K**, respectively. Thus, the integrator **6** is supplied, at its input terminal, with the signal of 0 which is integrated and reversed from 0 to 1 thereby and thereafter applied to the sampling-hold gate circuit **7**. The signal S_4 from the integrator **6** is sampled with the signals S_{6a} and S_{6b}. Thus, the sampling-hold gate circuit **7** produces the signal S_{11} with a constant voltage +E, as shown in FIG. **4L**. The signal S_{11} with the constant voltage +E is amplified by the amplifier **8** and then fed to the motor **9**. The voltage +E is much higher than a voltage corresponding to that of a signal within the normal phase range, so that the rotational speed of the motor **9** increases abruptly and arrives at the speed described in connection with FIG. **2**. Thus, even if the rotational speed of motor **9** is rotated at a speed lower than a speed within the predetermined control range, the voltage supplied to the motor **9** is changed to the fixed voltage and hence the motor **9** is abruptly brought to the predetermined phase control range.

With the phase control system of the invention described above, even if the rotational speed of the rotary member is much different from the predetermined one, it is quickly brought to the phase control range to achieve positive phase control.

In the above embodiment the motor **9** is a DC motor, but the present invention can be applied to a non-synchronous AC motor such, for example, as an eddy current motor, and to a synchronous motor. In the case of using the synchronous motor, the output signal from the sampling-hold gate circuit **7** is applied to a variable frequency oscillator and the output of the latter is amplified suitably and then applied to the synchronous motor.

Further, in the above embodiment the servo control is applied to the motor, but the present invention can be equally applied to the case where the rotary shaft **9***a* is not directly coupled to the motor **9**, but rotated by the motor through a slip means such as a belt at a speed higher than a reference speed, and a braking means such as a dynamic braking means is provided for the rotary shaft, which braking means is controlled by the output signal from the amplifier **8**.

Although the illustrative embodiment of the invention has been described in detail herein with reference to the accompanying drawings, it is to be understood that the invention need not be limited to the precise embodiment, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the invention as defined in the appended claims.

I claim as my invention:

1. A phase control system for a rotary member comprising:

reference signal generating means for generating a reference signal representing a predetermined rotary phase relationship for said rotary member; position signal generating means disposed to sense when said rotary member rotates to predetermined angular positions and to generate first and second position signals in response thereto;

square-wave signal generating means for generating a square-wave signal which has a predetermined phase relation with respect to the first position signal generated by said position signal generating means;

comparator means for comparing the second position signal generated by said position signal generating means with the square-wave signal, said comparator means exhibiting a first condition when the second position signal is in phase leading relationship with respect to said square-wave signal, a second condition when the second position signal is in phase lagging relationship with respect to said square-wave signal, and a third condition when the second position signal is in a predetermined phase range with respect to said square-wave signal; and

control signal generating means for generating a control signal to control the rotation of said rotary member in accordance with the phase relationship between said reference signal and at least one of said first and second position signals and further in accordance with the condition exhibited by said comparator means.

2. A phase control system according to claim **1** further comprising braking means for controlling the rotation of said rotary member, said braking means being controlled by said control signal generated by said control signal generating means.

3. A phase control system according to claim **1** in which said rotary member is rotated by a motor, said motor being controlled in phase by the control signal generated by said control signal generating means.

4. A phase control system according to claim **1** wherein said square-wave signal generating means comprises first monostable multivibrator means responsive to the first position signal for producing a first square-wave signal having a frequency equal to the frequency of the first position signal and having a first predetermined pulse width; and second monostable multivibrator means responsive to said first square-wave signal for producing a second square-wave signal having a frequency equal to the frequency of the first position signal and having a second predetermined pulse width.

5. A phase control system in accordance with claim **4** wherein said comparator means comprises first sampling means responsive to said first square-wave signal and the second position signal for producing a first output signal when said second position signal coincides with said first predetermined pulse witdth and for producing a second output signal when said second position signal does not coincide with said first predetermined pulse width; and second sampling means responsive to said second square-wave signal and the second position signal for producing a third output signal when said second position signal coincides with said second predetermined pulse width and for producing a fourth output signal when said second position signal does not coincide with said second predetermined pulse width.

6. A phase control system according to claim **5** wherein said control signal generating means comprises coincidence means responsive to said reference signal and said first, second, third and fourth output signals to generate a periodic signal having a frequency equal to the frequency of said reference signal when said second and third output signals coincide, a first level signal when said first and fourth output signals coincide, and a second level signal when said second and fourth output signals coincide; and further sampling means coupled to said coincidence means and said position signal generating means for sampling the signals generated by said coincidence means with said first and second position signals.

7. A phase control system according to claim **6** wherein said control signal generating means further comprises integrating means coupled to said coincidence means for producing a signal proportional to the time integral of said signals generated by said coincidence means, the signal produced by said integrating means having a limiting value; and wherein said further sampling means comprises a sample-and-hold circuit coupled to said integrating means for sampling the signal produced by said integrating means at sample times established by said first and second position signals and for storing the sampled signal between successive sampling times.

8. A phase control system according to claim **7** wherein said position signal generating means comprises first and second magnetic pick-up means spaced apart by a predetermined angular amount and positioned proximate the rotary member for sensing the passage of a magnetic element carried by the rotary member as said rotary member rotates.

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