

SPECIFICATION

Motor drive control system

The present invention relates to a direct-current (DC) motor drive control system and, more specifically, to a position control system for a DC motor operating in an analog mode.

Conventional systems designed to control the rotation of a DC motor make use of an encoder, i.e., a rotary encoder. Such systems have, however, been capable of regulating only the angular position or displacement and incapable of controlling the angular velocity as well. Consequently, in order to be controllable as regards the velocity as well, the prior arrangements must be equipped with a rate generator additionally directly coupled to the DC motor so that signals generated therein can be fed back to the driver circuit for regulating the rotary velocity of the motor. Such additional provision of a rate generator is disadvantageous in that it renders the system undesirably bulky, complex and costly.

Accordingly, the present invention seeks to provide a DC motor control system in which both the position and the velocity of the output member of the motor are controllable in a desired way, but without the need for such a separate rate generator.

The present invention also seeks to provide a control system which (a) permits the DC motor to rotate with rapid control response and stability in accordance with input command signals; (b) is capable of terminating rotation of the DC motor extremely accurately at a commanded angular position; and (c) has simplified maintenance and checking or is substantially trouble-free.

Thus the present invention is characterized not only by the elimination of the said rate generator, but also by, *inter alia*, the use of single sensing means or encoder, i.e. a rotary encoder, coupled in a sensing relationship with the DC motor for providing both "position" and "velocity" feedback signals for the control of rotation or angular displacement with precision and stability in accordance with an input command signal.

In accordance with the present invention there is provided a system arranged to controlledly drive a DC motor so as to effect a predetermined continuous angular displacement of an output member of said motor, which system comprises: a driver circuit for energizing a said motor; a command source for providing a sequence of input command pulses as an input position command for predetermining said continuous angular displacement of said output member, each such command pulse representing a desired predetermined angular displacement of said motor output member; an encoder coupled with said output member so as to respond throughout the course of said continuous displacement to the instantaneous angular position of said output member by producing a sequence of pulses for providing (a) a first sensed signal representing said instantaneous angular position and (b) a

second sensed signal representing the instantaneous angular velocity of said output member; and signal processor circuit means responsive, throughout said predetermined continuous angular displacement of said output member, to (1) each consecutive pulse of said sequence of input command pulses and to (2) said first and second sensed signals, instantaneously to produce one or more control signals and instantaneously to apply it or them to said driver circuit in such a manner that said motor is energized controlledly in dependence upon (i) the instantaneous difference between the instantaneous commanded and sensed angular positions and (ii) said instantaneous angular velocity.

In accordance with a more specific aspect of the invention, command and sensed signals may be applied to a comparator circuit, e.g., a differential counter, which provides a position drive signal. The sensed signal pulses outgoing from the encoder may also be applied to a frequency-voltage converter for producing a voltage signal (the "second sensed signal") representing the angular velocity of the DC motor output member. The position drive signal transformed into an analog signal and the velocity voltage signal may be combined at an analog comparator, e.g., a differential amplifier, which produces a comparison signal. The latter upon conversion to a frequency signal may then be applied to an operational or power amplifier in the driver circuit so as to allow the DC motor to be drive-controlled as to its output angular position and velocity. The operational or power amplifier may have an additional input fed by a sign generator which in response to the position-command signal from the command source provides a sign signal indicating the direction in which the DC motor is to be driven.

In an alternative embodiment of the invention, the command source may provide both position and velocity command signals which are combined with sensed position and velocity signals from the encoder, respectively, at distinct comparator circuits, e.g. differential counters. The output of the position signal comparator upon conversion to an appropriate analog value is applied to the driver circuit so that the motor may be driven precisely until it reaches the commanded position. The voltage comparison signal is likewise converted into a corresponding analog signal which is applied to a current regulating element, e.g. a transistor, in the driver circuit to control the magnitude of a drive current energizing the DC motor, thereby controlling the rate of rotation or velocity of the DC motor.

The present invention also provides a method of controlledly driving a DC motor so as to effect a predetermined continuous angular displacement of an output member of the motor.

The foregoing and other features and advantages of the invention will be apparent from the following more particular description of certain exemplary embodiments of the invention

as illustrated in the accompanying drawings, in which:—

Fig. 1 is a block diagram of a conventional drive control system for a DC motor;

Fig. 2 is a schematic diagram of one embodiment of a DC motor control system according to the present invention;

Fig. 3 is a similar diagram of another embodiment of a DC motor control system according to the present invention; and

Fig. 4 is a block diagram illustrating a further embodiment according to the present invention.

In Fig. 1 there is shown a conventional drive control system applied to a DC motor 1 energized by a driver circuit 2. The input to the driver circuit 2 includes a command source 3, and the DC motor has an encoder 4 coupled thereto. The signal from source 3 and a feedback signal from the encoder 4 are combined at a differential counter 5. The latter thus provides differential digital pulses which are converted by a D-A (digital-analog) converter 6 into an analog signal for application to drive circuit 2 to continuously rotate the DC motor 1 until a commanded angular position is reached. In order to control the DC motor 1 as to its velocity as well, a rate generator 7 is additionally provided directly coupled to the DC motor to provide a velocity signal. The latter is compared with a reference level set at an input 8a of a control circuit 8 to apply a resulting differential velocity signal to the driver circuit 2. As noted previously, provision of the rate generator 7 renders the system undesirably bulky, complex and expensive.

In Fig. 2 there is shown a DC motor drive control system of the present invention which as in the prior system as described operates in response to drive signals from the command source 3 and includes the encoder 4 coupled to the DC motor 1 controlled by the driver circuit 2. The command signal is a pulse train and the source 3 may comprise a register for memorizing and producing the pulse train from the readout of drive information stored on a record medium, a ROM (read-only-memory) assembly for memorizing and selectively regenerating the pulse train, or a signal processor coupled with an electrical machining gap to produce the pulse train representing a machining gap condition.

A signal comparator 9 is provided which receives on the one hand the input signal from the command source 3 and on the other hand a sensed position feedback signal provided by the encoder 4 to produce an output position drive signal upon comparing the input and sensed signals. The comparator 9 may be a differential counter. A D-A (digital-analog) converter 10 converts the digital position drive signal from the comparator 9 into a corresponding analog form which is applied to a differential control or comparator circuit 11 (that may take the form of a differential amplifier).

In accordance with the present invention, the encoder 4 is adapted to supply not only the position feedback signal to the comparator 9 but

also a velocity feedback signal, the latter in this embodiment being applied via a FV (frequency-voltage) converter 12 to the differential control or comparator circuit 11. The FV converter 12 transforms the digital velocity signal, i.e., a number of pulses per unit time or frequency, produced by the encoder 4 in response to rotation of the motor 1 into an analog signal represented as a voltage. Accordingly, a differential analog signal produced as a result of comparison of the position drive signal and the velocity signal is issued from the control or comparator circuit 11. A V-F (voltage-frequency) converter 13 is provided which converts the differential analog signal into a train of pulses of a corresponding frequency, which pulses are in turn applied to the driver circuit 2 at a first input. A second input of the driver circuit 2 is fed from a sign generator 14 which discriminates between the two signs (+, -) of the command signal received from the command source 3 to apply a corresponding signal to the drive circuit 2. The driver circuit is shown comprising an operational or power amplifier 21 (fabricated in an integrated circuit module), a power supply 22, and transistor switches Tr1, Tr2, Tr3 and Tr4 arranged to be selectively energized in pairs (Tr1+Tr4, Tr2+Tr3) to energize the motor 1 and so cause it to rotate in either a positive or a negative angular direction respectively.

In operation, the motor 1 is rotated under control by switches Tr1, Tr2, Tr3 and Tr4, either pair of which Tr1 and Tr4 or Tr2 and Tr3 is alternately turned on and off depending on the direction in which the motor is to be rotated. The angular displacement of motor 1 is detected by the encoder 4 producing pulses corresponding to the angular displacement effected. The encoder 4 thus provides a position signal in the form of the number of pulses produced, and a velocity signal which is represented by the number of pulses produced per unit time. The comparator circuit 9 receives the position command signal in the form of a pulse train from the source 3, and from the encoder 4 a pulse train representing the detected or sensed position signal, and processes the two signals to provide an output signal which represents said position drive signal in the form of digital pulses. The latter pulses are converted by the D-A converter 10 into a corresponding analog signal in the form of a voltage magnitude. On the other hand, the F-V converter 12 converts the detected pulse frequency at the encoder into a proportional voltage signal. The two voltage signals are applied to the differential control circuit or comparator 11 and are compared therein with one another to result in a differential signal.

Let it be assumed that a command signal is now applied to the system from the command source 3 to cause the motor 1 to perform a predetermined angular displacement. In the initial stage in which the command signal is applied, the rate of rotation detected by the encoder 4 is still so small that the velocity signal transmitted to the

comparator 11 from the F-V converter 12 is much smaller than the signal that it receives from the D-A converter 10. As a consequence, a large differential signal is produced by the comparator 11 and this results in digital pulses of a high frequency at the output of the V-F converter 13 and hence at the first input of the driver circuit 2. In the latter, with the switches Tr1 and Tr4 selectively placed under switching control (Tr2 and Tr3 being inactive), these switches are turned on and off to energize the motor 1 with a current flowing from power supply 22, through switch Tr1, motor 1, switch Tr4 and back to the supply 22, pulsed at that high frequency. Thus, the rate of rotation or velocity of the motor 1 (which is proportional to the frequency at which the switches are turned on) is controlled so as to be high in the initial stage of a predetermined displacement.

As the rate of rotation increases, the encoder 4 output applied to the comparator 11 increases and accordingly the F-V converter 13 output applied to the driver circuit 2 decreases, so that the frequency of drive pulses energizing the motor 1 is reduced. This continues until the commanded displacement of the motor 1 is completed upon equalisation of the numbers of the sensed position pulses and the command drive pulses, whereupon the motor 1 comes to a stop.

The sign generator 14 determines, from the signal incoming from the command source 3, the direction in which the motor 1 is intended to be driven, and produces an appropriate signal which selectively activates the pair of transistors Tr1 and Tr4 or the pair of transistors Tr2 and Tr3 for control of the motor 1 so as to rotate it in the positive or the negative direction, respectively.

The signal comparator 9 thus continues to output position drive pulses so as to continue to rotate the motor 1 until the position command signal and the encoder 4 output signal become equal. Completion of the commanded displacement is detected when the encoder-produced signal coincides with the command signal. Coincidence between the two terminates the operation of driver circuit 2 to halt the rotation of the motor 1. The determination of the sign of the command signal provides determination of the drive direction so that for every command signal an angular displacement of the motor over a commanded distance in a commanded direction is effected.

The comparison of the position drive signal dependent upon the command signal with the velocity signal and the use of the resulting differential signal to control the drive circuit 2 operating the motor 1 have advantages. Thus, an overtravel is effectively prevented, and positioning is achieved with extreme accuracy and promptness due to an acceleration of drive in the initial stage and a continuous deceleration thereafter, which are achieved by a proportional frequency control of the drive pulses.

In an embodiment illustrated in Fig. 3, the command source 3 provides both a position

command signal and a velocity command signal. The position command signal is again applied to a signal comparator circuit 9 adapted to receive the position feedback signal from the encoder 4. The comparator circuit 9 which may again be a differential counter outputs differential digital pulses which are transformed by the D-A converter 10 to a corresponding analog signal. The latter is modified in an A-V (analog-voltage) converter 11 to result in an appropriate continuous signal which is applied to an operational or power amplifier 21 in the drive circuit. The amplifier has a second input fed by the sign generator 14 and a third input which is grounded as in the previous embodiment.

The velocity command signal is applied from the source 3 to a comparator circuit 15 adapted to receive the velocity feedback signal from the encoder 4. The comparator circuit 15 which may again be a differential counter thus outputs a differential velocity drive signal in the form of digital pulses or a frequency signal which is transformed by a F-V converter 16 into a voltage signal which is applied to a current-control transistor Tr5 provided additionally in the drive circuit 2, the latter being basically identical to that of the previous embodiment. In this embodiment, a further switch 17 is connected in parallel with the motor 1 and is energized by a control circuit 18 controlled from the comparator circuit 9 to assure a precise positioning of the motor as it is brought to a stop.

In the driver circuit 2, transistors Tr1 and Tr4 are operated in unison to energize the motor 1 to cause it to rotate in the positive direction. Likewise, transistors Tr2 and Tr3 are operated in unison to energize the motor 1 to cause it to rotate in the negative direction. As in the previous embodiment, the signal comparator circuit 9 continues to provide position drive signals so as to have the motor 1 continuously rotated by the driver circuit 2 until the position command signal from the source 3 and the detected position signal coincide with each other i.e. become equal.

For each positioning command, the source 3 simultaneously provides a velocity signal represented by a number of clock pulses per unit time which is compared at the comparator circuit 15 with the detected velocity signal coming from the rotary encoder 4. The encoder 4 provides a pulse train whose frequency is proportional to the rate of rotation of the motor 1. The comparator circuit 15 thus provides a velocity drive signal or frequency output which upon conversion into a corresponding voltage signal at a F-V converter 16 is applied to the transistor Tr5.

In response to a positioning command the motor 1 is driven initially at a low velocity. In this state, the velocity signal detected by the encoder 4 is smaller than the command velocity signal so that a greater frequency signal is generated by the comparator circuit 15 and a greater voltage signal is applied to the transistor Tr5. The latter thus has its effective resistance reduced to permit a drive current of increased magnitude to be passed

therethrough and through the motor 1 to raise its rate of rotation. This continues until a predetermined rate of rotation is reached, at which the frequency signal levels down to a given value and the transistor Tr5 has consequently its resistance increased so as to reduce the drive current to a given level and so cause the motor to rotate at a constant velocity.

When the position drive signal from the comparator 9 becomes nil to bring the motor to a stop, not only is the operation of the driver circuit 2 terminated but an additional control is effected in this embodiment by means of the transistor switch 17 which is turned on to shunt and thereby short-circuit the motor 1 to ensure a prompt stoppage of the motor. Thus in this state, the comparator 9 transmits a stop signal to the control circuit 18 which in turn renders the switch 17 conductive. This arrangement is especially advantageous when the motor 1 drives a high-inertia load.

In Fig. 4 there is shown a modification of the embodiment just described, in which the position drive signal from the comparator 9 is applied via the D-A converter 10 and an A-D (analog-digital) converter 10A to a F-V converter 19 which in turn feeds into the first input of an AND gate 20 connected to the input of the driver circuit 2. The AND gate 20 has a second input fed with the velocity drive signal coming from the comparator circuit 15. Thus, in this embodiment, frequency-modulated signal pulses are applied to the driver circuit 2 to attain control both as regards the position and velocity of the motor 1.

In the foregoing description, it should be noted that the encoder 4 may be of optical, electromagnetic or any other appropriate type. Comparator circuits (i.e. processors) 9 and 15 may take the form of a differential counter, digital comparator, preset counter or up-down counter. They may be constructed to be settable by a command signal from the source 3 to initiate counting signal pulses from the encoder 4. The encoder output may be differentiated and then integrated with a time-constant network to produce a directly converted velocity signal.

Claims

1. A system arranged to controlledly drive a DC motor so as to effect a predetermined continuous angular displacement of an output member of said motor, the system comprising: a driver circuit for energizing a said motor; a command source for providing a sequence of input command pulses as an input position command signal for predetermining said continuous angular displacement of said output member, each such command pulse representing a desired predetermined angular displacement of said motor output member; an encoder coupled with said output member so as to respond throughout the course of said continuous displacement to the instantaneous angular position of said output member by producing a sequence of pulses for providing (a) a first sensed signal representing

65 said instantaneous angular position and (b) a second sensed signal representing the instantaneous angular velocity of said output member; and signal processor circuit means responsive, throughout said predetermined continuous angular displacement of said output member, to (1) each consecutive pulse of said sequence of input command pulses and to (2) said first and second sensed signals, instantaneously to produce one or more control signals and instantaneously to apply it or them to said driver circuit in such a manner that said motor is energized controlledly in dependence upon (i) the instantaneous difference between the instantaneous commanded and sensed angular positions and (ii) said instantaneous angular velocity.

2. The system defined in Claim 1 wherein said processor circuit means includes a first comparator responsive to said input position-command signal and to said first sensed signal for producing in response thereto a position drive signal; and a second comparator responsive to said second sensed signal and said position drive signal for producing in response thereto said one control signal and applying it to said driver circuit.

3. The system defined in Claim 2 wherein said input position-command signal comprises a first pulse train and said first sensed signal comprises a second pulse train, said first comparator comprising a differential counter responsive to said first and second pulse trains to produce therefrom differential digital pulses, and said signal processor circuit means including (a) a digital-analog converter for transforming said differential digital pulses to an analog signal; (b) a frequency-voltage converter responsive to said second pulse train to produce (as said second sensed signal) a voltage signal representing the frequency of that second train; (c) a differential amplifier constituting said second comparator and responsive to said analog signal and said voltage signal to produce a differential voltage signal; and (d) a voltage-frequency converter for transforming said differential voltage signal to a third pulse train constituting said one control signal.

4. The system defined in any one of the preceding claims wherein said signal processor circuit means comprises a sign generator responsive to said position-command signal for selectively providing a plus or a minus sign signal in accordance with the sign of said position-command signal, said driver circuit including a first pair of semiconductor switches adapted to pass an energizing current through said DC motor in a positive direction to rotate said output member in a positive angular direction and a second pair of semiconductor switches adapted to pass the energizing current through said DC motor in a negative direction to rotate said output member in a negative direction, said first and second pairs being selectively actuated in response to said plus and minus sign signals, respectively.

5. The system defined in Claim 1 wherein said



therethrough and through the motor 1 to raise its rate of rotation. This continues until a predetermined rate of rotation is reached, at which the frequency signal levels down to a given value and the transistor Tr5 has consequently its resistance increased so as to reduce the drive current to a given level and so cause the motor to rotate at a constant velocity.

When the position drive signal from the comparator 9 becomes nil to bring the motor to a stop, not only is the operation of the driver circuit 2 terminated but an additional control is effected in this embodiment by means of the transistor switch 17 which is turned on to shunt and thereby short-circuit the motor 1 to ensure a prompt stoppage of the motor. Thus in this state, the comparator 9 transmits a stop signal to the control circuit 18 which in turn renders the switch 17 conductive. This arrangement is especially advantageous when the motor 1 drives a high-inertia load.

In Fig. 4 there is shown a modification of the embodiment just described, in which the position drive signal from the comparator 9 is applied via the D-A converter 10 and an A-D (analog-digital) converter 10A to a F-V converter 19 which in turn feeds into the first input of an AND gate 20 connected to the input of the driver circuit 2. The AND gate 20 has a second input fed with the velocity drive signal coming from the comparator circuit 15. Thus, in this embodiment, frequency-modulated signal pulses are applied to the driver circuit 2 to attain control both as regards the position and velocity of the motor 1.

In the foregoing description, it should be noted that the encoder 4 may be of optical electromagnetic or any other appropriate type. Comparator circuits (i.e. processors) 9 and 15 may take the form of a differential counter, digital comparator, preset counter or up-down counter. They may be constructed to be settable by a command signal from the source 3 to initiate counting signal pulses from the encoder 4. The encoder output may be differentiated and then integrated with a time-constant network to produce a directly converted velocity signal.

Claims

1. A system arranged to controlledly drive a DC motor so as to effect a predetermined continuous angular displacement of an output member of said motor, the system comprising: a driver circuit for energizing a said motor; a command source for providing a sequence of input command pulses as an input position command signal for predetermining said continuous angular displacement of said output member, each such command pulse representing a desired predetermined angular displacement of said motor output member; an encoder coupled with said output member so as to respond throughout the course of said continuous displacement to the instantaneous angular position of said output member by producing a sequence of pulses for providing (a) a first sensed signal representing

65 said instantaneous angular position and (b) a second sensed signal representing the instantaneous angular velocity of said output member; and signal processor circuit means responsive, throughout said predetermined continuous angular displacement of said output member, to (1) each consecutive pulse of said sequence of input command pulses and to (2) said first and second sensed signals, instantaneously to produce one or more control signals and instantaneously to apply it or them to said driver circuit in such a manner that said motor is energized controlledly in dependence upon (i) the instantaneous difference between the instantaneous commanded and sensed angular positions and (ii) said instantaneous angular velocity.

2. The system defined in Claim 1 wherein said processor circuit means includes a first comparator responsive to said input position-command signal and to said first sensed signal for producing in response thereto a position drive signal; and a second comparator responsive to said second sensed signal and said position drive signal for producing in response thereto said one control signal and applying it to said driver circuit.

3. The system defined in Claim 2 wherein said input position-command signal comprises a first pulse train and said first sensed signal comprises a second pulse train, said first comparator comprising a differential counter responsive to said first and second pulse trains to produce therefrom differential digital pulses, and said signal processor circuit means including (a) a digital-analog converter for transforming said differential digital pulses to an analog signal; (b) a frequency-voltage converter responsive to said second pulse train to produce (as said second sensed signal) a voltage signal representing the frequency of that second train; (c) a differential amplifier constituting said second comparator and responsive to said analog signal and said voltage signal to produce a differential voltage signal; and (d) a voltage-frequency converter for transforming said differential voltage signal to a third pulse train constituting said one control signal.

4. The system defined in any one of the preceding claims wherein said signal processor circuit means comprises a sign generator responsive to said position-command signal for selectively providing a plus or a minus sign signal in accordance with the sign of said position-command signal, said driver circuit including a first pair of semiconductor switches adapted to pass an energizing current through said DC motor in a positive direction to rotate said output member in a positive angular direction and a second pair of semiconductor switches adapted to pass the energizing current through said DC motor in a negative direction to rotate said output member in a negative direction, said first and second pairs being selectively actuated in response to said plus and minus sign signals, respectively.

5. The system defined in Claim 1 wherein said



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signal processor circuit means includes a first comparator responsive to said piston-command signal and to said first sensed signal for producing in response thereto a position drive signal; and a
5 second comparator responsive to an input velocity command signal provided by said command source and to said second sensed signal to provide a differential velocity signal, said position drive signal and said differential velocity
10 signal constituting said control signals.

6. The system defined in Claim 5 wherein said driver circuit includes an operational or power amplifier responsive to said position drive signal for energizing said motor, and a current-regulating element responsive to said differential
15 velocity signal for controlling the magnitude of a drive current energizing said DC motor.

7. The system defined in Claim 5 or 6 wherein said first comparator includes a differential
20 counter responsive to said position-command signal and said first sensed signal to produce differential digital pulses, a digital-analog converter for converting said digital pulses into an analog signal, and an analog-voltage converter for
25 transforming said analog signal into a modified voltage signal constituting said position drive signal.

8. The system defined in any one of Claims 5 to 7 wherein said second comparator includes a
30 differential counter responsive to said velocity command signal and said second sensed signal to produce differential digital pulses constituting said differential velocity signal.

9. The system defined in Claim 6, or Claim 7 or
35 8 when appendant directly or indirectly to Claim 6, wherein said signal processor circuit means further includes a sign generator responsive to said position-command signal for providing a positive or a negative sign signal in accordance
40 with the sign of said position command signal and applying it to said operational or power amplifier so as to vary accordingly the sense of the energization of said motor.

10. The system defined in any one of the
45 preceding claims, further comprising switch means connected in parallel with said DC motor and adapted to be turned on when said difference of said commanded and sensed angular positions of said output member falls to zero value, so as to
50 shunt said motor thereby.

11. A position control system for a DC driving motor, constructed, arranged and adapted to
operate substantially as hereinbefore described with reference to, and as illustrated in any one of
55 Figures 2 to 4 of the accompanying diagrammatic drawings.

12. The system defined in any one of the

preceding claims wherein said command source
comprises a register for memorizing and
60 producing a pulse train which constitutes an input command signal from the readout of drive information stored on a record medium.

13. The system defined in any one of the
Claims 1 to 11 wherein said command source
65 comprises a read-only-memory assembly for memorizing and selectively regenerating a pulse train which constituted an input command signal.

14. The system defined in any one of the
Claims 1 to 11 wherein said command source
70 comprises a signal processor coupled with an electrical machining gap to produce a pulse train representing a machining gap condition and constituting an input command signal.

15. A DC motor provided with a position
75 control system as defined in any preceding claim.

16. A method of controlledly driving a DC motor so as to effect a predetermined continuous angular displacement of an output member of
said motor, the method comprising: energizing a
80 said motor by a driver circuit; providing a sequence of input command pulses as an input position command signal for predetermining said continuous angular displacement of said output member, each such command pulse representing
85 a desired predetermined angular displacement of said motor output member; throughout the course of said continuous displacement sensing the instantaneous angular position of said output member and producing in response thereto a
90 sequence of pulses for providing (a) a first signal representing said sensed instantaneous angular position and (b) a second signal representing the instantaneous angular velocity of said output member; and responsive, throughout said
95 predetermined continuous angular displacement of said output member, to (1) each consecutive pulse of said sequence of input command pulses and to (2) said first and second signals, instantaneously producing one or more control
100 signals and instantaneously applying it or them to said driver circuit in such a manner that said motor is energized controlledly in dependence upon (i) the instantaneous difference between the instantaneous commanded and sensed angular
105 positions and (ii) said instantaneous angular velocity.

17. A method of controlledly driving a DC motor so as to effect a predetermined continuous angular displacement of an output member of
said motor, substantially as hereinbefore
110 described with reference to any one of the Figures 2 to 4 of the accompanying diagrammatic drawings.