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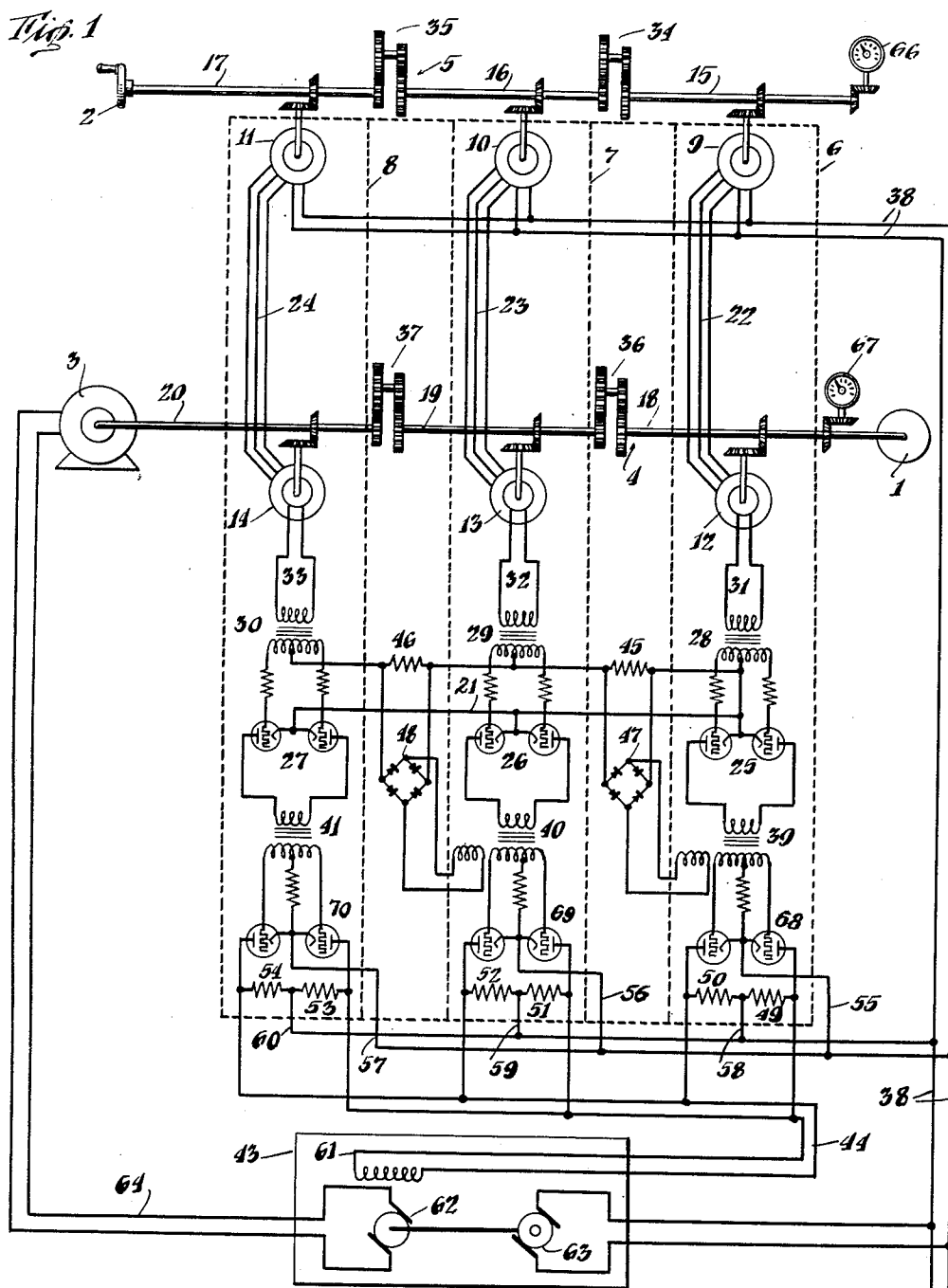
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2,560,337

THREE-CHANNEL FINE-COARSE CONTROL SYSTEM

Filed June 25, 1948

2 Sheets-Sheet 1



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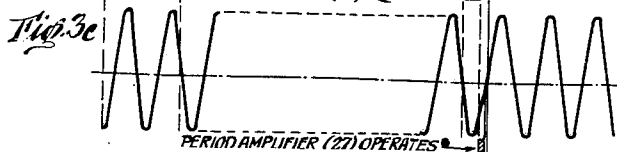
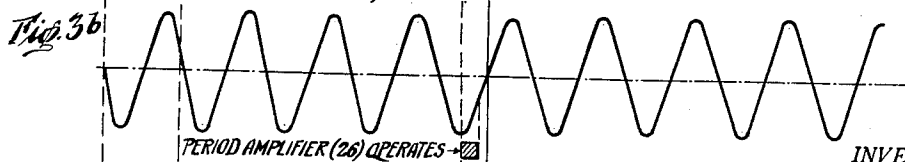
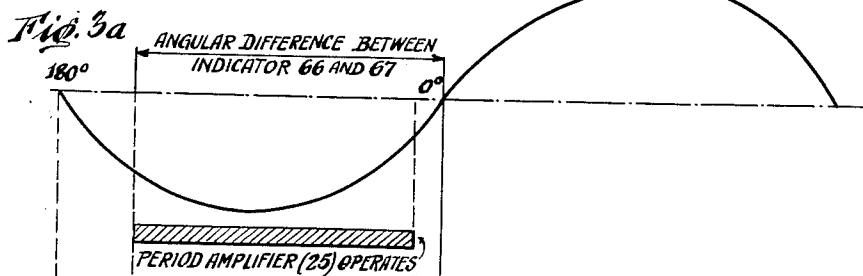
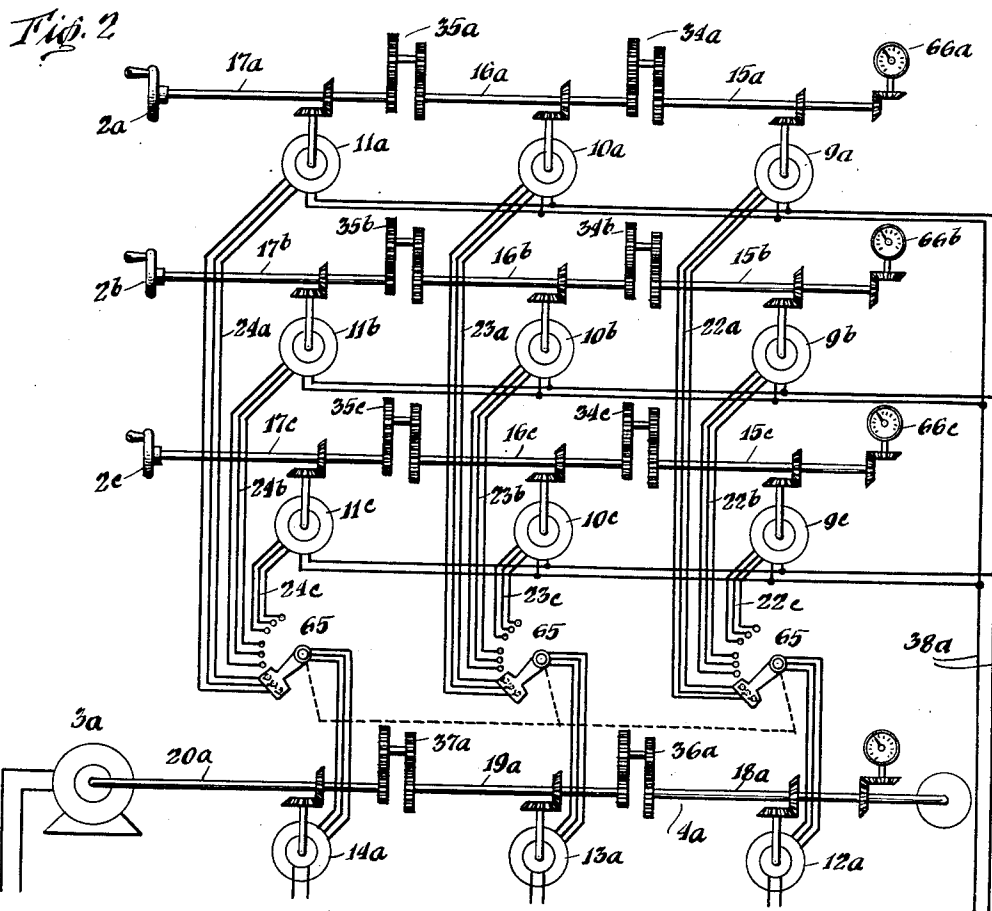
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2 Sheets-Sheet 2



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THREE-CHANNEL FINE-COARSE
CONTROL SYSTEM

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6 Claims. (Cl. 318—30)

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The present invention relates generally to improvements in control systems and more particularly to control systems adapted to be used to adjust a mechanism to a particular setting.

In the operation of machinery of the rotatable or translatable type it is often necessary to adjust the movable members to different positions with speed and accuracy. In industry the movable parts of rolling mills, presses, cutting machines and other types of machinery often have to be rapidly changed from one accurate setting to another to shape the worked piece to dimensions with minimum of tolerance or error. Also in military and naval services it is desirable to change gun turrets, antenna and the like from one azimuth and elevation to another azimuth and elevation with the least delay in time and with the greatest accuracy and precision.

The present invention aims to provide a control device which may adjust the various types of mechanisms more rapidly than previous devices and with a greater degree of accuracy.

An object of this invention is to provide a new and improved control device.

Another object of the invention is to provide a control device adapted to rapidly and accurately obtain various desired settings of elements or parts of machinery and the like.

A further object of the invention is to provide a control device for adjusting the working elements of machines and the like with greater accuracy.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for purposes of illustration and description and is shown in the accompanying drawings, forming a part of the specification, wherein:

Fig. 1 shows a schematic diagram of one embodiment of the invention;

Fig. 2 shows a schematic diagram of another embodiment providing for a plurality of advance settings; and

Figs. 3a, b, c show a graphical representation of the adjusting signals.

Referring generally to Fig. 1 of the drawings there is shown a control system adapted to

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adjust parts or elements of a rotatable or movable machine such as a turntable, turret, roller, or the like to a particular position designated by the presetting mechanism or hand wheel 2. The machine 1 may be driven by a motor 3 through a drive coupling unit 4 connecting the motor 3 to the machine 1. The preset mechanism 2 which may be a motor, another machine or, as in this embodiment, a hand wheel, is connected to a presetting coupling unit 5 for coupling the presetting mechanism 2 to a position indicator 66. The drive coupling unit 4 and coupling unit 5 are electrically interconnected by a plurality of differential control circuits for comparing the settings of the preset mechanism 2 with the machine 1 and to create an adjusting signal corresponding to the difference in these settings to drive the motor 3. The adjusting signal is applied successively by the control circuits to a controller 43 designed to actuate the motor 3 in accordance with the adjusting signal, each succeeding signal resulting in a finer or closer adjustment of the position of the machine 1 to the desired position.

The control circuits may be of any synchronous type but in this embodiment the synchronous generator and synchronous transformer type are preferred. In each circuit the generator is coupled to and driven by the presetting coupling unit 5, and the transformer is coupled to and driven by the drive coupling unit 4. The synchronous generators and transformers of the control circuits may be coupled to these coupling units in many different ways to attain successive voltages of finer and closer adjustment of the machine to the desired position; however, it is preferable that the control circuits should have an effectively different turn relation. With control circuits of substantially the same electrical characteristics the generators of each control circuit are preferably coupled to the presetting coupling unit in different turn relations so that for a particular change in the setting of the presetting mechanism each control circuit providing a succeeding adjusting voltage will have the generator revolving a greater number of turns than the generator of the control circuit of the preceding voltage. Similarly the synchronous transformers are coupled in different turn relations to the driven machine 1 and in the same turn relation with the corresponding generator of the same synchronous control circuit. Various suitable coupling arrangements

may be used. The ones in the drawings are illustrated for purposes of clarity of explanation and are not intended to limit the invention to the particular mode shown.

In Fig. 1 the control system has three synchronous control circuits 6, 7, 8 providing for first, second and third adjustment of the machine 1 respectively with the outputs coupled to the controller 43 to impress the successive adjusting voltages thereon. Shaft 16 and generator 10 are driven at a reduced number of turns by reduction gear 35 coupled to shaft 17, and shaft 15 and generator 9 are driven at a further reduced number of turns by reduction gear 34 coupled to shaft 16.

Similarly the rotors of the transformers 12, 13, 14 may be coupled to shafts 18, 19, 20 of the driving coupling unit 4 with the reduction gears 21, 22 of the same reduction ratio as reduction gears 9, 10 coupling shafts 18, 19 and 19, 20, respectively so that the synchronous transformers and the synchronous generators of the same control circuit make the same number of turns. The generator and transformer of each unit are preferably arranged to have zero error voltage when these rotors are at the same angular setting.

With the synchronous generator and synchronous transformers of the control circuits 6, 7, 8 coupled in this manner it is seen that the rotor of the synchronous generator 9 and the rotor of the synchronous transformer 12 of control circuit 6 may be in substantially the same angular setting, and therefore not providing any further adjusting signal, while the rotor of the synchronous generator 10 and the rotor of the synchronous transformer 13 of the control circuit 7 will be sufficiently out of angular coincidence to produce an adjusting signal to further correct the position of the machine 1 adjusting it closer to the desired position. Similarly the generator and transformer of the control circuit 8 will produce a substantial adjusting signal after the voltage of the control circuit 7 becomes negligible.

Referring now to the electrical arrangement of the control device the rotors of synchronous generators 9, 10, 11 are connected to an alternating current reference line 38. The stators of the generators 9, 10, 11 and transformers 12, 13, 14 are preferably of the three phase type. The three conductor lines 22, 23, 24 connect the windings of the respective stators of the generators and transformers and transmit the angular position of the rotors of the generators in the form of electrical voltages to the stator windings of the respective transformers. If the rotors of a transformer are not in proper relation with the rotor of the respective generator an adjusting voltage will be produced therein and appear across the terminals of the winding.

The rotors of the synchronous transformers 12, 13, 14 are coupled to the input of the amplifiers 25, 26, 27 respectively by the transformers 28, 29, 30. The primary windings of the coupling transformers 28, 29, 30 are connected to the windings of the rotors of the synchronous transformers 12, 13, 14 by the pairs of conductors 31, 32, 33.

The amplifiers 25, 26, 27 may be of any conventional type but are preferably of the "push pull" type design so that the plate current is zero unless an error signal is impressed upon the input. The error signal thus amplified may be impressed in its alternating form on a motor control circuit, or preferably as in this embodiment to rectify the amplified signal by rectifiers

68, 69, 70 and to impress a unidirectional voltage on the control generator of the controller 43. The polarity of the voltage determines the direction of rotation of the motor 3. The rectifiers

68, 69, 70 each comprise a pair of vacuum tubes preferably of the triode type also coupled in push pull arrangement. The grids are connected to the secondary of the transformers 39, 40, 41 coupling the output of the amplifiers to the input of the respective rectifiers. The plates are coupled across the series resistances 49, 50; 51, 52; 53, 54 respectively. The error signal produced by the generator and transformer is either in phase or in phase opposition with the voltage of line 38 depending on the direction of the smallest angular difference between the position of the generator and transformer rotors. Therefore by rendering the rectifiers conductive on alternate half cycles the polarity of the error voltage will be either positive or negative depending on the phase relation. This is accomplished by connecting the line voltage 38 between the cathodes and the plates of the rectifiers. Lines 55, 56, 57 connect one conductor of line 38 to the cathodes; and lines 58, 59, 60 connect the other conductor of line 38 to the plates of the rectifiers through the load resistors. With this arrangement the plates of the rectifiers are simultaneously rendered positive. The polarity of the unidirectional output voltage will then depend upon whether the error signal impressed on the grids and the line voltage are in or out of phase.

The unidirectional error voltages of the rectifiers are applied to the controller 43 over a common line 44. The output of the rectifiers, series load resistors 49, 50; 51, 52; 53, 54, are connected respectively in parallel across the line 44. Interference between the output voltages of the rectifiers 68, 69, 70 is prevented by blocking all except one of the conducting amplifiers. At the input of each of the amplifiers a common blocking circuit is provided so that a conducting amplifier will block the amplifiers of the finer adjusting control circuits and provide the unidirectional adjusting signal to appear across line 44. In this embodiment the blocking circuit comprises a common biasing arrangement on the input circuits of the amplifiers 26, 27. The grids of the amplifier 27 are connected to the cathodes of the amplifier through the resistors 46 and 45 connected in series and the common line 21 or ground connecting all the cathodes. The grids of amplifier 26 are coupled to the cathodes through the resistor 45. A negative voltage applied to the resistor 45 will apply a negative voltage to amplifiers 26 and 27, and if sufficient voltage is supplied they will be cut off so that no signal will pass through them. To supply this voltage a full wave bridge rectifier may be used with one diagonal coupled to the output of the amplifier 25 and the other diagonal connected across the resistor 45, similarly rectifier 48 is coupled to the output of amplifier 26 and resistor 46.

Amplifier 25, normally biased to cut off, is rendered conductive by the impression of an error signal on the transformer 28. The amplified error signal appears in the primary of the transformer 39 and is impressed on the secondary windings connected to the rectifier 47. The adjusting voltage that is converted into a unidirectional voltage by the rectifier 47, biases amplifiers 26 and 27 so that the error signals appearing on the transformers 29 and 30 will not render the amplifiers 26 and 27 conductive. The am-

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plified error signal of control circuit 6 is applied through the rectifier 68 to the common input of controller 43.

When the motor 3 of the controller 43 has adjusted the load 1 so that the synchronous generator 9 and the synchronous transformer 12 are in substantially the same position the generators and transformers of the control circuits 7 and 8 will still be out of alignment and may impress an adjusting signal on the transformers 29 and 30. Since the error signal of the control circuit 6 is negligible or below a minimum value the amplifier 25 will return to its normally cut off condition, and the voltage impressed on resistor 45 removed. With this voltage removed, the signal impressed on transformer 29 will render the amplifier 26 conductive. Rectifier 48 will then apply a voltage to resistor 46 holding amplifier 27 non-conductive. Since amplifiers 25 and 27 are non-conductive the error signal of control circuit 7 will be impressed without interference on controller 43 to further correct the position of the load. When the synchros of control circuit 7 are in substantial alignment the error signal will become negligible, and the voltage will decrease across resistor 46 permitting the error signal of the control circuit 8 to adjust the load to the final and most accurate position.

The controller 43 is a schematic diagram of a simplified motor control circuit with the field winding 61 controlling the output of the generator 62 in response to the error signals supplied by control circuits. Any well known motor control circuit may be used that is responsive to a unidirectional error voltage.

For a machine having a series of different positions this invention facilitates the use of a plurality of presetting mechanisms, coupling units, and synchros with the presetting synchros coupled to the synchros of the drive mechanism through a multi-position switch 65 (Fig. 2). Each presetting mechanism may be set to one of the desired positions and on the completion of the operation at one position the switch 65 may be set at the next desired position. The drive mechanism will immediately adjust itself to the new position. Such a system obviates the necessity of continual resetting of the presetting mechanism. When a series of operations are repeated the presetting mechanisms may be set and it will only be necessary to change the switch 65.

In Figs. 3a, b, c the amplitudes of the unidirectional adjusting signal at the output of the control circuits 6, 7, 8 are respectively shown in graphical representation. These graphs represent the variations in the amplitude or modulation of the 60 cycle at the output of the transformers, when the presetting synchronous generators are set to the desired position prior to connecting them with the synchronous transformers. This condition would arise when a plurality of presetting mechanisms and coupling units are set for a series of operations and the switch 65 is changed from one position to another.

One cycle of variation of the amplitude represents a complete revolution of the rotor of the synchronous transformer. The rotors of transformers 13 and 14 make several revolutions on the adjustment of the machine 1 to the desired position. The rotor of transformer 12 is in one to one turn relation with the machine 1 therefore the signal cycle in Fig. 3a also represents a complete revolution of the machine 1. With the negative amplitudes causing rotation in one direction and the positive amplitudes in the

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other direction the machine 1 is never more than 180° from the same angular setting of the rotor of generator 9. Such is not the case with the rotors of transformers 12 and 13 which are not in a one to one turning relation with the machine 1. Each time the amplitude of these control circuits passes through zero the presetting mechanism 2 and the machine 1 are not in alignment. For this reason the control circuit 6 provides the adjusting signal until the rotor of transformer 13 is within the last half revolution of the final position. Similarly the adjusting signal provided by control circuit 8 does not control until it is within the last half cycle of the final position.

It will be seen from this description that without the possibility of the synchros going out of phase the preset mechanism may be set at a very rapid speed or as in this embodiment a plurality of preset mechanisms may be provided, each set to a different position prior to the operation of the control device. This is very advantageous for it facilitates the setting up of the positions of the preset mechanisms for a series of operations that may be continually repeated.

As various changes may be made in the form, construction and arrangement of the parts herein without departing from the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. A positional control system for controlling a driven mechanism by a presettable mechanism, comprising a plurality of electrical differential means, means for coupling said differential means to said presettable mechanism and said driven mechanism to provide in the output of each differential means an error signal having a rate of amplitude change different from the error signals in the other differential means, a plurality of amplifiers each coupled to a separate differential means to receive an error signal having a different rate of modulation, blocking means coupled to the input of the amplifiers passing higher rate of change signals, means for coupling the inputs of said amplifiers passing higher rate of change signals across smaller portions of the blocking means in inverse order of the rate of change ratio of the error signal in the higher rate amplifier, and separate means for coupling each of said portions of the blocking means to the output of a preceding lower rate amplifier to selectively block the higher rate of change amplifiers during the passage of an error signal through an amplifier having a lower rate of change ratio.

2. In a trichannel differential control system with each channel providing an error signal having a different rate of amplitude variation on the impression of a differential on said system, the combination of a plurality of amplifiers one coupled to each of said channels, a first resistor coupled to the input of the amplifier passing an error signal having the highest rate of change ratio and the input of the amplifier passing the middle rate of change ratio, a blocking circuit coupled between the output of the amplifier having the lowest rate ratio and said resistor to render the high and middle rate of change amplifiers non-conductive on the passage of a signal through the lowest rate amplifier, a second bias resistor coupled to the input of the amplifier passing the signal having the highest rate of change ratio, a second blocking circuit coupled

between the output of the amplifier passing the signal having the middle rate of change ratio and said second resistor to render the highest rate of change amplifier non-conductive on the passage of a signal through the middle rate of change amplifier.

3. A positional control system for controlling a driven mechanism by a presettable mechanism comprising a plurality of electrical differential means, means for coupling said differential means to said presettable mechanism and said driven mechanism to provide in each differential means an error signal having a rate of amplitude change different from the error signals in the other differential means, a plurality of electrically conductive signal channels each coupled to a separate differential means to receive an error signal having a different rate of modulation, blocking means coupled to the channels passing higher rate of change signals across smaller portions of the rate of change ratio of the error signal in the higher rate channel, and separate means for coupling each of said portions of the blocking means to the preceding lower rate channel to selectively block the higher rate of change channel during the passage of an error signal through a channel having a lower rate of change ratio.

4. A positional control system for controlling a driven mechanism by a presettable mechanism comprising a plurality of electrical differential means, means for coupling said differential means to said presettable mechanism and said driven mechanism to provide in each differential means an error signal having a rate of amplitude change different from the error signals in the other differential means, a plurality of electrically conductive signal channels each coupled to one of said differential means to each pass an error signal having different rate of amplitude change, blocking means for blocking said channels passing higher rate of change signals, means for coupling said blocking means across the channel having the highest rate of change, means for coupling the lower rate channels across successively smaller portions of said blocking means with each channel having a blocking portion common with the succeeding channels of high rate of change signal for blocking said channel and said succeeding channels, and means for separately coupling each of said common blocking portions to the channel passing the next lower rate of amplitude change signal to selectively block said channel having the common portion and said succeeding channels during the passage of an error signal through

the preceding channel having a lower rate of change signal.

5. A positional control system as claimed in claim 1 wherein an alternating energy source is provided coupled to said differential means and supplying an alternating signal to said differential means that produce a phase shift in said signal on a difference of setting to indicate direction of change, a phase differentiating circuit in the output of said channels comprising a balanced pair of vacuum tubes, means coupling the alternating current supply across the plate cathode circuit of the tubes to impress a voltage of the same polarity to the plates and means for coupling the output of said channels to corresponding elements of said tubes to impress the error signal thereon rendering one tube less conductive and the other tube more conductive depending on the direction of change.

6. A positional control system for controlling a driven mechanism in accordance with previously prepared settings comprising a plurality of presettable mechanisms each having a separate set of differential means, a second differential means coupled to said driven mechanism, means for separately coupling each of said separate differential means to said second differential means, each set producing error signals having a different rate of amplitude change, block means for blocking said channels having a higher rate of change signals, means for coupling said blocking means across the channel having the highest rate of change, means for coupling the lower rate channels across successively smaller portions of said blocking means with each channel having a blocking portion common with the succeeding channels of higher rate of change signal for blocking said channel and said succeeding channels, and means for separately coupling each of said common blocking portions to the channel passing the next lower rate of amplitude change signal to selectively block said channel having the common portion and said succeeding channels during the passage of an error signal through the preceding channel having a lower rate of change signal.

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