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ELECTRONIC FINE AND COARSE SIGNAL CONTROL SYSTEM

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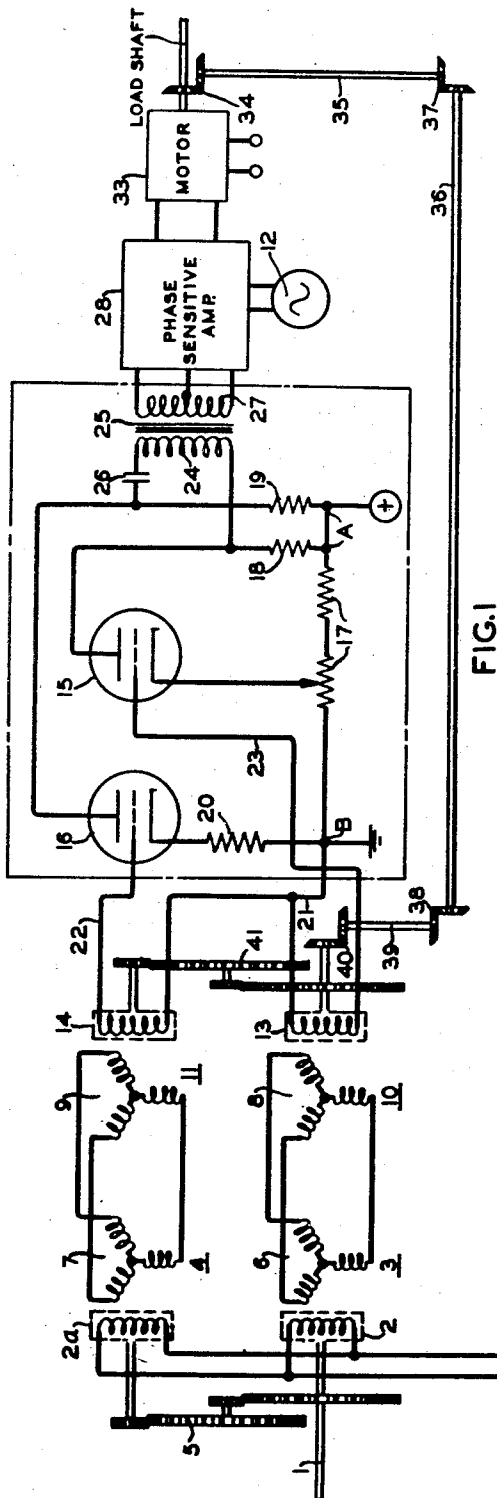


FIG. 1

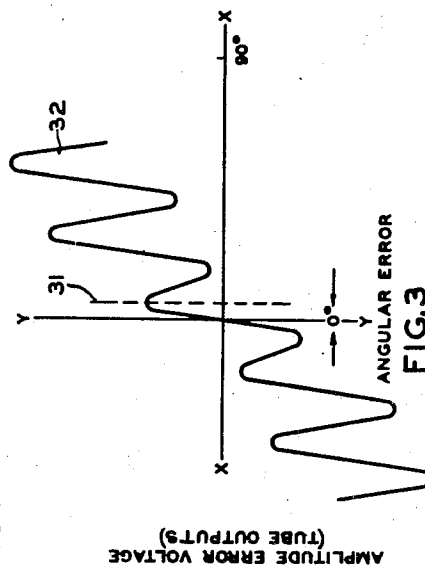


FIG. 3

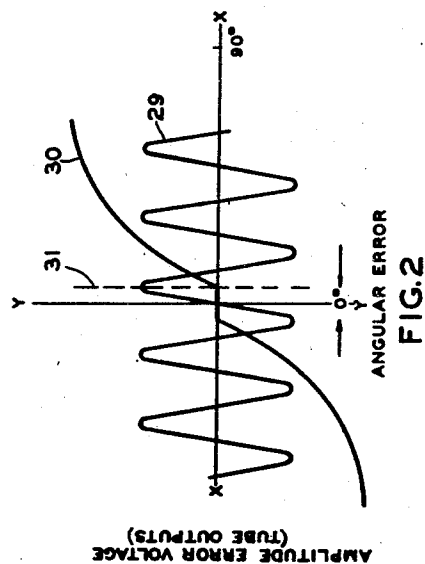


FIG. 2

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13 Claims. (Cl. 318—30)

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My invention particularly relates to a fine and coarse error signal system in which novel electronic means is provided primarily to control the coarse signal voltage in its application to an amplifier, which, in turn, is adapted to control a servomotor or other mechanism.

Fine and coarse error systems are employed where a close and accurate control over a servomotor is desired as where, for example, a load shaft is driven by the motor to follow an input shaft or reference. Ordinarily, the fine and coarse error systems respectively include a signal transmitter and a signal receiver. The transmitter of the coarse system may be directly connected with the data input or the reference member so that the rotor thereof rotates in a 1:1 ratio with respect thereto, while the rotor of the fine transmitter is rotated in some ratio, such, for example, as 15:1, or any other desired ratio with respect to the input shaft. Therefore, the coarse signal voltage derived from the coarse error system will vary in amplitude directly with rotation of the input shaft, while the fine error voltage derived from the fine system will vary in amplitude in the adopted ratio, such as 15:1 with respect to rotation of the input shaft. These signal voltages are usually supplied to an amplifier which is associated in controlling relationship with a suitable servomotor or other controlled device.

In the instant case, it is assumed that the fine and coarse ratio of the signal system is 15:1. Since the assumed ratio is an odd numbered ratio, the two signal voltages derived from the system will simultaneously reduce to zero only at zero error and not, for example, at a 180° relative angular displacement of the rotors of the two transmitters. The particular ratio adopted in any case will depend on the requirements of the work to be performed, or the device in which it is designed to be incorporated.

Where no control is exercised over the fine and coarse signals and both are supplied to the amplifier, interference between the two signals may constitute a source of error. This is especially true in the zones around zero actual error where it is desirable that the fine signal alone controls the servo. For example, around zero error, the spurious error voltages derived from the coarse signal system may materially affect the control over the servo and the precision and accuracy with which the load shaft, or, more accurately, the positionable object driven thereby, follows the movements of the input shaft or reference member.

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It is therefore the primary object of my invention to provide in a fine and coarse signal system electronic means for rendering the coarse signal ineffective until the actual error exceeds a predetermined value.

Another object resides in providing electron tube means for controlling the fine and coarse error signal voltages, said tubes being so arranged in a circuit and so biased that a coarse error voltage will be supplied to the output of the circuit, or to an amplifier which serves to control the servomotor, only when the actual error exceeds some predetermined value.

More particularly, it is an object of my invention to provide a signal control circuit including a pair of electron tubes, one of which is controlled by the fine signal and the other by the coarse, the coarse tube being biased beyond cut-off for actual errors below a predetermined value and the outputs of both tubes being supplied together in an additive sense to the output of said circuit, or to the input of a phase sensitive amplifier, whereby the fine signal alone may be used to control the operation of a servo when small actual errors exist and both signals will be employed when the actual error exceeds some predetermined value.

With the foregoing and other objects in view, my invention includes the novel elements and the combinations and relative arrangements thereof described below and illustrated in the accompanying drawings, in which

Fig. 1 schematically represents a positional control system embodying the fine and coarse signal control system of the present invention;

Fig. 2 represents the envelope of the fine and coarse signal voltage amplitude curves of the tube outputs, somewhat exaggerated for clearness of illustration; and

Fig. 3 is a view similar to Fig. 2 but showing the envelope of the signal voltage supplied from the signal control circuit to the amplifier.

In Fig. 1, I have illustrated a positional control system as illustrative of a preferred application or use of the present invention. 1 indicates a reference or input shaft to which the rotor 2 of a signal transmitter 3 is directly coupled so that both elements rotate together. The input shaft is also coupled with the rotor 2a of a second signal transmitter 4 through a gear train indicated generally at 5. The gear train is arranged to drive the rotor 3 at some desired ratio with respect to rotor 2, for example, a 15:1 ratio as herein assumed for descriptive purposes.

The stators 6 and 7, respectively, of the signal

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transmitters 3 and 4 comprise polycircuit windings which are connected in polycircuit relation with the stators 8 and 9 of signal receivers 10 and 11. Selsyn or Autosyn transmitters and receivers may be employed as well as other types of transmitters and receivers, and for descriptive purposes, I may hereinafter refer thereto as Selsyns.

The rotors of the transmitters 3 and 4 are connected across a source of suitable alternating current 12 and the rotors 13 and 14, respectively, of receivers 10 and 11 are connected to supply signal voltages respectively to the grids of tubes 15 and 16. The coarse error signal derived from the coarse system and rotor 13 is applied to the tube 15 while the fine error derived from rotor 14 controls the tube 16. Hence, I will refer to tube 15 as the coarse tube and to tube 16 as the fine tube. Of course, I may employ a single twin-diode tube or pentodes or any other suitable type of tube.

The circuit of the present invention which functions to control the supply of the coarse and fine error voltages to the servo amplifier is contained within the dot-dash enclosing line. A source of suitable D. C. anode or plate voltage is connected across the voltage divider indicated generally at 17, the point A of the voltage divider being connected through resistors 18 and 19, respectively, to the plates of the two tubes. The cathode of tube 16 is connected through resistor 20 to point B or the negative end of the voltage divider 17. The cathode of tube 15 is connected preferably directly with some point along the voltage divider so as to apply a small bias to the tube 15 sufficient to bias it a few volts beyond cut-off. Two ends of the rotors 13 and 14 of the signal receivers are connected together through conductor 21 to the point B or ground, as illustrated, while the other ends of these rotors are connected respectively through conductors 22 and 23 to the grids of the tubes 15 and 16. The primary 24 of the coupling transformer 25 is connected in series with a blocking condenser 26 and between the plates of the two tubes 15 and 16, and the secondary 27 of transformer 25 is connected to a suitable phase sensitive amplifier 28 as shown.

The operation of the signal control circuit above described is as follows. The bias on the cathode of coarse tube 15 which is derived from the voltage divider 17 is preferably so adjusted that tube 15 for zero error is biased a few volts beyond cut-off. The fine tube 16 is arranged to operate as a conventional amplifier, the cathode resistor 20 being preferably of such magnitude as to provide considerable cathode degeneration. For actual errors below some predetermined value, for example, about 2°, the fine tube will amplify the signal voltage supplied thereto and supply a signal voltage to the phase sensitive amplifier through the coupling transformer 25. As the actual error increases, the coarse error voltage will become larger than the bias on tube 15 at which time tube 15 will begin to conduct. For example, the tube 15 may be biased so that it will conduct at and above an actual error of 2°. The coarse tube preferably has very little degeneration so that when it conducts it will amplify the coarse signal to a much greater degree than the amplification provided by tube 16, and the relative magnitudes of the fine and coarse error voltage outputs from the two tubes are so adjusted that the input to the servo amplifier will not reverse in phase as the error continues to increase.

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Fig. 2 illustrates the envelope of the fine and coarse error voltage outputs of tubes 15 and 16 when these outputs are considered separately. Curve 29 represents the output of the fine tube 16 and it will be observed that the coarse tube 15 provides zero voltage output when the actual error lies within some predetermined distance from zero error. Assuming that an actual error increases from zero to some magnitude, say 2° as represented by the dot-dash line 31, during this interval, coarse tube 15 provides no voltage output, while the amplitude of the voltage output of tube 16 will vary as represented by that portion of curve 29 lying between zero on axis $x-x$ and the dot-dash line 31. As the error continues to increase and starting at an error value represented by line 31, the voltage output from tube 15 increases as represented by curve 30. Since both of these voltage signals are supplied to the primary of coupling transformer 25 in an additive sense, the two voltage curves will add together to provide the curve indicated at 32 in Fig. 3.

As shown in Fig. 3, the servomotor is controlled by both signal voltages when the error exceeds the value represented by dot-dash line 31, while the fine error voltage alone controls when the actual error does not exceed in magnitude the value represented by said line 31. Furthermore, it will be observed that the amplitudes of the two signals are so arranged that curve 32 does not cross the $x-x$ axis except at zero error and therefore the phase sense of the signal does not reverse and the output of the servo amplifier likewise will not reverse. Since a reversal of phase occurs when the voltage curve goes through zero error, voltage values to one side of the $y-y$ axis will drive the servo in one direction while voltage values to the other side thereof will drive the servo in the opposite direction. It should also be noted that since the voltages represented by curves 29 and 30 are added together in primary of transformer 25, the signal voltages derived from the rotors 13 and 14 of the signal receivers are supplied to the grids of tubes 15 and 16 in opposite phase sense. By so doing, the primary of transformer 25 may be connected between the plates of these tubes as shown.

Referring again to Fig. 1, it will be seen that the phase sensitive amplifier 28 is connected with a source of reference potential, preferably source 12, in order that the output of the amplifier will reverse in phase or polarity sense when the signal supplied to the amplifier reverses in phase with respect to the reference voltage. The output of the phase sensitive amplifier is connected as shown with a suitable motor 33 which, in turn, is operatively connected to drive a load or load shaft as shown. For repeat back purposes, as for example where no repeat back is otherwise provided, bevel gears 34 may be provided, one of which is driven by the motor and the other of which drives shaft 35. Shaft 35 is coupled to shaft 36 through bevel gears 37 and through bevel gears 38, shaft 39 and bevel gears 40 to the rotor 13 of the coarse signal receiver. A train of gears indicated generally at 41 connects the rotor 13 of the coarse receiver with the rotor 14 of the fine receiver to provide the same ratio of angular movement therebetween as exists between the rotors 2 and 3 of the signal transmitters.

For a more complete showing of one form of phase-sensitive amplifier and for a more com-

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plete description of the manner in which a phase-sensitive amplifier functions to control a servomotor in accordance with a signal voltage supplied to the amplifier, reference may be had to Patent No. 2,040,014 granted to Francis L. Moseley on May 5, 1936.

It will be noted from the foregoing description that I have provided a relatively simple but accurate control over the fine and coarse signal voltages derived from a fine and coarse signal system whereby the coarse error voltage is eliminated when small actual errors exist thereby preventing spurious error voltages from the coarse Selsyns from affecting the control when the system is close to synchronization and such errors are of greatest moment. Since both error signals are employed together when the error exceeds some predetermined value, it will be noted that the control circuit of the present invention is particularly adapted for use with fine and coarse systems having fairly low ratios of relative angular movement. For this reason, I have herein assumed a ratio of 15:1 since it has been found that the present invention is well adapted for use with a system operating on this ratio.

While I have described my invention in its preferred embodiment, it is to be understood that the words which I have used are words of description rather than of limitation and that changes within the purview of the appendant claims may be made without departing from the true scope and spirit of my invention in its broader aspects.

What is claimed is:

1. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, an electrical circuit including electron tube means connected respectively to receive the error voltage outputs of said receivers, and an electrical energy source external to said circuit for biasing the tube controlled by the coarse signal beyond cut-off for small coarse error voltages whereby an output including a component corresponding to the coarse signal voltage is obtained only when the actual error exceeds a predetermined value, and means for combining the signal voltage outputs of said tubes, said circuit being so constructed and arranged that the polarity or phase sense of the combined coarse and fine voltages is the same as that of said coarse voltage.

2. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a circuit including a fine and coarse electron tube connected respectively to receive the error voltage outputs of said receivers, a battery for biasing said coarse electron tube beyond cut-off for small coarse error voltages but said coarse tube being rendered conductive by error voltages above a predetermined value, and means for adding together the outputs from both tubes, said circuit being so constructed and arranged that the polarity or phase sense of the combined coarse and fine voltages is the same as that of the coarse voltage.

3. The combination with a fine and coarse electrical signal transmitters and receivers connected respectively therewith, of a fine and coarse electron tube connected respectively to receive the error voltages from said receivers, the fine tube being rendered conductive by all fine error voltages and the coarse tube being arranged in cut-off condition for small coarse error voltages but rendered conductive by error voltages above

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a predetermined value, and means for combining the signal voltage outputs of said tubes, said circuit being so constructed and arranged that the polarity or phase sense of the combined coarse and fine voltages is the same as that of said coarse voltage.

4. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a fine and coarse electron tube connected respectively to receive the error voltages from said receivers, the coarse tube having appreciably higher amplification than said fine tube and arranged in cut-off condition for small coarse error voltages but rendered conductive by error voltages above a predetermined value, and means for combining the outputs of said tubes, the relative amplification values of said tubes being such that the polarity or phase sense of the combined coarse and fine voltages is the same as that of the coarse voltage.

5. A system of the character recited in claim 3 in which the amplification provided by the coarse tube is so correlated with respect to the fine and coarse signal voltage magnitudes and the ratio of fine to coarse receivers that the phase sense of the resultant signal output of the tubes does not reverse as the error increases.

6. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a fine and coarse electron tube connected respectively to receive the error voltages from said receivers, means for providing greater cathode degeneration of said fine tube than said coarse tube, means for biasing the coarse tube beyond cut-off for small coarse error voltages below a predetermined magnitude whereby said coarse tube is rendered conductive by coarse error voltages above a predetermined value, and means for combining the outputs of said tubes, the relative cathode degeneration of said tubes being such that the polarity or phase sense of the combined coarse and fine voltages is the same as that of the coarse voltage.

7. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a fine and coarse electron tube connected respectively to receive the error voltages from said receivers, a source of bias potential connected to bias said coarse tube beyond cut-off for small error voltages below a predetermined value on the grid thereof, a high cathode impedance connected with said fine tube of a value sufficient to provide appreciable degeneration and low gain, said coarse tube being arranged for low degeneration and an output circuit in which the outputs of said tubes are combined, the relative gain of said tubes being such that the polarity or phase sense of the combined coarse and fine voltages is the same as that of the coarse voltage.

8. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, an electrical circuit including electron tube means connected respectively to receive the error voltage outputs of said receivers, and an electrical energy source external to said circuit for biasing the tube controlled by the coarse signal beyond cut-off for small coarse error voltages whereby an output including a component corresponding to the coarse signal voltage is obtained only when the actual error exceeds a predetermined value, the amplification provided by the respective tubes

being so correlated with respect to the fine and coarse signal voltage magnitudes and the ratio of the fine to coarse receivers that the phase-sense of the resultant signal output of the tubes does not reverse as the error increases.

9. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a circuit including a fine and coarse electron tube connected respectively to receive the error voltage outputs of said receivers, a source of direct current for biasing the coarse electron tube beyond cut-off for small coarse error voltages, but said coarse tube being rendered conductive by error voltages above a predetermined value, and means for adding together the outputs from both tubes, said circuit being so constructed and arranged that the polarity or phase sense of the combined coarse and fine voltages is the same as that of the coarse voltage.

10. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a fine and coarse electron tube connected respectively to receive the error voltages from said receivers, means for providing greater cathode degeneration of said fine tube than said coarse tube, means for biasing the coarse tube beyond cut-off for small coarse error voltages below a predetermined magnitude whereby said coarse tube is rendered conductive by coarse error voltages above a predetermined value, and means for combining the outputs of said tubes, the amplification provided by the coarse tube being so correlated with respect to the fine and coarse signal-voltage magnitudes and the ratio of fine to coarse receivers that the phase-sense of the resultant signal output of the tubes does not reverse as the error increases.

11. In a control system for supplying a voltage output dependent upon a pair of control signal voltages, the combination with means for supplying two signal voltages cyclically variable through positive and negative values as measures of the same quantity, one thereof having a relatively high ratio of signal magnitude to quantity magnitude and the other having a low ratio, of an electrical circuit including a pair of electronic tubes to which said two signal voltages are respectively applied in controlling relation, one of said tubes being so constructed and arranged as to conduct for all values of signal voltage applied thereto, means for applying a bias to the other tube whereby to render it conductive only for values of controlling signal voltages applied thereto exceeding a predetermined value, and

means for combining the outputs of said tubes in like polarity or phase sense relationship.

12. In an automatic control system responsive to the difference in magnitude of two quantities, the combination with a first generator for providing an electrical signal having a magnitude proportional to the magnitude of said difference and of a polarity or phase sense dependent upon the positive or negative sense of said difference, a first electronic amplifier therefor, a second generator for providing an electrical signal having a polarity or phase sense dependent upon the positive or negative sense of said difference and of a greater magnitude than the output of said first generator for small difference values but reversing in polarity or phase sense for some larger difference values, a second electronic amplifier for said second signal, means for combining the amplified signals, and a motor controlled by the combined signals for reducing the difference value, said first amplifier being biased to provide substantially zero output for small difference values and having its gain so proportioned to the gain of said second amplifier that the polarity or phase sense of the combined amplified signal always corresponds to the positive or negative sense of the difference value.

13. In a system comprising fine and coarse electrical signal transmitters and receivers connected respectively one with the other, a fine and coarse electron tube connected respectively to receive the error voltages from said receivers, a source of bias potential connected to bias said coarse tube beyond cut-off for small error voltages below a predetermined value on the grid thereof, a high cathode impedance connected with said fine tube of a value sufficient to provide appreciable degeneration and low gain, said coarse tube being arranged for low degeneration, and an output circuit in which the outputs of said tubes are combined, the relative amplifications of the coarse and fine tubes being so correlated that the phase sense of the resultant signal does not reverse as the error increases.

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