

April 1, 1952

R. S. CURRY, JR
SIGNAL TRANSFORMER

2,590,845

Filed June 20, 1945

4 Sheets-Sheet 1

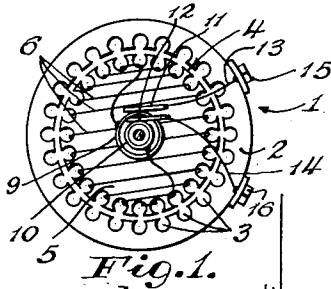


Fig. 1.

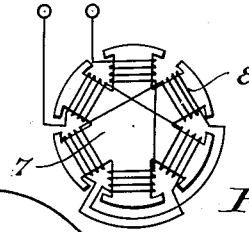


Fig. 2.

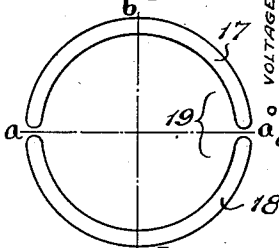


Fig. 3.

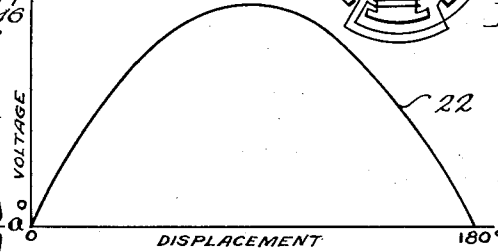


Fig. 4.

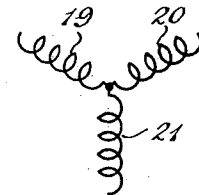


Fig. 5.

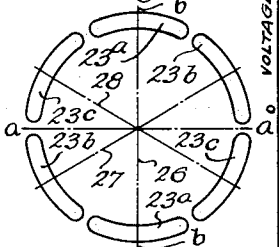


Fig. 6.

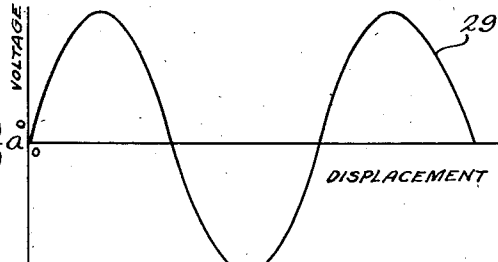


Fig. 9.

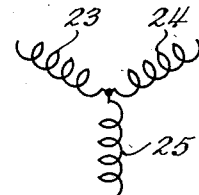


Fig. 12.

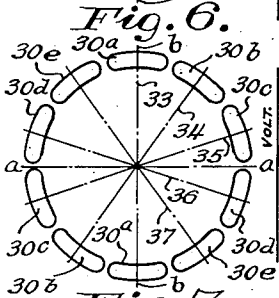


Fig. 7.

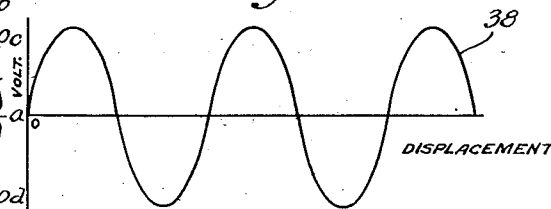


Fig. 10.

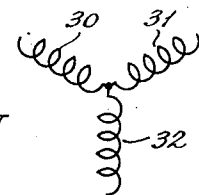


Fig. 13.

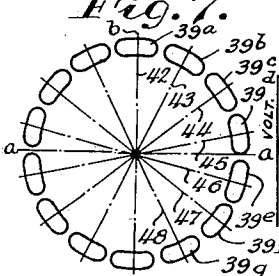


Fig. 8.

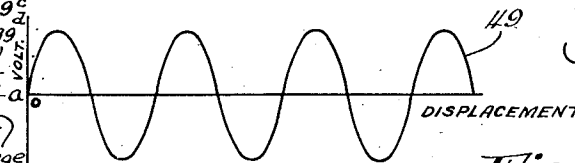


Fig. 11.

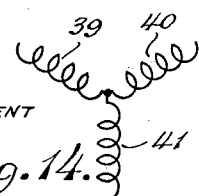


Fig. 14.

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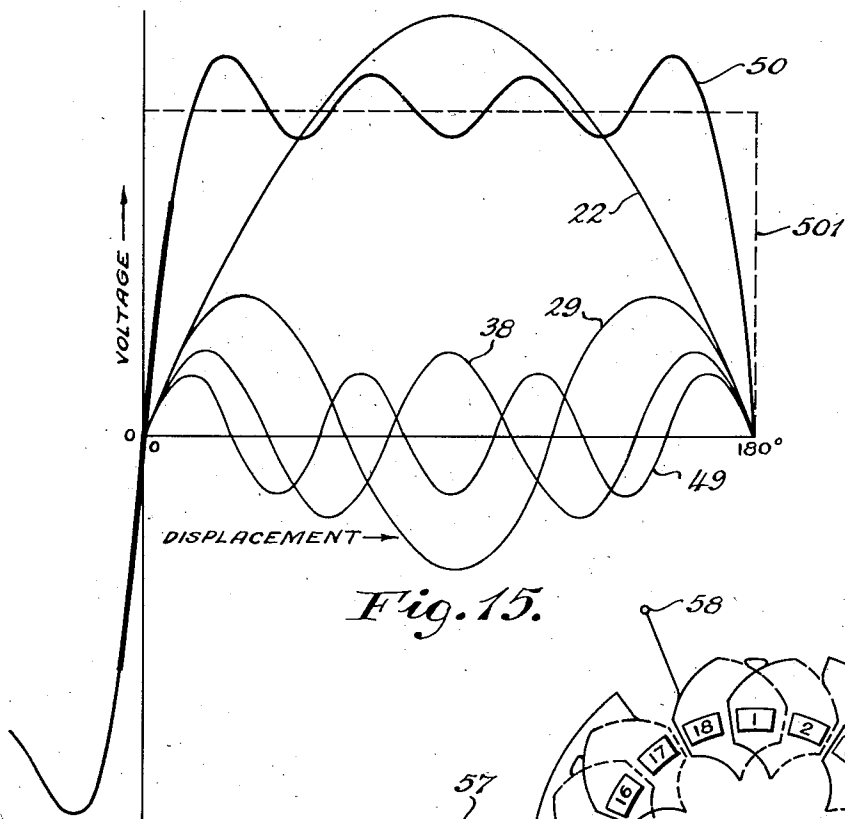


Fig. 15.

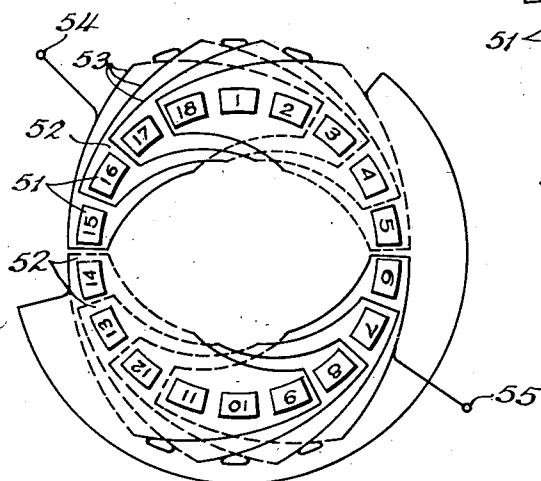


Fig. 16.

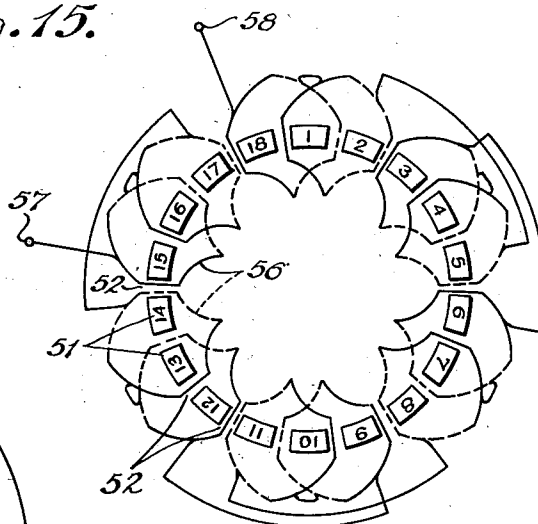


Fig. 17.

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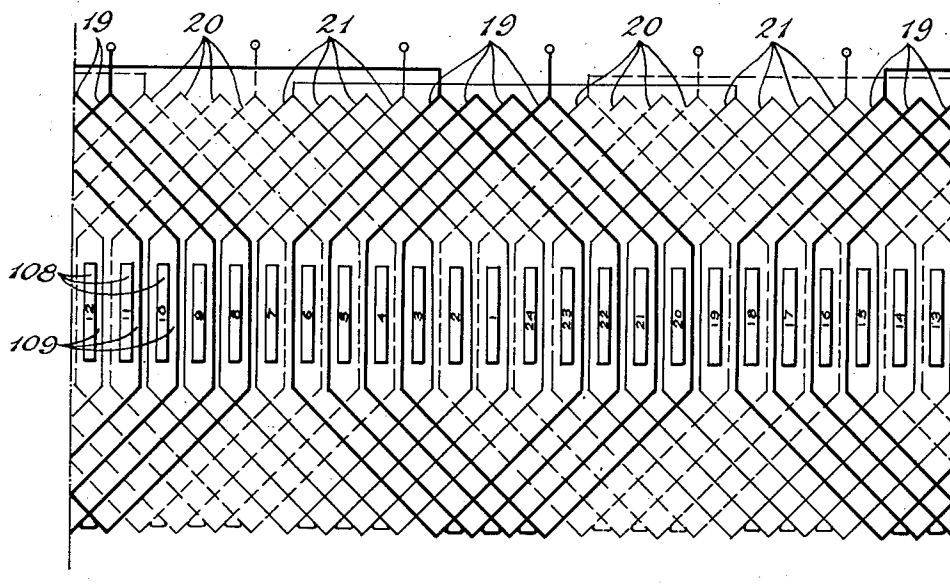


Fig. 18.

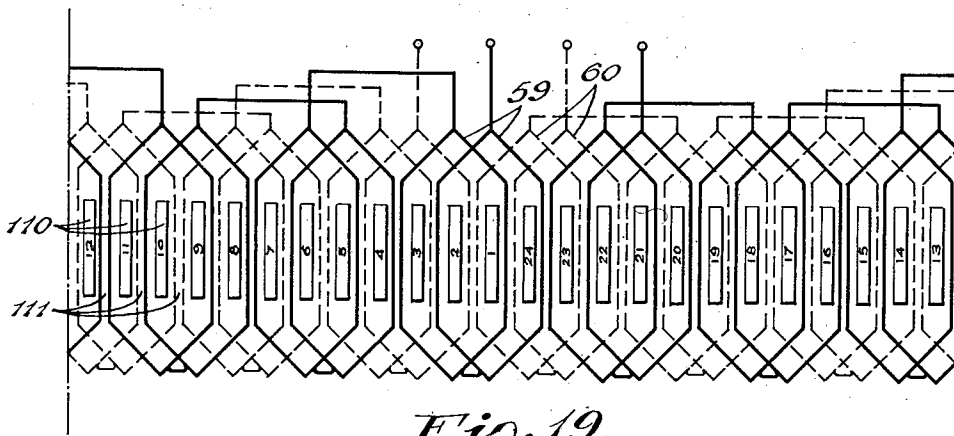
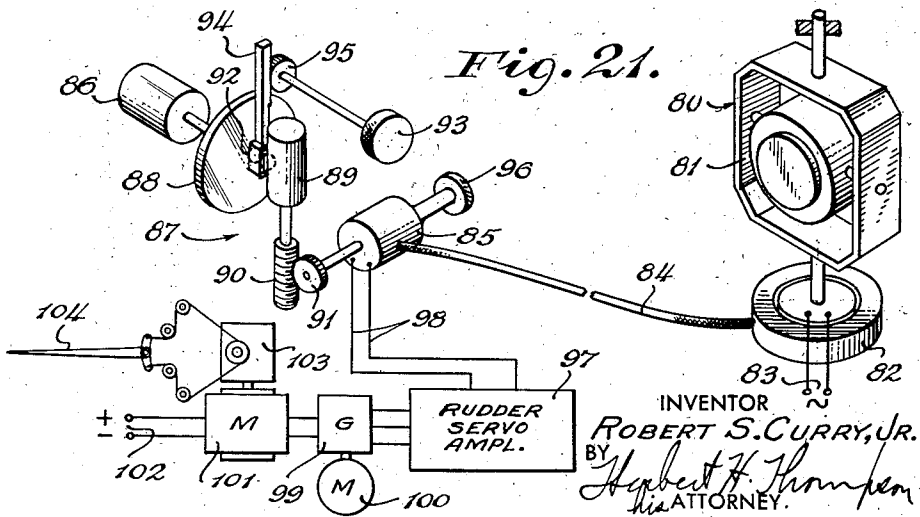


Fig. 19.

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UNITED STATES PATENT OFFICE

2,590,845

SIGNAL TRANSFORMER

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Application June 20, 1945, Serial No. 600,603

3 Claims. (Cl. 318—30)

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My invention particularly relates to signal transformers or signal generators of the type comprising a stator and rotor; and it is the primary object of this invention to provide, such a transformer which is characterized by the fact that the variations in voltage output thereof approximate a square wave or more nearly correspond to a square wave than to a sine wave.

Signal transformers of the character to which the present invention relates have found considerable usage in control systems, as in positional control systems where a positionable object is caused automatically to follow and be positioned in correspondence with a reference or control member. Such transformers are designed to provide a signal voltage output which in magnitude is dependent upon the angular displacement between the positionable object and the reference member. It should therefore be quite clearly seen that signal transformers, when employed to provide voltage outputs as a measure of angular displacement and where it is extremely desirable to maintain the displacement or error angle as small as possible, should provide a voltage output having a steep gradient with respect to displacements near and on both sides of zero error.

Heretofore, signal transformers of the selsyn type have been employed in the capacities above referred to and it has been found that in a great many instances the signal voltage output, e. g., that of a single transformer where the parts thereof are relatively rotated as a direct measure of the angle of error, does not experience a sufficiently great change in amplitude per unit of angular error, so that it is impossible to hold the angle of error down to prescribed and relatively small size orders.

In view of the above, fine and coarse data transmission systems have been incorporated in control systems, such as positional control systems, so that a more precise following of the positionable object with respect to the reference member is provided. A fine and coarse system embodies two separate data transmission channels, each thereof comprising a transmitter and signal transformer remotely situated, but electrically connected together. The co-called coarse transmitter is connected ordinarily in a 1:1 ratio with respect to the reference member which, for example, may be a sight (optical, radio and the like) which is connected to direct some positionable object such as a searchlight. The coarse signal transformer has its stator windings connected with correspondingly arranged stator

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windings of the coarse transmitter, and the rotor thereof is driven in a 1:1 ratio with the positionable object. In other words, the rotor of the coarse transmitter is driven synchronously with the positionable member, while the rotor of the coarse transformer is driven synchronously with the positionable object. The rotor winding of the coarse transmitter is, of course, energized from any suitable source of alternating current, while the winding of the rotor in the coarse receiver or transformer, from which a control signal voltage is derived, is connected through a suitable mixing circuit to the input of any conventional type of amplifier, the output of which controls the servomotor driving the searchlight or other positionable object.

The fine transmitter is driven at a much higher speed with respect to the reference member, as for example, in a ratio of 15:1 or even 36:1 or some other advantageous and suitable ratio. This is usually accomplished through a gear train and the rotor of the fine transformer or signal voltage generator is similarly driven at a ratio of 15:1 or 36:1, as the case may be, relative to the rotor of the coarse transformer or the positionable object.

The signal voltages derived from the fine and coarse transformers are generally of a sinusoidal nature and because of the fixed ratio between the fine transmitter and transformer and the reference member and positionable object, a voltage component will be derived from the fine data transmission system which will vary in amplitude through some number of cycles, for example, 15 or 36 cycles, depending on the adopted ratio, for a relative movement throughout 360° of the rotors of the transmitter and transformer. Therefore, the wave form of the envelope of the voltage output in the fine system will be much steeper than that of the coarse, and when both coarse and fine signal voltages are combined, the voltage change per unit of error angle between the reference member and the positionable object will be much greater than if only a coarse transmission were employed. The fine signal is most important at and near the synchronous point of zero error in the system, while the coarse signal voltage is best suited for control purpose under conditions of greater error. These facts should be obvious when it is realized that the coarse signal voltage experiences but one cycle of variation throughout 360° of error change, while the fine signal voltage experiences many cycles of variation and its amplitude will therefore drop off along a steeper gradient in zones quite close

to the zero error point or point of synchronization.

It should be evident from the foregoing brief allusion to positional control systems in general that fine and coarse data transmission systems serve greatly to improve the synchronous operation of these systems and to minimize lag and error therein. However, there are many types of systems which by the very nature thereof will not permit of the use of both fine and coarse data systems. For example, automatic pilot systems embody gyroscopes which are employed as references in controlling the attitude and direction of flight of the craft. Pick-offs or signal voltage generators are associated with such gyroscopes for supplying the primary control signal to an amplifier or the like, which in turn controls servomotors which function to maintain the craft on its chosen course or to maintain its desired attitude. Loading limitations are placed on such pick-offs since excessive loading will affect the reference provided by the gyroscope, and although a higher precision or control is greatly desired over that possible with the ordinary selsyn-type signal transformer providing a sine wave variation, fine and coarse transmitters cannot be used because of the load imposed upon the gyro by virtue of the necessary step-up gear train.

My invention, therefore, is particularly adapted for use under conditions such as those above pointed out wherein a single or unit speed transformer may be employed, but high speed units may not. In connection with the foregoing, it should be noted that the voltage gradient of the signal voltage output derived from such signal transformers having sine wave outputs cannot be made steeper simply by increasing the amplitude or magnitude of the voltage because magnetic saturation will then occur in the iron core, resulting in the formation of harmful harmonics which is, of course, undesirable because of the harmful effect of such harmonics on the signal voltage wave form. In this connection, moreover, it must be noted that in some cases, as in apparatus for aircraft, unit size and weight of parts are at a premium.

It is, therefore, the primary object of the present invention to provide a signal generator or transformer, the output of which is characterized by its approximation to a square wave and providing a steep voltage gradient adjacent and on both sides of the zero axis or point of synchronism in the system in which the transformer is used.

Another object resides in providing a signal generator or transformer having a stator and rotor for producing a signal voltage output comprising two voltage components having a different number of cycles of variation in magnitude throughout a given angular movement of said stator and rotor, the variations of said voltage components being individually of such magnitudes and so correlated as to provide a relatively steep voltage gradient for small angles of relative angular movement between said rotor and said stator fields or an output approximating a square wave.

A still further object resides in providing a synchronous transformer of the character above pointed out in which the voltage components having the greater number of cycles of variation experiences an odd number of such variations, or, in which the wave form of one of the voltage components corresponds to a fundamental volt-

age wave and the wave form of the other voltage component corresponds to some odd harmonic.

Still another object resides in providing synchronous transformers of the characters last above recited, in which the voltage components having the greater numbers of cycles of variation are of lesser maximum magnitude than the other of said voltage components.

More specifically, it is an object of this invention to provide a signal generator or signal transformer in which the signal voltage output is a summation of voltage components, one of which varies as a fundamental wave, another of which varies as a third harmonic, and still other voltage components vary as the fifth and seventh harmonics, whereby the resultant voltage wave or voltage output of the transformer more closely approximates a square wave than a sine wave and provides a steep voltage gradient at and adjacent the zero voltage output position of the transformer parts.

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

Fig. 1 illustrates generally the type of signal transformer to which the present invention relates, schematically showing windings on the rotor only for clearness of illustration;

Fig. 2 shows a slightly different form of rotor from that shown in Fig. 1 and one wound to form a six-pole rotor;

Fig. 3 is a schematic representation of one group of stator windings of the transformer of the present invention, illustrating the relative arrangement and circumferential extent thereof;

Fig. 4 is a curve representing the voltage output derived through cooperation between a two-pole rotor and the two-pole stator windings of Fig. 3 when those parts are relatively rotated through-out 180°;

Fig. 5 is a wiring diagram showing the preferred number and electrical interconnection of phases, each of which comprises a group of windings corresponding to that shown in Fig. 3, embodied in the transformer of my invention;

Figs. 6, 7 and 8 are views generally similar to Fig. 3 but illustrating further winding groups on the stator of the transformer of my invention which respectively provide 6, 10 and 14 pole fields.

Figs. 9, 10 and 11 illustrate curves of the general nature of that illustrated in Fig. 3, but in each case illustrating the voltage outputs derived through interaction between the 6, 10 and 14 pole stator windings and a similarly poled rotor;

Figs. 12, 13 and 14 are winding diagrams similar to Fig. 5, illustrating the stator phases each of which comprises a group of windings corresponding to the windings shown in Figs. 6, 7 and 8, respectively, which are embodied in the preferred embodiment of the transformer of the present invention;

Fig. 15 illustrates the voltage curves of Figs. 4, 9, 10 and 11 plotted together and algebraically combined to provide the summation voltage curve or resultant voltage output of the transformer;

Fig. 16 is a winding diagram illustrating a two-pole stator winding of the character employed in forming in part the stator of my signal transformer;

Fig. 17 is a winding diagram illustrating stator windings forming a six-pole stator field;

Fig. 18 is a schematic development and winding diagram of the stator of a transformer of

the present invention showing the relative arrangement of the windings to form a three-phase, two-pole stator;

Fig. 19 is a schematic development and winding diagram of a modified form of stator;

Fig. 20 is a wiring diagram of a system including a signal transformer arranged in accordance with the principles of the present invention; and

Fig. 21 is a schematic representation of the azimuth control elements of one form of automatic pilot.

For purposes of description, I will in the following refer to various windings as phases although, it will be understood, that the phases of the present invention are not, strictly speaking, separate phases as understood in A. C. practice but are only relatively angularly arranged windings. The space relation of the phase windings depends upon the design of the multicircuit data transmission network connected therewith, that is, whether of two, three or more phases; and no motor action attains, of course, the signal voltages or alternating exciting voltages being of an in-phase character.

Referring first to Fig. 1, 1 indicates generally the stator of a transformer of the character to which the present invention relates. For clearness in illustration and description, I have not herein illustrated a housing, stator core or a rotor core carrying all the windings which it would carry when formed in accordance with the present invention, but I have represented these windings separately, and it will be understood that the windings when combined on the same cores, stator and rotor, will function to provide a signal voltage output having the wave form hereinafter particularly pointed out. The stator 1 comprises the core 2 formed with a plurality of slots 3 which are adapted to receive the stator windings. I have not, in Fig. 1, attempted to illustrate the slots as of a preferred design, but have merely shown them for exemplary purposes.

The rotor 4 shown in Fig. 1 is of the round rotor type as compared to the salient pole type rotor shown in Fig. 2 and for the purposes of the present invention the former or round rotor is preferred to that of the latter type. The rotor core is provided with the windings 6 which are schematically illustrated and are intended in Fig. 1 to represent the windings for a two-pole rotor. Fig. 2, on the other hand, discloses a salient pole type rotor comprising the core 7 which is provided with the windings 8 and arranged to form a six-pole rotor. This type of rotor is shown in Fig. 2 solely for the sake of clearness to illustrate how a six-pole or some greater numbered pole rotor may be formed and to show an alternative construction.

Referring again to Fig. 1, it will be understood that the stator and rotor in a machine formed in accordance with the present invention are supported for relative rotation in any suitable manner and that the single-phase rotor winding is connected to output taps or suitable terminals whereby it may be connected in circuit with a signal voltage-responsive device or system. For example, as schematically shown, the two ends of the winding 6 are connected respectively to slip rings 9 and 10 which engage brushes 11 and 12 which in turn are connected through leads 13 and 14 with output taps or terminals 15 and 16.

In accordance with my invention and in order to provide a signal voltage output which varies approximately or more nearly as a square wave rather than as a sine wave, I propose to form

a signal or synchro transformer of the general character of that shown in Fig. 1 with a plurality of groups of windings on both the stator and rotor. In the preferred embodiment, groups of windings are comprised in each phase of three phases and these phases may be interconnected in three-phase delta or Y-connections as the windings of the conventional form of signal transformer or transmitter such as those of the selsyn type. Generally speaking, a first group of such windings are arranged within the stator slots to form a two-pole, three-phase unit which is adapted to cooperate with a single-phase, two-pole rotor unit. A second group of windings is arranged on the stator to form a six-pole, three-phase field and the rotor correspondingly is provided with a single phase winding forming a six-pole rotor.

In accordance with my invention, these units and the others hereinafter described may be formed essentially as separate synchro transformers or signal generators having, for example, their stators aligned and their rotors mounted on a common rotor shaft. Such units could also be associated together in any other desired manner provided the rotors or stators of each unit move in synchronism, or as a unit in the field of the stators. On the other hand, the units may be formed in a unitary machine. That is to say, the windings of each group may be arranged on a common stator core to provide the multipole fields herein set forth and, similarly, the rotor core may carry a plurality of so-called single-phase windings to provide it with the necessary number of poles properly to cooperate with the stator fields in the formation of a signal voltage output of the character herein contemplated.

The arrangement of the groups of stator windings to provide the two-pole unit above referred to is quite schematically illustrated in Fig. 3 and the arrangement of winding groups to form the 6, 10 and 14 pole stator fields of the other units are shown in the same schematic manner in Figs. 6 through 8 without regard to the precise number of stator slots employed. However, the groups of windings in these figures bear the relationship with respect to each other as determined by the axes labeled $a-a$ and $b-b$ passing therethrough. In other words, these figures may be superimposed with corresponding axes in registry to show the relative disposition of all of the windings forming the complete machine.

Referring again to Fig. 3 it will be seen that part of the stator field of this unit is formed by one group comprised of windings 17 and 18, the windings 17 extending substantially about 180° circumferentially of the stator and the winding 18 likewise extending circumferentially about substantially the other 180° of the stator whereby to form a two-pole field winding having the pole axis coincident with the axis $b-b$. In the case of the first unit or part of the stator, the windings 17 and 18 constitute one phase (phase 19 in Fig. 5) of the three phases of the first or two-pole unit of my transformer. Therefore, it will be understood that the other three phases thereof as represented at 20 and 21 in Fig. 5 also each comprise relatively arranged windings or a group corresponding to windings 17 and 18 in Fig. 3. Each of the phases, however, is disposed at an angle with respect to the other phases and in the formation of the two-pole, 3-phase unit these phases will lie in 120° spaced angular relation.

In Fig. 4 I have plotted the voltage output of a two-pole unit of the character above described against displacement or relative movement of the rotor and stator from a zero voltage output position through 180° . It will be noted that the curve 22 representing the voltage output is generally of a sine form and corresponds to the usual voltage output derived from a signal transformer of conventional type.

The other units of the preferred embodiment of my invention form 6, 10 and 14 pole fields, and the single phase windings of the rotor form 6, 10 and 14 poles for cooperation with the stator fields. As shown in Figs. 6, 9 and 12, a second unit of the signal transformer similarly comprises the three phases of a stator winding indicated at 23, 24 and 25 in Fig. 12. Each of these phases, as shown in Fig. 6, comprises a plurality of groups of windings 23a, 23b and 23c which are grouped circumferentially about the stator core to form a six-pole stator, the magnetic axes of these poles being represented by the dot-dash lines 26, 27 and 28. To cooperate with the field produced by the field windings of the six-pole unit of the present invention, I also form the rotor as a six-pole rotor. The rotor winding, of course, is of a single-phase type and the rotor, or rotors, as the case may be, is preferably of the distributed winding, round rotor type. As shown in Fig. 9, the single-phase, 6 pole rotor winding will have induced therein a voltage changing in the manner represented by the curve 29 when the rotor is rotated through 180° relative to the three-phase, six-pole stator.

Likewise, the third unit of my preferred form of transformer comprises a three-phase stator winding, the phases of which are represented by the windings 30, 31 and 32 in Fig. 13. Each of these phases comprises the groups of windings shown in Fig. 7 which are circumferentially arranged on the stator to provide a ten-pole stator, the axes of which are represented by the dot-dash lines 33-37. Each phase comprises the groups of windings 30a, 30b, etc., which by virtue of their relative arrangements cooperably form the poles having the axes 33 to 37 above indicated, each group forming a pole. The rotor cooperating with the three-phase, ten-pole stator comprises a single-phase winding forming a ten-pole rotor and the voltage induced therein when rotated throughout 180° relative to the ten-pole stator field is represented by the curve 38 in Fig. 10.

In accordance with the preferred construction of my signal transformer I also provide a fourth unit comprising a 14-pole, three-phase stator and cooperative 14-pole, single-phase rotor. Each phase of this unit is indicated generally at 39, 40 and 41 in Fig. 14, the respective phases being relatively angularly disposed in 120° spaced relation as represented in Fig. 14 in the same manner as all of the stator phases of the first, second and third units. Each phase, as for example, phase 39 comprises a plurality of groups of windings arranged as shown in Fig. 8 and therein represented as windings 39a, etc., to form 14 poles, the magnetic axes of which are represented by the dot-dash lines 42-48. The single-phase, 14-pole rotor will have a voltage induced therein varying in the manner depicted by the curve 49 in Fig. 11 when the rotor and stator are relatively rotated throughout 180° .

It should be evident from an examination of Fig. 15 that an algebraic summation of the voltages derived from the single-phase rotor wind-

ings of the four units above described will produce a signal voltage output approximating a square wave in form and one which has a decidedly steep voltage gradient at and adjacent the zero signal output position of the transformer unit. It should be observed that I preferably so arrange the second, third and fourth units that the maximum amplitude of the voltage derived therefrom is only a fractional part of that derived from the first unit or, in other words, the voltage components, which by analogy may be said to vary in the nature of third, fifth and seventh harmonics, are of much smaller maximum amplitude than the fundamental wave. By so correlating the maximum voltage amplitudes of these signals, the general relative magnitudes of which are more precisely shown in Fig. 15, I obtain as a summation voltage a voltage which varies in the manner depicted by the curve 50, being the algebraic summation of curves 22, 29, 38 and 49.

I prefer so to arrange the various windings on the transformer of the present invention as to produce voltage components having cyclic changes corresponding to odd harmonics and to combine these with one varying as the fundamental in order to produce a generally square wave form of the character of that shown in Fig. 15, approximating the square wave indicated at 50. However, in accordance with my invention I may employ voltage components which vary in manners other than those which may be said to correspond to odd harmonics as above pointed out, and, furthermore, the wave form of the various voltage components may not be of a sine nature. However, for voltages which vary generally sinusoidally and for the most desirable wave form, I prefer to combine voltage components which vary with respect to each other as fundamental and odd harmonics.

In Figs. 16 and 17 I have represented schematically the winding diagrams for one phase of the stator windings forming a two-pole field and one phase forming a six-pole field. In each of these figures, the stator core is represented by the circumferentially extending portions 51 defining therebetween the core slots 52. In Fig. 16, the conductors 53 are shown in the slots they would occupy to form a two-pole unit and in this instance the continuous conductor extending between the terminals 54 and 55 constitutes one phase of the group of windings employed in forming the two-pole, three-phase unit of my transformer. Similarly, in Fig. 17, the slots 52 in core 51 are shown as accommodating the conductors 56. In Fig. 17, the continuous conductor is connected between the terminals 57 and 58 and forms a six-pole winding, constituting one of the phases of the six-pole unit of my transformer. In other words, the conductors 53 of Fig. 16 correspond to the group of windings consisting of windings 17 and 18 of Fig. 3 and the conductors 56 correspond to all of the groups of windings in Fig. 6.

In Fig. 18 I have illustrated somewhat schematically a development of the stator of my transformer and shown a winding diagram for all three phases of the three-phase, two-pole stator unit. The stator is indicated at 108 and the stator slots at 109. In this figure, the windings of one phase are represented by full, heavy lines and indicated by the reference numeral 19, those of the second phase being represented by the dash line indicated generally at 20, and those of the third phase being represented by

the full, light lines and indicated by reference numeral 21. This figure serves to show the relative arrangement of the windings in the core slots of the stator so as to form a three-phase, two-pole stator field.

In Fig. 19 I have similarly shown a development of a stator and the windings thereon to form a two-pole two-phase stator. The stator is indicated at 110 and the stator slots at 111. The windings represented by the full lines and indicated by the numeral 59 constitute one phase while the windings represented by the dash lines and indicated by the numeral 60 constitute the second phase. These windings have been shown as arranged in the slots of a stator corresponding to the stator construction shown in Fig. 18, so that the two figures may be compared and thereby provide a clear indication of how a two-phase construction may be employed in substitution for or as a modification of a three-phase arrangement. In other words, so long as the data transmission circuit, with which the transformer of my invention is employed, is arranged to be connected in the manner of a two-phase circuit to any one or more of the units of my signal transformer, that unit or units may be of such phase character. However, I prefer to arrange all the units of my invention for three-phase connections, although I do not wish to be limited thereto since other, plural phase arrangements may be used.

Fig. 20 shows a wiring diagram of a data transmission system wherein the various units of the transformer of my invention are connected with corresponding unit parts of a transmitter. The stator windings in one unit of my signal transformer are indicated generally at 61 and the windings of the other three stator units are similarly indicated at 62, 63 and 64, respectively. Correspondingly arranged stator windings of corresponding units are connected in polycircuit or polyphase relation between the transmitter and signal transformer as indicated. For example, the three-phase, two-pole stator winding 65 of the transmitter is connected with the three-phase, two-pole winding 61 of the signal transformer while similar windings 66, 67 and 68 of the transmitter forming three-phase, 6, 10 and 14 pole windings, respectively, are connected with the three-phase—6, 10 and 14 pole windings indicated at 62, 63 and 64, respectively, of the transformer. The single-phase rotor windings of the transmitter indicated generally at 69, 70, 71 and 72 and forming 2, 6, 10 and 14 poles, respectively, are energized from a suitable source of alternating current 73 for cooperation with the correspondingly poled stator windings. The single-phase windings of the rotors of the transformer are indicated at 74, 75, 76 and 77, the winding 74 constituting a two-pole winding, while winding 75, 76 and 77 constituting 6, 10 and 14 pole windings, respectively. The transformer rotor windings are preferably connected in series and across output taps 78 and 79. In practice, the several voltage components derived from the rotor windings 74 through 77 should be of the same time phase when operating into a given load; and a voltage having generally the wave form shown in Fig. 15 will appear across these output taps for the conditions of relative maximum voltage magnitudes, frequencies of variation with respect to displacement and time phase relation herein indicated as preferred.

Although I have hereinbefore referred to the curves in Figs. 4, 9, 10 and 11 as voltage curves,

it is of course to be realized that they show variations in amplitude or the envelope of the alternating voltage with respect to displacement or angular change in relation of stator and rotor producing a signal voltage output or variation therein which is indicative of error or lack of synchronism in the system.

As hereinbefore indicated, a signal transformer of the character of that herein described finds particular use as a source of signal voltage in controlling a servomotor such as the rudder servo of an automatic pilot. As schematically shown in Fig. 21, the directional gyro indicated generally at 80, or more precisely the vertical ring 81 thereof, is maintained in a predetermined azimuthal position by suitable means not shown. A pick-off unit of the Selsyn type and preferably of the character of the transmitter shown in Fig. 20, is indicated generally at 82, the stator thereof being fixed to move in azimuth with the craft and the rotor being oriented by the vertical ring of the gyro. The rotor windings are, of course, energized from a suitable source 83 of alternating current. The various stator windings of the pick-off 82 are connected as hereinabove described (see Fig. 20) through cable 84 to the stator windings of signal transformer 85 which is formed in accordance with the present invention. For rate of turn control purposes, the rotor of signal transformer 85 is operated at any prescribed angular rate by means of constant speed motor 86 driving through variable speed drive 87, the disc 88 of which is connected with the motor and the cylinder 89 of which is coupled with the rotor of signal transformer 85 through worm 90 and worm wheel 91. A ball carriage 92 is mounted to move in translation radially of the disc 88 and to transmit motion between the disc and cylinder, the radial position thereof being controlled by the "rate of turn" knob 93 through rack 94 and pinion 95 which meshes therewith. Knob 96 may be provided for direction-changing purposes and is adapted when rotated to position the stator of transformer 85 relative to the rotor thereof. The output of transformer 85, which will vary in the manner shown by the curve 50 in Fig. 15 for variations in direction of flight of the craft relative to the reference provided by the directional gyro, is supplied to a rudder servo amplifier 97 through leads 98. The output of the rudder amplifier, in the embodiment herein illustrated, controls the fields of a generator 99, driven by motor 100, the output of generator 99 being connected with the servomotor 101 having, for example, its field constantly excited from a suitable current source indicated generally at 102. The servo amplifier serves to control the polarity and magnitude of the voltage output from generator 99 and thereby the direction and rate or magnitude of operation of servomotor 101. Servomotor 101 drives through a suitable gear transmission 103 and functions to actuate and position the rudder 104 of the craft as schematically shown.

With the foregoing arrangement and by employing a signal transformer of the character of that contemplated by the present invention, it should be obvious that an automatic pilot is provided having a much higher sensitivity and thereby a much more accurate and closer control of the direction of flight of the craft than could otherwise be obtained with selsyn type instruments or signal generators of the same unit size and weight. Similarly, the attitude of the craft both in pitch and roll may be controlled in the

same precise manner by employing signal transformers of the character herein described.

In control systems such as automatic pilots of the character above referred to, large angles of error are not encountered, but the systems are arranged to operate within a very few degrees on both sides of zero error. Therefore, the heavy line portion of curve 50 in Fig. 15 will serve to indicate that portion of the curve along which it is customary to operate under normal conditions. The steep slopes of the curve in these regions demonstrate that the signal transformer of my invention which will not impose an excessive load on the gyro is admirably adapted for use, for example, in automatic pilots where the heading of the craft as in military craft should be maintained very accurately because in aircraft of this type, control thereof about its yaw axis should be maintained within errors of not more than about $\frac{1}{8}$ of a degree for accurate determination of the ground track of a bomb.

While I have described my invention in its preferred embodiments 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 appended claims may be made without departing from the true scope and spirit of my invention in its broader aspects.

What is claimed is:

1. A data transmission system for use in a servomotor system comprising a transmitter adapted to be driven by a first data input device and a signal transformer unit adapted to be driven by a second data input device, said transmitter and transformer being of substantially like electrical design, said transmitter and transformer each including a stator having a field and a rotor mounted to rotate as a unit in the field of said stator, the rotor and stator of each unit including windings forming a different number of magnetic poles whereby to produce at least two signal voltage components in the rotor winding of said transformer having a different number of cycles of variation in magnitude throughout a given displacement between the rotors of the two units, the windings of the rotor of said transmitter being connected with a source of single phase alternating current, corresponding windings of the stators of said units being electrically connected together, and the windings of the rotor of the transformer being connected together across a pair of output taps whereby algebraically to combine the signal voltage components induced in the rotor windings of said transformer, and said

output taps being connected to a voltage-responsive device.

2. A data transmission system for use in a servomotor system comprising a transmitter adapted to be driven by a first data input device and a signal transformer unit adapted to be driven by a second data input device, each unit comprising a stator having a field and a rotor mounted to rotate as a unit in the field of said stator, windings on said rotors and stators including two-pole windings for generating a signal voltage having one cycle variation in magnitude for 360° of angular displacement between said rotors and multipole windings for producing voltage components having more than one and an odd number of cycles of variation in magnitude for 360° of displacement, corresponding stator windings of said transmitter and transformer being connected together, the rotor windings of said transmitter being connected to a source of single phase alternating current, and a pair of output taps, the windings of the rotor of said transformer being connected across said output taps, and said output taps being connected to a voltage-responsive device.

3. A data transmission system for use in a servomotor system comprising a transmitter adapted to be driven by a first data input device and a signal transformer unit adapted to be driven by a second data input device, each unit comprising a rotor and stator having windings thereon cooperatively forming two and six pole machines, the rotor windings of said transmitter being connected to a source of single phase alternating current, corresponding stator windings of said transmitter and transformer being connected together, and a pair of output terminals across which the rotor windings of said transformer are connected, said output terminals being connected to a voltage-responsive device.

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