

July 13, 1965

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3,194,990

HALL PLATE SOLID STATE RESOLVER

Filed Sept. 22, 1961

3 Sheets-Sheet 1

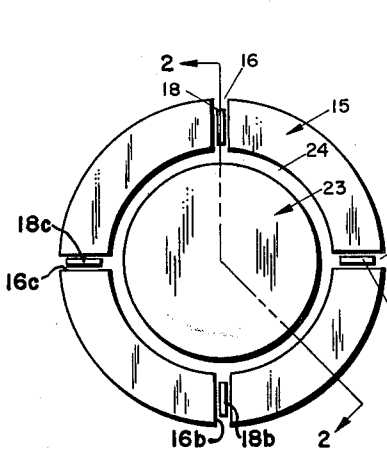


FIGURE 1

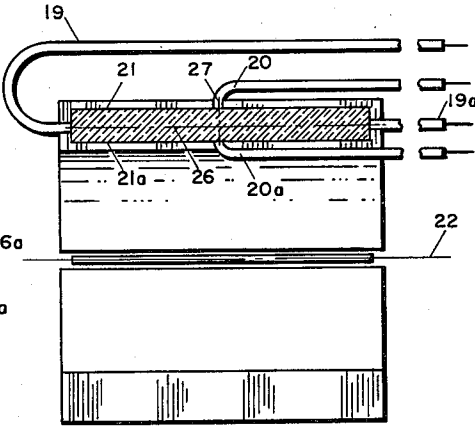


FIGURE 2

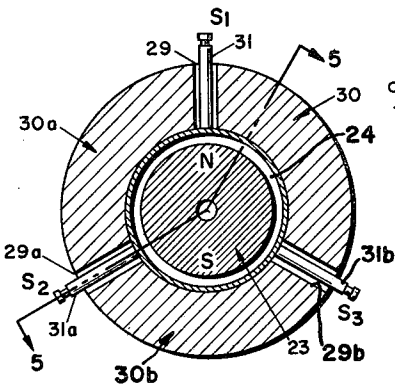


FIGURE 3

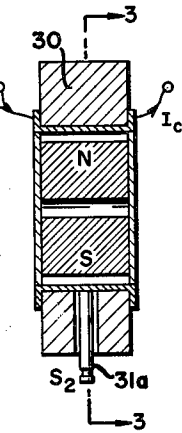


FIGURE 5

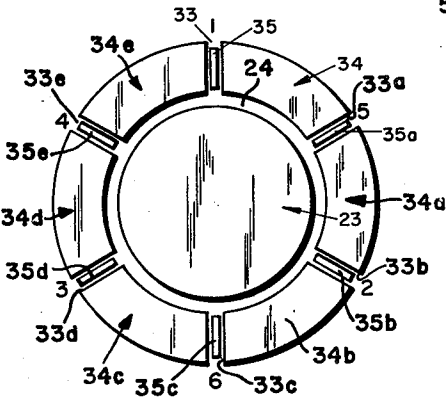


FIGURE 4

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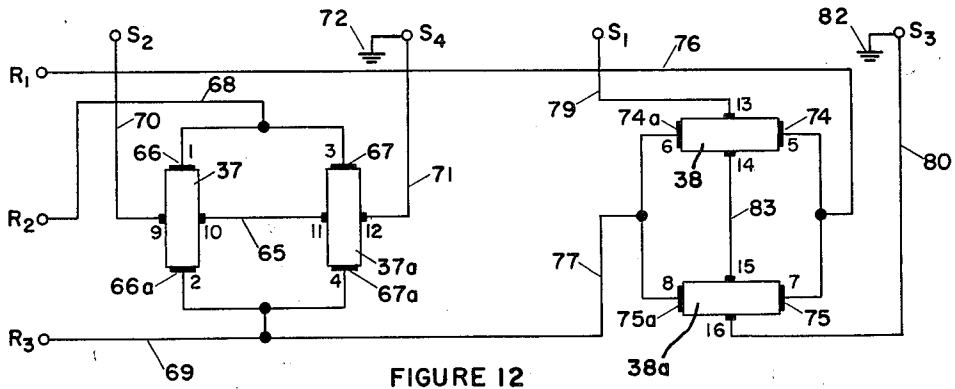
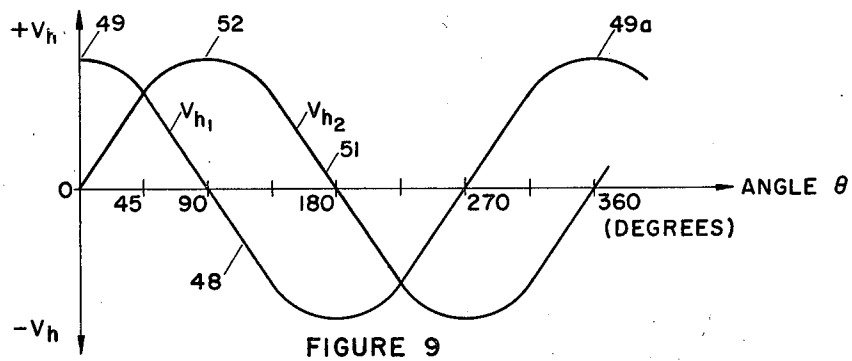
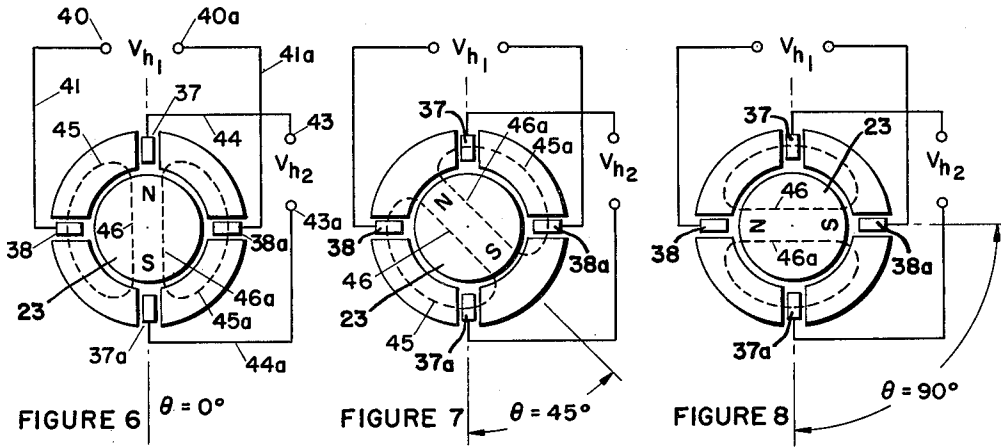
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HALL PLATE SOLID STATE RESOLVER

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3 Sheets-Sheet 2



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HALL PLATE SOLID STATE RESOLVER

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3 Sheets-Sheet 3

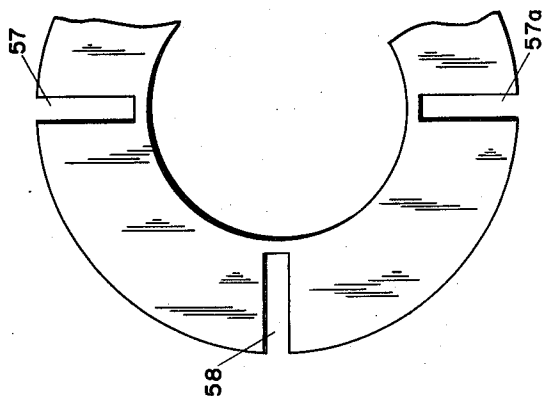


FIGURE II

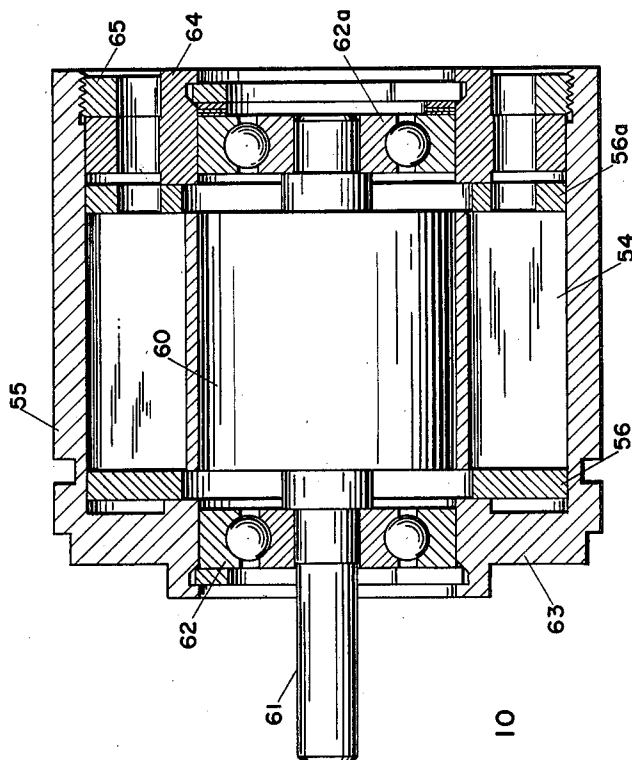


FIGURE 10

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3,194,990

**HALL PLATE SOLID STATE RESOLVER**  
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6 Claims. (Cl. 310—10)

This invention relates to resolvers and other types of synchros.

In conventional synchros, particularly in the smaller sizes such as those used for aircraft and the like, it is necessary to form coil windings of extremely fine insulation-coated wire and fit the coils into narrow slots between the poles of the stator and rotor. Due to the extreme fineness of the wire and the thinness of its insulation it is very difficult to wind and insert the coils. This results in frequent breaks in the insulation causing short circuits; consequently, the manufacture of small synchros is characterized by a high rejection rate of substantially completed synchro components.

With the increasing demand for continuously smaller size synchros, the relatively large number of turns of fine wire in each coil have tended to aggravate this situation.

A primary object of the invention is to provide synchros, which can be made in smaller diameters than the conventional types heretofore available.

A further object is to eliminate the windings used in conventional synchros and thereby reduce construction costs by simplifying construction and sharply reducing the rejection rate of finished synchros and sub-assemblies thereof.

To the attainment of these and further objects the present invention contemplates a synchro which comprises a hollow cylindrical stator member containing a plurality of radial slots symmetrically distributed about its circumference and subdividing the stator member into arcuate sectors constituting magnetic flux paths. A rotor member is disposed within the stator member for coaxial rotation and has magnetic poles of unlike polarity at diametrically opposed regions on its periphery, the flux paths between the poles traversing the shortest route through the stator sectors. A Hall generator plate is disposed in each of the slots of the stator with its major planar surfaces intercepting the flux paths between respective adjacent sectors of the stator. Means are provided, including contacts on one pair of parallel edges of each of the Hall generator plates, for causing a flow of electrical current through the plates; and additional means are provided, including voltage contacts on the other pair of parallel edges of each of the Hall generator plates for deriving a Hall voltage output generated in response to magnetic flux flowing through the stator and intercepted by the plates.

Additional objects of the invention, its advantages, scope and the manner in which it may be practiced will be more fully apparent to persons skilled in the art from the following description of exemplary embodiments thereof taken in conjunction with the subjected claims and the annexed drawings in which like reference numerals denote like parts throughout the several views and

FIGURE 1 is a schematic end elevational view of one embodiment of a synchro resolver in accordance with the present invention;

FIGURE 2 is a longitudinal section through the synchro resolver taken on the line 2—2, FIGURE 1, with the central rotor removed;

FIGURE 3 is a cross-section through a modification of the resolver shown on FIGURE 1;

FIGURE 4 is a view similar to FIGURE 1, of another embodiment of the invention;

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FIGURE 5 is a section on line 5—5, FIGURE 3;

FIGURES 6, 7 and 8 are schematic views similar to FIGURE 1 but including electrical connections to the synchro and representing the synchro with its rotor in various angular positions;

FIGURE 9 is a plot of synchro output voltage variation with rotor angle;

FIGURE 10 is a longitudinal sectional view of the actual structure of a synchro similar to those shown schematically in FIGURES 1—8;

FIGURE 11 is a fragmentary elevational view of one structural element of the synchro shown in FIGURE 10; and

FIGURE 12 is a schematic wiring diagram showing the electrical aspects of synchros of the type depicted in FIGURES 1, 2 and 6.

It will be understood that the following description of the construction and the method of operation and utilization of the Solid State Resolver, is intended as explanatory of the invention and not restrictive thereof.

Referring to the drawings and first particularly to FIGURES 1 and 2, there is shown a synchro or resolver, the stator 15 of which has four radially extending equi-angularly spaced slots 16, 16a therein, each containing a Hall generator 18, 18a.

Briefly and generally stated, a Hall generator consists of a quadrangular plate of semiconductive material having an ohmic contact or electrode on each edge. The electrodes on parallel edges are located directly opposite each other and symmetrically disposed with respect to a line drawn perpendicular to such edges. When a potential is applied between one pair of opposed electrodes, known as the current electrodes, and the plate of semiconductive material is disposed in an electromagnetic flux field directed perpendicular to its major planar surfaces, a voltage, known as the Hall voltage is generated between the other pairs of electrodes.

Hall generator plates of germanium, silicon, or any other suitable material may be used. Entirely satisfactory results are obtained with germanium plates doped for a resistivity of 1 ohm-cm. and oriented crystallographically for minimum magneto-resistive effect.

The Hall generator crystals may also be made of a metal-coated ferrite plate having an outer layer of semiconductive material deposited thereon.

In accordance with the present invention, the Hall generator plates 18, 18a, . . . 18e are disposed in radial planes with the edges carrying the Hall voltage electrodes parallel to the central axis 22 of stator 15. Accordingly, conductors 19, 19a connected to the ends of the plate, are the current leads and 20, 20a, connected to its longitudinal edges, are the Hall voltage leads.

The stator is made of a magnetizable material, such as iron, which has been heat treated to eliminate hysteresis effects.

Coaxially disposed within stator 15 for rotation about axis 22 is a substantially cylindrical rotor 23, forming an annular air gap 24 between its outer circumference and the inner circumferential surface of the stator.

Rotor 23 may be either of the wound or permanent magnet type which will produce a sinusoidally distributed field around the air gap. Satisfactory results are achieved with a magnetic ferrite rotor having its circumferential outer surface machined to a high degree of concentricity, the rotor being specially magnetized to form uniform sinusoidal flux distribution.

From the structure thus far described it will be seen that the axis 26 of current flow of each Hall generator is parallel to the axis of rotation 22 of rotor 23 and the Hall voltage or output axis 27 of each generator is disposed radially of the rotation axis 22.

FIGURE 3 represents a modification of the synchro

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construction shown in FIGURES 1 and 2. The essential difference is that there are three slots 29, 29a, 29b spaced 120° apart around the stator, thus dividing the stator into three radial segments 30, 30a, 30b. Respective Hall generators 31, 31a, 31b are disposed in slots 29, 29a, 29b in the same manner as shown in FIGURES 1 and 2.

FIGURE 4 shows another modification of the stator shown in FIGURES 1 and 2. In this construction, the stator segments are separated by six equally-spaced 33, 33a, . . . 33e spaced 60° apart, around the outer circumference of the stator, thus dividing the stator into six segments 34, 34a, . . . 34e. Respective Hall generators 35, 35a, . . . 35e are disposed in radial slots 33, 33a, . . . 33e in the stator.

A single phase of the component output circuit would be provided by a unit having one or more Hall generators, spaced around the stator, with their outputs connected in series. The spacing may be used to eliminate harmonics from the output voltage.

Two and three phase components can be made by duplicating the Hall generator crystals in the manner shown in FIGURES 1, 3 and 4.

Thus, when the Hall generators are spaced 90° apart around the stator circumference, as in FIGURE 1, the voltage generated would be two-phase.

In the construction shown in FIGURE 3, the Hall generators 31, 31a and 31b spaced 120° apart provide a three-phase voltage output.

A six-generator unit, such as that shown in FIGURE 4, can be connected to provide two-phase voltage or three-phase voltage, depending upon whether the Hall generators are connected in pairs or in sets of three.

FIGURES 6, 7, and 8 shows schematically the arrangement of the magnetic poles of the rotor, relative to the stator Hall generators during a portion of one complete revolution of the rotor. The stator is substantially the same as that shown in FIGURE 1 but has its four Hall generators designated 37, 37a, 38, 38a and connected respectively to output terminals 43, 43a, 40, 40a by leads 44, 44a, 41, 41a.

Rotor 23 which likewise is substantially the same as that shown in FIGURE 1 is shown in FIGURES 6-8 with magnetic poles N, S designated thereon at diametrically opposite regions of its periphery and with liens of flux 46, 46a and flux return paths 47, 47a designated in broken lines.

In the position shown in FIGURE 6, the arcuate magnetic flux return paths 45, 45a between poles N, S. of the permanent magnet rotor are intercepted, substantially at right angles, by Hall generators 38, 38a producing a Hall voltage output appearing at terminals 40, 40a. Meanwhile, generators 37, 37a are outside the flux path and produce substantially zero output. This position is designated as the zero angle of rotation, i.e.,  $\theta=0$ .

In the position shown in FIGURE 7,  $\theta=45^\circ$ , flux return path 45 is intercepted by Hall generators 37a and 38 while flux return path 45a is intercepted by Hall generators 37 and 38a. When  $\theta=90^\circ$  (FIGURE 8) flux return paths 45 and 45a are intercepted respectively by Hall generators 37a and 37.

In FIGURE 9, curve 48 shows the relation between rotor angle  $\theta$  and the output voltage  $V_{H1}$  of Hall generators 38, 38a; the curve is sinusoidal, having positive peaks 49 and 49a at 0° and 360°, respectively, and a negative peak at 180°.

Curve 51 shows the voltage generated by Hall generators 37, 37a; also sinusoidal, this voltage has a positive peak at the 90° rotor position and a negative peak at the 270° rotor position.

FIGURES 10 and 11 show an actual resolver incorporating a stator, similar to that shown in FIGURE 1, the Hall generators and the rotor following the same arrangement.

In the construction shown in FIGURE 10, the stator

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54 is mounted in a hollow cylindrical housing 55 and includes pair of axially-spaced, concentrically-disposed, annular plates 56, 56a of brass or other non-ferrous (i.e., non-magnetic) material. As shown in FIGURE 11, the stator has four equi-angularly spaced, parallel-faced, radial slots 57, 58, therein, for the reception of Hall generators (not shown) as hereinbefore described.

The rotor 60 is coaxially supported within stator 54 by a central shaft 61 having its ends rotatably journaled in housing 55 by a pair of ball bearings 62, 62a.

Ball bearing 62 is mounted in end wall 63 of the housing 55 while ball bearing 62a is supported by a tubular insert 64 fitted to the open end of the housing. Insert 64 is held in place by a tubular nut 65 threadably fitted to the open end of housing 55, and abuts the righthand plate 56a which is located adjacent the righthand end of the stator 55.

FIGURE 12 shows the method of electrically connecting Hall generators 37, 37a and 38, 38a shown in FIGURES 1 and 6.

Hall generators 37 and 37a are connected in parallel between a current source potential  $R_2$  and a current drain or return potential  $R_3$  as indicated by conductors 68 and 69, respectively, leading to source connections 66, 67 and drain connections 66a, 67a. Hall generators 38 and 38a have their current source electrodes 74, 75 connected by way of conductor 76 to a second source potential  $R_1$  and have drain electrodes 74a, 75a returned in common with generators 37, 37a via conductors 77, 69 to potential  $R_3$ . Thus the diametrically opposed pairs of Hall generators are connected in parallel to respective current sources  $R_1$  and  $R_2$  and are returned to a common drain potential  $R_3$ .

The Hall voltage electrodes of generators 37 and 37a are connected in series via conductors 65, 70 and 71 between an output terminal  $S_2$  and a terminal  $S_4$  at ground potential as indicated at 72. In like manner Hall generators 38 and 38a are connected in series by means of conductors 79, 83 and 80 between an output terminal  $S_1$  and a terminal  $S_3$  at ground potential as indicated at 82.

It will be apparent to those skilled in the art, that the present invention is not limited to the specific details described above and shown in the drawings, and that various modifications are possible in carrying out the features of the invention and the operation, actuation and the method of utilization thereof, without departing from the spirit and scope of the appended claims.

What I claim is:

1. A synchro comprising:

- a hollow cylindrical stator member containing a plurality of radial slots symmetrically distributed about its circumference and sub-dividing the stator member into arcuate sectors constituting magnetic flux paths;
- a rotor member, disposed within said stator member for coaxial rotation relative thereto, having magnetic poles of unlike polarity at diametrically opposed regions on its periphery, the flux paths between said poles traversing the shortest route through said rotor sections;
- a Hall generator plate disposed in each of said slots with its major planar surfaces intercepting the flux paths between respective adjacent sectors of the stator;
- means including current contacts on one pair of parallel edges of each of said Hall generator plates for causing a flow of electrical current through the plates; and
- means including voltage contacts on the other pair of parallel edges of each of said Hall generator plates for deriving a Hall voltage output generated in response to magnetic flux flowing through said stator and intercepted by said plates.

2. A synchro in accordance with claim 1 wherein said radial slots are four in number and equi-angularly spaced.

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3. A synchro in accordance with claim 2 wherein the current contacts of the Hall generators in diametrically opposed slots are connected in parallel between respective first and second potential sources and a common drain potential and said Hall generator plates in diametrically opposed slots are connected in series between respective first and second output terminals and ground potentials.

4. A synchro in accordance with claim 1 wherein said slots are six in number and equi-angularly spaced.

5. A synchro in accordance with claim 4 wherein the Hall voltage electrodes of the Hall generators in each pair of diametrically opposed slots are connected in

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series to respective first, second and third output terminals to provide a three phase output voltage thereon.

6. A synchro in accordance with claim 1 wherein said rotor is a substantially cylindrical body of permanently magnetizable ferrite material permanently magnetized to produce said magnetic poles of unlike polarity.

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