July 27, 1965 C. R. RIEGE 3,197,684

SERVO SYNCHRONIZATION CIRCUIT WITH LOCK-OUT PREVENTION

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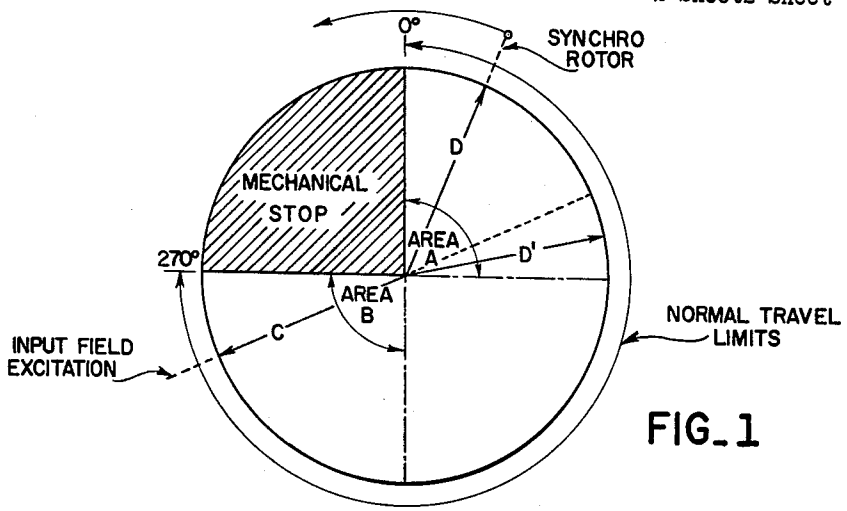


FIG_1

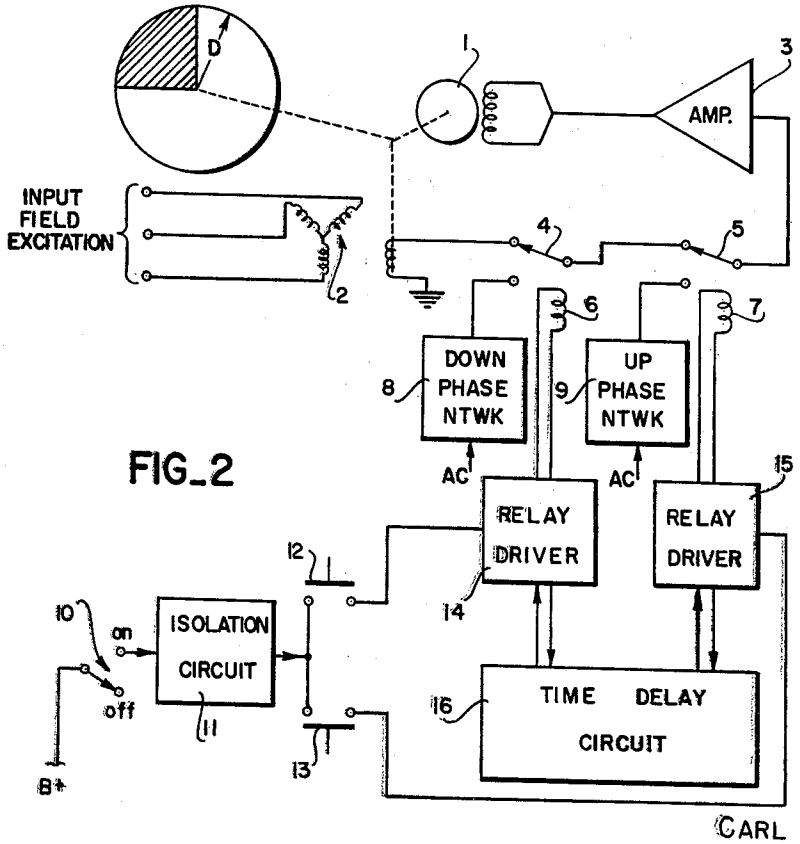


FIG_2

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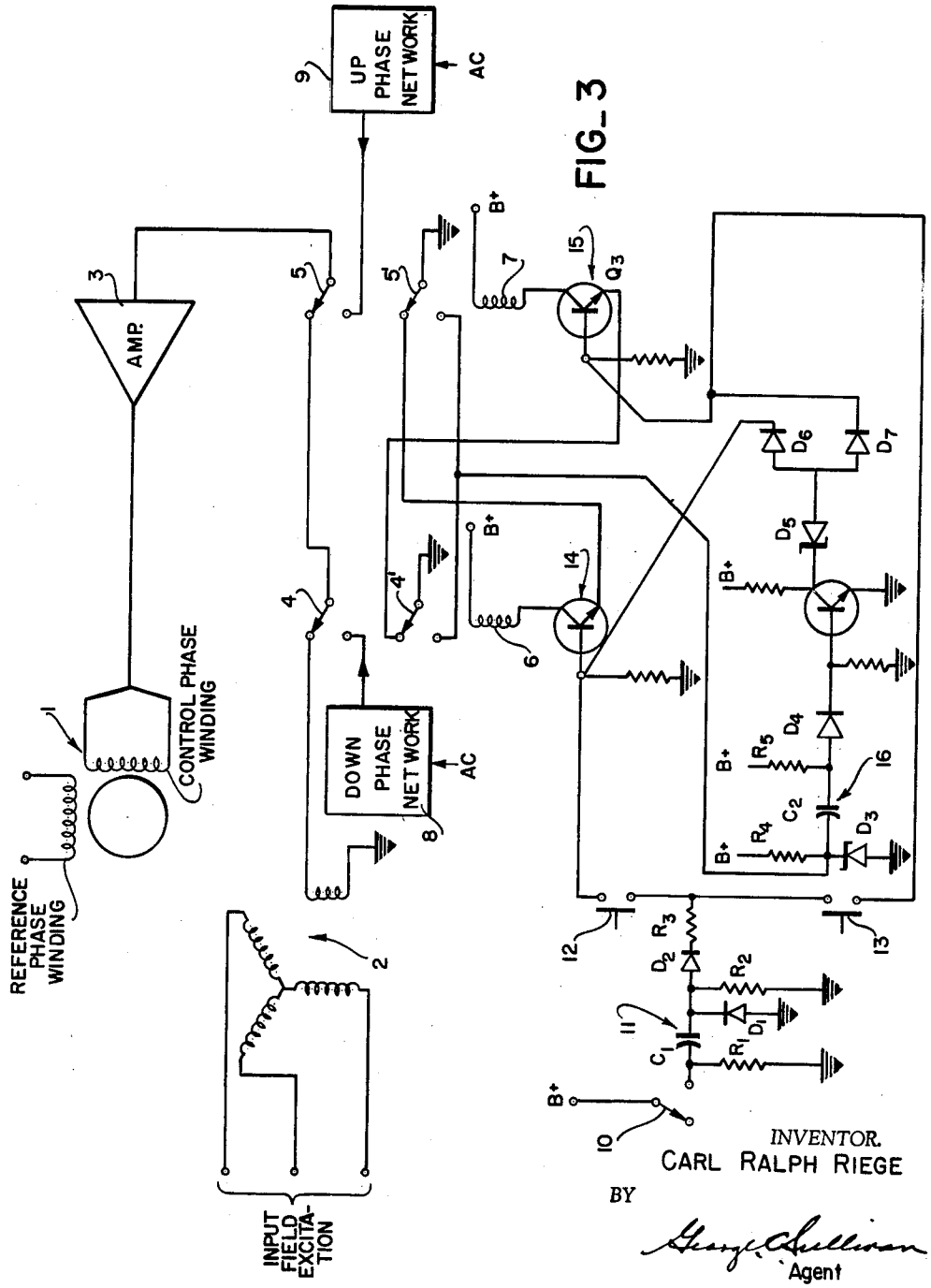


FIG_3

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SERVO SYNCHRONIZATION CIRCUIT WITH LOCK-OUT PREVENTION

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This invention relates to a servo synchronization circuit and more particularly to a servo synchronization circuit wherein provision is made to prevent servo loop lock-out action.

An object of the invention is to eliminate a lock condition on a servo-synchro nulling loop with mechanical stops and a normal arc travel greater than 180°.

Another object of the invention is to provide a syncronization circuit which will always drive to null condition when switching to automatic mode.

A further object of the invention is to provide means for moving a synchro system away from mechanical stops when an unbalanced null exists.

These and other objects will become apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a graphical representation to aid in explaining the invention;

FIGURE 2 is a block diagram of a servo system utilizing the present invention;

FIGURE 3 is a detail schematic of a preferred form of the invention.

Referring to the drawings, FIGURE 1 illustrates a typical travel arc of 270° and a mechanical stop to prevent coverage of the remaining 90°. This allows the condition to arise where the synchro input field excitation is at C, while the synchro rotor physically is at D. In this position, and since the shortest travel to the synchro stable null is through the mechanical stop, the synchro motor receives the error signal and turns the rotor into the mechanical stop and holds it there. That this is so is evident from the diagram wherein the dotted line extension of the field excitation C is drawn 180° out of phase therewith. According to synchro theory, error signals on either side of this extension will be identified by a certain magnitude and phase and will move the motor so that the error is reduced to null or minimum. Direction of motion is determined by the relative phase of the field excitation and rotor position.

In order to move the motor out of the areas of unbalance, designated as A and B, the servo synchronization system of the present invention is used.

In FIGURE 2, the motor **1**, synchro **2** and amplifier **3** constitute a standard servo loop. Relay contacts **4** and **5** are connected within the loop and in series therewith. When either the relay **6** or relay **7** is energized, the corresponding contacts **4** or **5** are connected to a phase shift network **8** or **9** which has the proper polarity or sign to move the motor out of the particular area A or B.

Power for the relays is applied through a switch **10** and isolation circuit **11** to upper limit switch **12** and lower limit switch **13**. These limit switches are associated with the mechanical stop area, one for either side, so that as the motor moves into or against the mechanical stop from either direction, one of the limit switches is operated.

Upper limit switch **12** is connected to the relay driver **14** which in turn energizes relay **6**. Lower limit switch **13** is connected to relay driver **15**, which in turn operates relay **7**. A time-delay circuit **16** is connected to the relay drivers **8** and **9** for controlling the time the relays are energized.

In operation, the power switch **10** is turned on and the power (B+) is applied through the isolation circuit to

the two limit switches **12** and **13**. If the unbalanced null condition exists, the motor will drive the mechanism to one of the two stops, depressing the respective limit switch. Of course, if the field excitation and rotor are displaced less than 180° along the normal travel arc, null will be reached without actuation of the limit switches.

However, where the condition illustrated in FIGURE 1 exists, the motor drives into one of the stops and actuates the corresponding limit switch. The closing of one of the limit switches applies power to the corresponding relay driver, which then energizes its relay for a length of time determined by the time-delay circuit **16**. Operation of one of the relays temporarily disconnects the field excitation and applies a voltage from the phase shift networks **8** or **9** to the motor. The phase of the voltage applied to the motor should be such as to move the rotor of the motor from either the areas A or B so that the rotor will be physically displaced from the input field excitation less than 180° when the relay is de-energized after a time delay determined by the time-delay circuit **16**.

The isolation circuit between the power switch **10** and the limit switches **12** and **13** is necessary if the circuit is to operate only once when the power switch **10** is turned on. The isolation circuit is designed so that it discharges during the one operation and subsequent depressions of limit switches **12** and **13** will not start the servo synchronization circuit operation a second time. This is necessary if, during normal circuit operation, even a remote possibility exists that the servo system may overtravel far enough to hit either of the two limit switches **12** and **13**.

FIGURE 3 illustrates a suggested servo synchronization system utilizing transistorized circuitry. It will be understood that vacuum tubes or complete relay circuits are equally adaptable to the present invention.

The standard servo loop is shown as before to comprise the motor **1**, synchro **2**, amplifier **3** and normally closed contacts **4** and **5**. The phase shift networks **8** and **9** are designated respectively as down-phase network and up-phase network and are connected to relay contacts associated with the upper armatures of relays **6** and **7** as before.

Isolation circuit **11** is shown as comprising series-connected C_1, D_2, and R_3 with shunt-connected R_1, D_1 and R_2. When the power switch is off, capacitor C_1 is completely discharged by R_1, R_2 and D_1. The diode D_1 offers a rapid discharge path needed in case the power switch is rapidly switched off and on again.

When switch **10** is turned on, the B+ voltage is dropped across R_1. Because of the long time constant of R_2, C_1, B+ will also appear across R_2. The decay of the voltage across R_2 as C_1 charges is slow enough to allow the circuit to operate if the servo system is close to a mechanical stop and it is fast enough to prevent the servo system from running the full travel length from one mechanical stop to the other. The latter operation would be a normal synchro follow-up. In other words, referring again to FIGURE 1, and assuming the field excitation to be as illustrated by the vector C, if the synchro rotor is physically located by D, the shortest travel to the synchro null would be through the stop area and of course the rotor would begin its run in a counter-clockwise direction and engage the mechanical stop and a corresponding limit switch, which would then actuate the synchronization circuit.

However, if we assume that the rotor is physically located at D^1 and with the same assumed field excitation C, then the shortest travel will be a clockwise movement away from area A and, in such case, normal synchro follow-up should take place, and the decay of the voltage across R_2 should be fast enough so that in the event of

overrun of the synchro rotor and contact of the other limit switch is made, insufficient voltage will remain on R_2 to operate the synchronization circuit.

If the limit switch 12, for example, is depressed by the servo loop before decay of the voltage across R_2, a current will be applied to the base of the transistor Q_2 of relay driver 14. Q_2 amplifies this current to a level high enough to energize relay 6. It will be noted that the emitter of Q_2 is grounded through relay 7, which assures that only one of the two relays 6 and 7 will operate at any one time.

As soon as relay 6 is energized, the lower armature 4' moves from the position shown to the lower contact, thereby removing the ground connection to the emitter of Q_3 and grounding the junction between R_4 and C_2 in the time-delay circuit 16. This potential drop is coupled through C_2 and diode D_4 to the base of transistor Q_1.

Diode D_3 is a zener diode which keeps the voltage at the junction of R_4–C_2 constant even if B+ variations occur, thereby insuring a fixed voltage drop when either relay closes. A constant voltage drop insures a constant time period of discharge of C_2 through R_5. The diode D_4 prevents the application of large negative voltages between the base and emitter of Q_1. Q_1 is cut off and will be held cut off while C_2 discharges through R_5. As long as Q_1 is cut off, its collector is held almost at B+ potential. This high potential is applied through diode D_5 to transistor Q_2. Since Q_2 was turned on by the voltage from R_2 which was applied through limit switch 12, the high potential holds Q_2 on and thereby relay 6 energized even though switch 12 opens. Diodes D_6 and D_7 isolate the two limit switches from each other.

The length of time that Q_2 (or Q_3) and relay 6 (or 7) are on, therefore, depends on the cutoff period of Q_1 which in turn depends on the tine constant R_5C_2. Time constant R_5C_2 must be chosen judiciously since it directly controls the length of time that the motor 1 will be driven by the UP or DOWN phase network after either limit switch is depressed. For example, if we assume the extreme condition, wherein the field excitation C in FIGURE 1 is moved clockwise until it is adjacent the mechanical stop area, and the synchro rotor position D is in area A, then in such case the rotor must be moved substantially 90° from the mechanical stop to permit normal synchro follow-up. Thus considering system inertia, synchro speed, etc., the time constant and the Up-Down phase networks must be such as to assure 90° movement from stop. For this reason the Up-Down phase networks may be simple RC networks which will shift the alternating current reference which is applied to the phase networks +90° or −90° at the motor control winding to turn the motor in the desired Up or Down direction.

Where the field excitation C and rotor position D as shown in FIGURE 1 are reversed at the time the switch 10 is closed, the other limit switch 13 will be first actuated, causing transistor Q_3 and relay 7 to operate in the same manner as described for Q_2 and relay 6.

While a specific embodiment of the invention has been shown and described it should be understood that certain alterations, modifications and substitutions may be made to the instant disclosure without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. In a synchro loop wherein the motor is provided with mechanical stops whereby a lock condition exists by virtue of said stops, the improvement comprising relay contacts connected in the synchro loop, phase shift networks, and relay means responsive to said lock condition to shift one of said relay contacts from said synchro loop to one of said phase shift networks to drive the motor from said lock condition, timing means for de-energizing said relay means after a predetermined delay and isolation circuit means to prevent further operation of said relay means after said lock condition is eliminated.

2. A servo synchronization circuit comprising a synchro nulling loop having mechanical stops and a normal arc travel greater than 180 electrical degrees, switch means closed when the motor of said loop engages said stops from either direction, movable contact means series-connected in said loop, phase network means for providing oppositely-phased signals, relay means responsive to said switch means for moving said contacts from the normal loop signal to one of said phase networks, whereby the synchro loop motor is driven away from the mechanical stop, time-delay means for de-energizing said relay means after a predetermined delay so that normal nulling exists and the error signal is less than 180° on the normal travel arc opposite to the mechanical stop and an isolation circuit connected to said switch means for limiting said relay means to one operation.

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