

## 4.3 - SERVOMECHANISM

A servomechanism is an electric control system for an automatic powered mechanism that produces motion or force using a low energy input signal. The amplified system typically drives an electric or hydraulic motor however the motion can be rotary or linear depending on the mechanical transmission of the force. Servomechanisms are integral in automatic flight control systems (autopilots). They are also used in auto throttle systems, radar scanner systems and more. The discussion that follow focuses on autopilot systems but the principles are the same for any servomechanism

### SERVOMECHANISM TERMS

#### OPEN AND CLOSED SYSTEMS

An open loop system is one in which the controls are set to the desired setting. The signal produced in the controller is amplified to operate a motor which moves the controlled unit, in this case the flight controls, to the selected setting. If there is something that prevents the unit from actually reaching the desired setting, the control system does not know this. The system is said to be open because of this lack of feedback as to the results of the setting. Bearing friction, wind resistance and other factors may cause a flight control setting on the controller to not actually be achieved. Open systems are not used on advanced aircraft autopilot or automatic flight control systems.

#### FEEDBACK AND FOLLOW-UP

A closed servomechanism system is one in which there is feedback, or follow-up, from the controlled unit. This is done in the form of an electric or electronic signal. The actual position of the unit is fed back as an input to the controller so that adjustments can be made to achieve or maintain the original selected settings. The follow-up information on the position of a controlled device is often accomplished with an analog transducer.

#### ANALOG TRANSDUCER

A transducer is an electric device which converts the differing position of the physical flight control surface in to a variable electric output signal that can be processed by the controller. It is basically a transformer with two secondary induction coils and a moving core that is attached to the controlled unit. As the unit moves, the core moves, which changes the value of the voltage

induced in the two secondary coils. The differential of the output voltages of the coils is the feedback signal sent to the controller. (*Figure 3-1*)

Both linear (LVDT) and rotary differential transducers (RVDT's) are used. Since there is only an inductive connection between the primary and secondary coils, the transducers are very stable linear devices that operate accurately and reliably for long periods of time. The core, which is mechanically linked to the flight control, or other unit whose movement is being controlled, is the only moving part.

### OPERATION OF SERVOMECHANISM

#### SYNCHRO SYSTEMS

Another type of position monitoring system that incorporates feedback is known as a synchro system. A synchro system is an electric system used for transmitting information from one point to another. The word "synchro" is a shortened form of the word "synchronous" and refers to any one of a number of similarly operating two-unit electrical systems capable of measuring, transmitting, and indicating a certain parameter on the aircraft. Most analog position-indicating instruments are designed around a synchro system, such as a flap

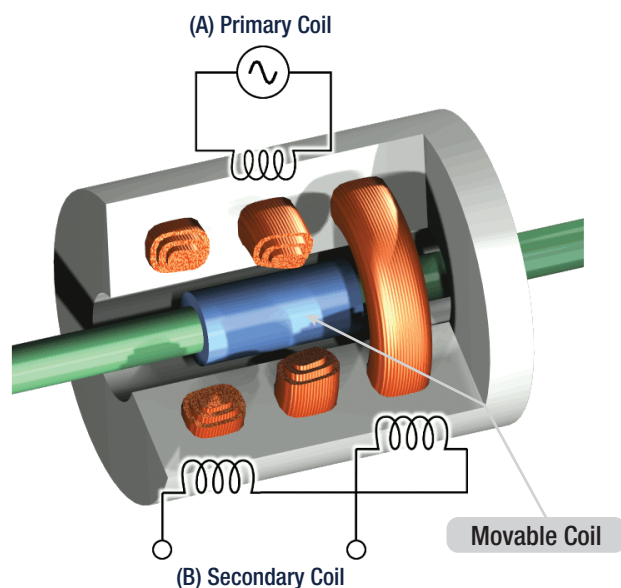


Figure 3-1. Cutaway view of a Linear Variable Differential Transducer (LVDT). Current is driven through the primary coil at A, causing an induction current to be generated through the secondary coils at B.

position indicator. Fluid pressure indicators may also use synchro systems. Synchro systems are used as remote position indicators for landing gear, autopilot systems, radar, and many other remote-indicating applications.

Common types of synchro systems include the autosyn, selsyn, and magnesyn synchro systems. These systems are similar in construction, and all operate by exploiting the consistent relationship between electricity and magnetism. The fact that electricity can be used to create magnetic fields that have definite direction, and that magnetic fields can interact with magnets and other electromagnetic fields, is the basis of their operation. A description of a DC synchro system provides the basic concept of how a synchro system works. AC systems are more refined and common on transport category aircraft.

### DC SELSYN SYSTEMS

On aircraft with direct current (DC) electrical systems, the DC selsyn system is widely used. The DC selsyn system consists of a transmitter, an indicator, and connecting wires. The transmitter consists of a circular resistance winding and a rotatable contact arm. The rotatable contact arm turns on a shaft in the center of the resistance winding. The two ends of the arm are brushes and always touch the winding on opposite sides.

(Figure 3-2)

On position indicating systems, the shaft to which the contact arm is fastened protrudes through the end of transmitter housing and is attached to the unit whose position is to be transmitted (e.g., flaps, landing gear). The transmitter is often connected to the moving unit through a mechanical linkage. As the unit moves, it causes the transmitter shaft to turn. The arm is turned so that voltage is applied through the brushes to any two points around the circumference of the resistance winding. The rotor shaft of DC selsyn systems, measuring other kinds of data, operates the same way, but may not protrude outside of the housing. The sensing device, which imparts rotary motion to the shaft, could be located inside the transmitter housing.

Referring to *Figure 3-2* note that the resistance winding of the transmitter is tapped off in three fixed places, usually  $120^\circ$  apart. These taps distribute current through the toroidal windings of the indicator motor. When current flows through these windings, a magnetic field is created. Like all magnetic fields, a definite north and

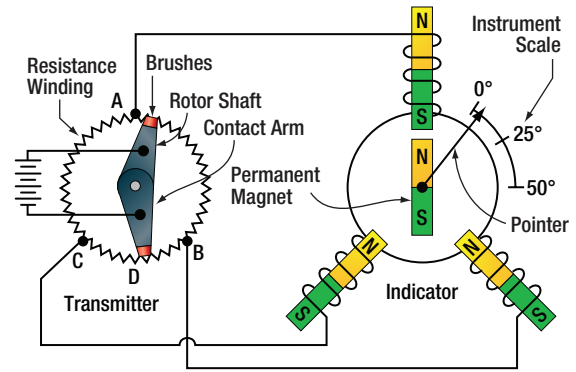


Figure 3-2. A schematic of a DC selsyn synchro remote indicating system.

south direction to the field exists. As the transmitter rotor shaft is turned, the voltage-supplying contact arm moves. Because it contacts the transmitter resistance winding in different positions, the resistance between the supply arm and the various tapoffs changes. This causes the voltage flowing through the tapoffs to change as the resistance of sections of the winding become longer or shorter. The result is that varied current is sent via the tapoffs to the three windings in the indicator motor.

The resultant magnetic field created by current flowing through the indicator coils changes as each receives varied current from the transmitter tapoffs. The direction of the magnetic field also changes. Thus, the direction of the magnetic field across the indicating element corresponds in position to the moving arm in the transmitter. A permanent magnet is attached to the centered rotor shaft in the indicator, as is the indicator pointer. The magnet aligns itself with the direction of the magnetic field and the pointer does as well. Whenever the magnetic field changes direction, the permanent magnet and pointer realign with the new position of the field. Thus, the position of the aircraft device is indicated.

Landing gear contain mechanical devices that lock the gear up, called an up-lock, or down, called a down-lock. When the DC selsyn system is used to indicate the position of the landing gear, the indicator can also show that the up-lock or down-lock is engaged. This is done by again varying the current flowing through the indicator's coils. Switches located on the actual locking devices close when the locks engage. Current from the selsyn system described above flows through the switch and a small additional circuit. The circuit adds an additional resistor to one of the transmitter winding sections created by the rotor arm and a tapoff. This

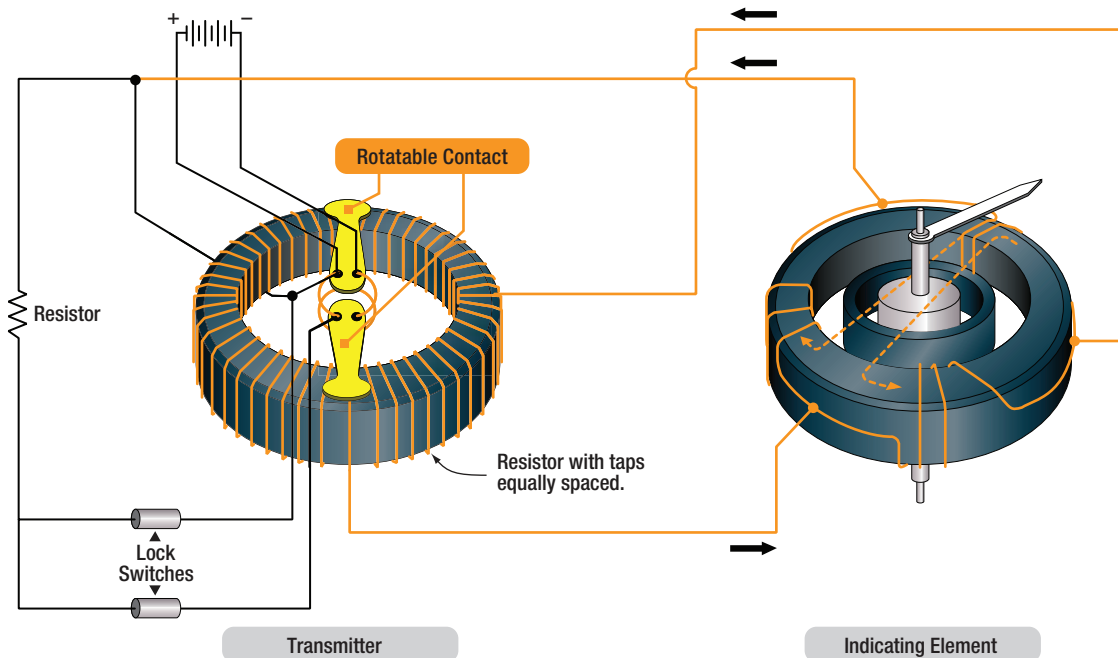


Figure 3-3. A lock switch circuit can be added to the basic DC selsyn synchro system when used to indicate landing gear position and up- and down-locked conditions on the same indicator.

changes the total resistance of that section. The result is a change in the current flowing through one of the indicator's motor coils.

This, in turn, changes the magnetic field around that coil. Therefore, the combined magnetic field created by all three motor coils is also affected, causing a shift in the direction of the indicator's magnetic field. The permanent magnet and pointer align with the new direction and shift to the locked position on the indicator dial. *Figure 3-3* shows a simplified diagram of a lock switch in a three-wire selsyn system and an indicator dial.

### AC SYNCHRO SYSTEMS

Aircraft with alternating current (AC) electrical power systems make use of autosyn or magnasyn synchro remote indicating systems. Both operate in a similar way to the DC selsyn system, except that AC power is used. Thus, they make use of electric induction, rather than resistance current flows defined by the rotor brushes.

Magnasyn systems use permanent magnet rotors such as those found in the DC selsyn system. Usually, the transmitter magnet is larger than the indicator magnet, but the electromagnetic response of the indicator rotor magnet and pointer remains the same. It aligns with the magnetic field set up by the coils, adopting

the same angle of deflection as the transmitter rotor. (*Figure 3-4*) Again, the flight control surface or other unit whose position is being monitored is attached to the transmitter rotor.

Autosyn systems are further distinguished by the fact that the transmitter and indicator rotors used are electro-magnets rather than permanent magnets. Nonetheless, like a permanent magnet, an electro-magnet aligns with the direction of the magnetic field created by current flowing through the stator coils in the indicator. Thus, the indicator pointer position mirrors the transmitter rotor position. (*Figure 3-5*)

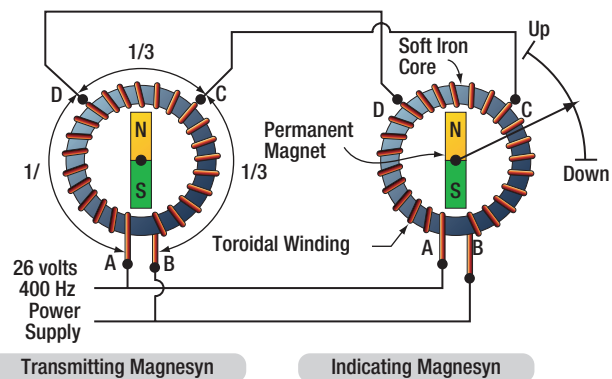


Figure 3-4. A magnasyn synchro remote-indicating system uses AC. It has permanent magnet rotors in the transmitter and indicator.

AC synchro systems are wired differently than DC systems. The varying current flows through the transmitter and indicator stator coils are induced as the AC cycles through zero and the rotor magnetic field flux is allowed to flow. The important characteristic of all synchro systems is maintained by both the autosyn and magnasyn systems. That is, the position of the transmitter rotor is mirrored by the rotor in the indicator. These systems are used in many of the same applications as the DC systems and more. Since they are usually part of instrumentation for high performance aircraft, adaptations of autosyn and magnasyn synchro systems are frequently used in directional indicators and in autopilot systems.

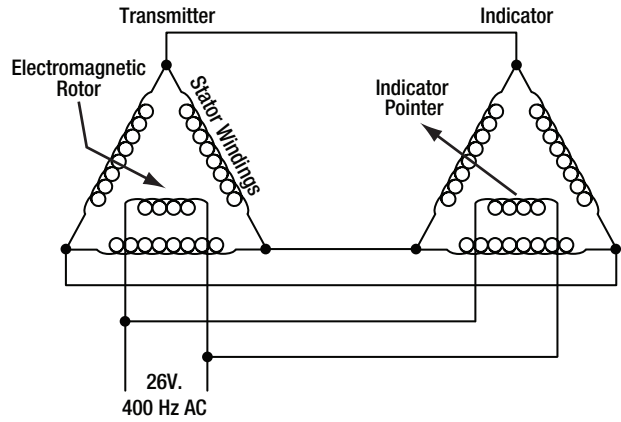


Figure 3-5. An autosyn remote-indicating system utilizes the interaction between magnetic fields set up by electric current flow to position the indicator pointer.

Modern AC synchro systems include variants of the AC synchros described. A torque synchro system was alluded to above. The transmitter synchro sets up the electromagnetic field in the receiver synchro and the electromagnetic rotor of the receiver, responding to the field, has enough torque to move the indicator pointer or some other small-torque device. In a control synchro, the receiver is known as the control transformer. It amplifies the signals from the transmitter which then turn a motor to position an indicator, or more typically, a larger device or heavier load. The signal produced in a control synchro is known as an error signal. This is because the voltage represents the amount and direction that the synchro rotors are out of correspondence. It is this error signal that is used to ultimately move the load once the signal has been amplified. **Figure 3-6** illustrates the basic setup of a control synchro system.

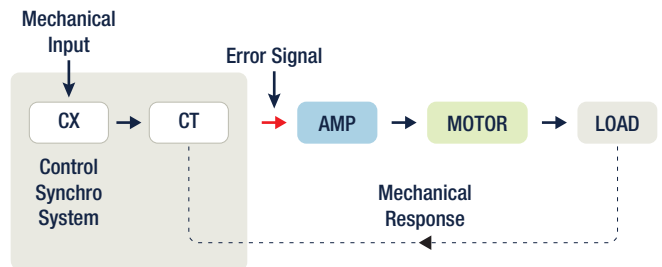


Figure 3-6. A positioning servo system using a control synchro system.

A differential synchro system includes the transmitter and receiver but also includes a differential synchro between the two. The basic concept is that the differential synchro accepts position input from two synchros and creates an output that is the differences between the two input synchros. This can be either the sum or difference between the inputs.

A resolver is a type of synchro system. Unlike those described, the stator windings on a resolver are at 90 degree angles to each other instead of 120 degrees. The 90 degree spacing provides Sine and Cosine stator outputs that represent the angular displacement of the rotor attached to the device being sensed. Signals from resolvers are typically input into analog to digital converters. **Figure 3-7** is a simplified diagram of a resolver.

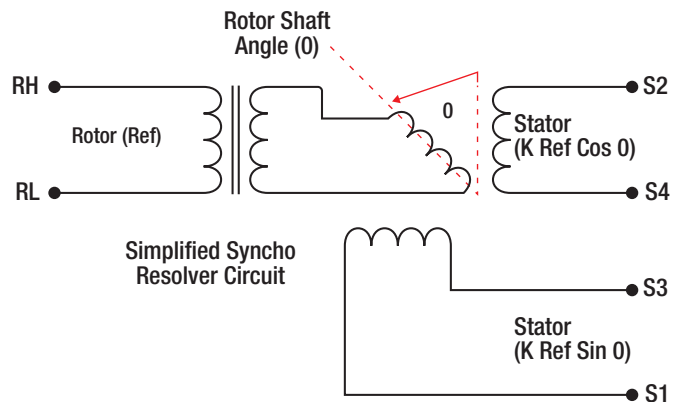


Figure 3-7. A simplified synchro resolver circuit.

### INDUCTANCE TRANSMITTERS

There are other methods of transmitting condition information on aircraft. An inductance transmitter is used in older instruments, acceleration sensors and air data computers. It uses inductance windings similar to a synchro but the shape and spatial location of the laminated core is that of a capital letter “E”. The center limb of the E is fed primary voltage and the upper and lower limbs contain secondary windings. An I-shaped bar of conductive material pivots in synch with the position of the element being sensed. It is located at the

open end of the E. As the bar pivots, the space between the upper and lower limbs of the E changes. The voltage induced in the secondary coils on these limbs also changes due to the bar's influence on the electromagnetic field. The varied output of the secondary windings is interpreted as the sensor position.

Figure 3-8 shows the inductance transmitter set up with the pivoting sensor/bar in three different positions.

### CAPACITANCE TRANSMITTERS

A capacitance transmitter is another type of device used on aircraft to transmit condition. It is found most often in transport category aircraft fuel quantity systems. Since a capacitor is a device that stores electricity, the amount it can store depends on three factors: the area of its plates, the distance between the plates, and the dielectric constant of the material separating the plates. A fuel tank unit contains two concentric plates that are a fixed distance apart. Therefore, the capacitance of a

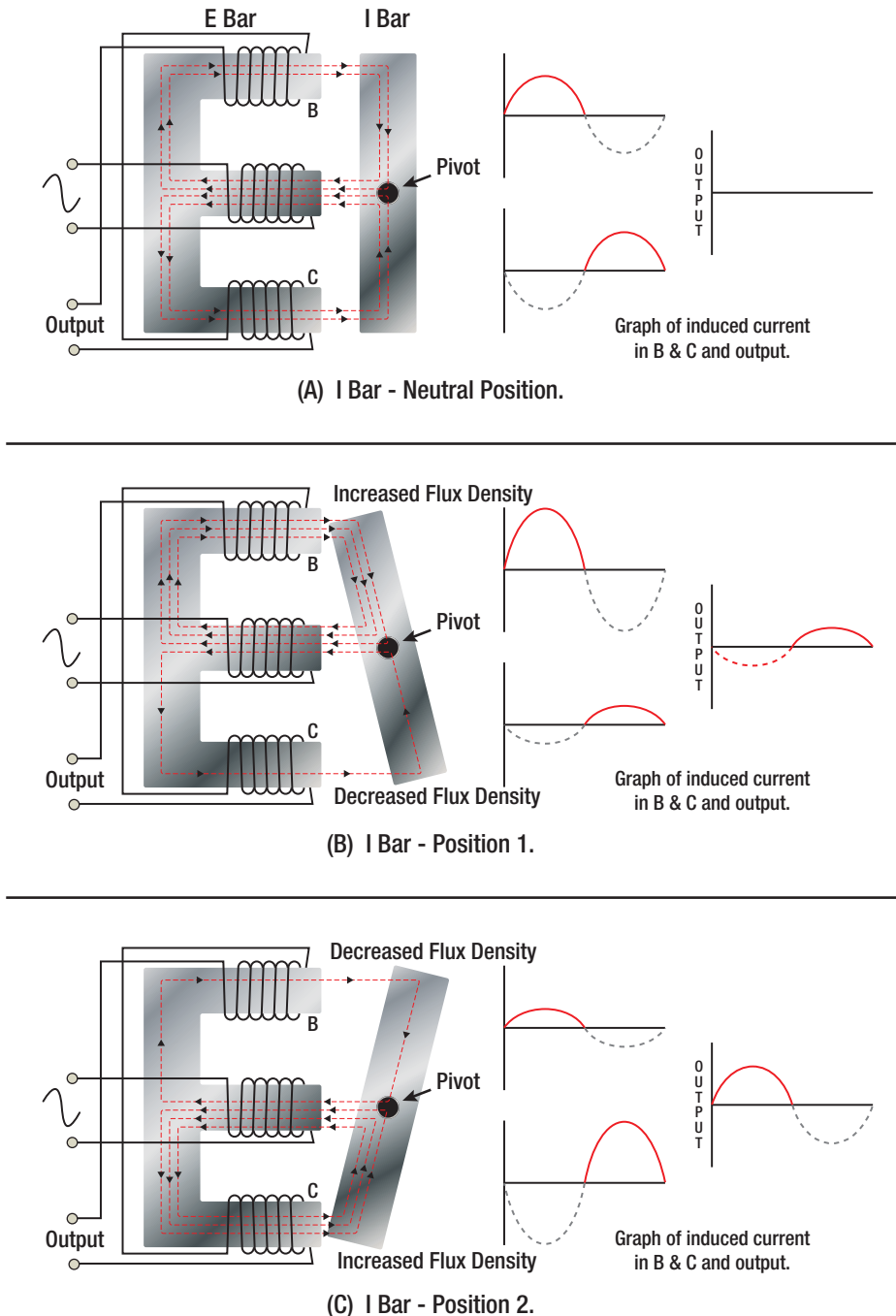


Figure 3-8. Configuration of an inductance transmitter.



unit can change if the dielectric constant of the material separating the plates varies. The units are open at the top and bottom so they can assume the same level of fuel as is in the tanks. Therefore, the material between the plates is either fuel (if the tank is full), air (if the tank is empty), or some ratio of fuel and air depending on how much fuel remains in the tank. *Figure 3-9* shows a simplified illustration of this construction.

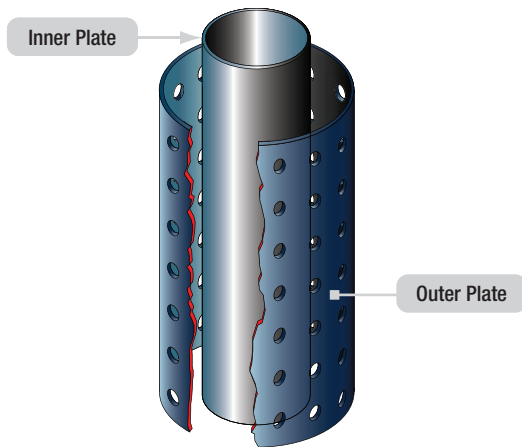


Figure 3-9. The capacitance of tank probes varies in a capacitance-type fuel tank indicator system as the space between the inner and outer plates is filled with varying quantities of fuel and air depending on the amount of fuel in the tank.

The voltage stored in a reference capacitor completely submerged in fuel is compared to the transmitter capacitor or group of capacitors wired in parallel. The basic bridge circuit for this is shown in *Figure 3-10*. The difference is a signal which is translated for display on the flight deck.

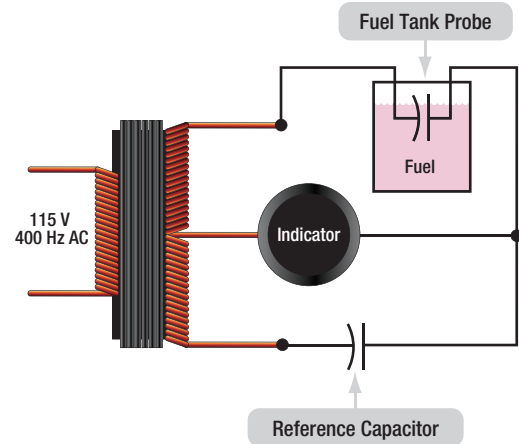


Figure 3-10. A simplified capacitance bridge for a fuel quantity system.