SERVOMECHANISMS

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INTRODUCTION

- One of the most potent features of civilization is the ability of man to harness the forces of nature for performing physical tasks far beyond the capabilities of his own strength. Control is the name given to the process of applying, releasing and stopping these forces and governing their action. Machines were invented which could use these forces, and they were quickly improved when the discovery that heat (from coal and oil) could be converted into mechanical energy; hence, the industrial revolution was born.
- Initially, machines were required to perform only simple tasks and a human operator was quite capable of having complete control over them to complete any process. As man became more ambitious and knowledgeable, more complex machines were developed to carry out more complex tasks, and it soon became apparent, that man was an imperfect controller of the machines he had created. Thus, it was a natural step to replace the human controller by some form of automatic controller wherever possible, to increase the efficiency and accuracy of the process.

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CONTROL SYSTEMS

- Generally speaking, automatic control systems are devised to *regulate* or *govern* a flow of energy and, therefore, can include electronic, electro-mechanical, pneumatic, hydraulic and mechanical devices. Their arrangement and complexity varies with the function they have been designed to perform, together with the required speed and accuracy.
- The output to be controlled can take many forms; it could be for example the automatic piloting or stabilising of an aircraft, the precise positioning of a radar aerial, or maintaining the position of an inertial platform, regardless of any manoeuvres the vehicle to which it is mounted performs. Disregarding the nature of the tasks involved, the basic components and their arrangements have a strong family likeness and they behave in very similar ways. A common theory can, therefore, be applied to all forms of automatic control.
- A *servomechanism* is a particular type of automatic control system. It is the action of the control system causing the output (the **position** or **velocity** of a shaft) to follow an input demand.

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TYPES OF SERVOMECHANISM

- A servomechanism may be classified according to two main categories:

 Open Loop

 Closed Loop

- An input transducer will generate an electrical signal which is equivalent to the demanded angular position. This demand voltage is amplified to a power level sufficient to enable the motor to drive the load. This will control the output shaft:

 Velocity in a rate servo.

 Position in a remote position control (RPC) servo.

- The output will depend on the following factors:

 Variation of load conditions

 Frictional forces within the motor and its load, and the mechanical interconnection (gear trains, clutches, linkages, drives etc.)

 Variations of power supply.

 Value of the demand voltage.

 Variations of amplifier gain.

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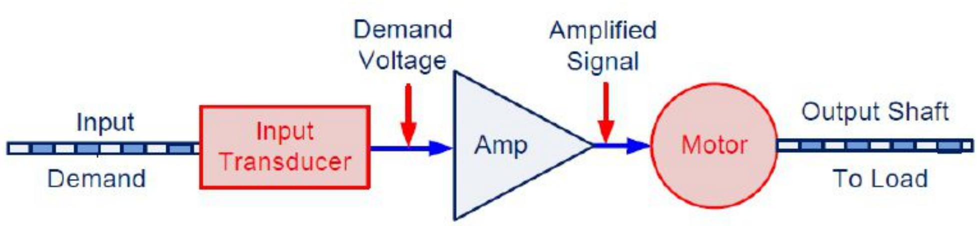
Open Loop Systems

Figure shows such a system. The open loop system suffers from the major disadvantages that the above-mentioned factors do not remain constant. For example, for a given demand, the value of output voltage will vary as the gain of the amplifier alters with time and temperature. The frictional forces within the motor and load will change with velocity, temperature and load. Variation of supply voltage and frequency will cause variation of the speed of the motor and ultimately of the load speed and position, even if the load torque remains constant. There is no means of precisely controlling these factors and, therefore, the open loop system is not good enough for close tolerance control. To remove the variables and uncertainties present in open loop, it is necessary to obtain information about the behaviour of the *output* shaft and to compare this with the *input* demand. A control system that does this is said to be operating under closed loop conditions.



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Close Loop Systems

- If an operator observes what the load is doing and makes appropriate corrections at the input, the system is no longer open loop; it is now, in fact, a closed loop system, the human operator completing the loop between output and input. He compares the desired effect with the actual effect and adjusts the system so as to reduce the error between them. He is therefore detecting the amount of error that is present in the system and applying a correction signal as appropriate.
- To show the difference between open and closed loop let's consider a professional footballer. How easy would it be to do "keep-ups" if blindfolded? The player needs his eyes to provide feedback to where the ball is in order to correct his foot.

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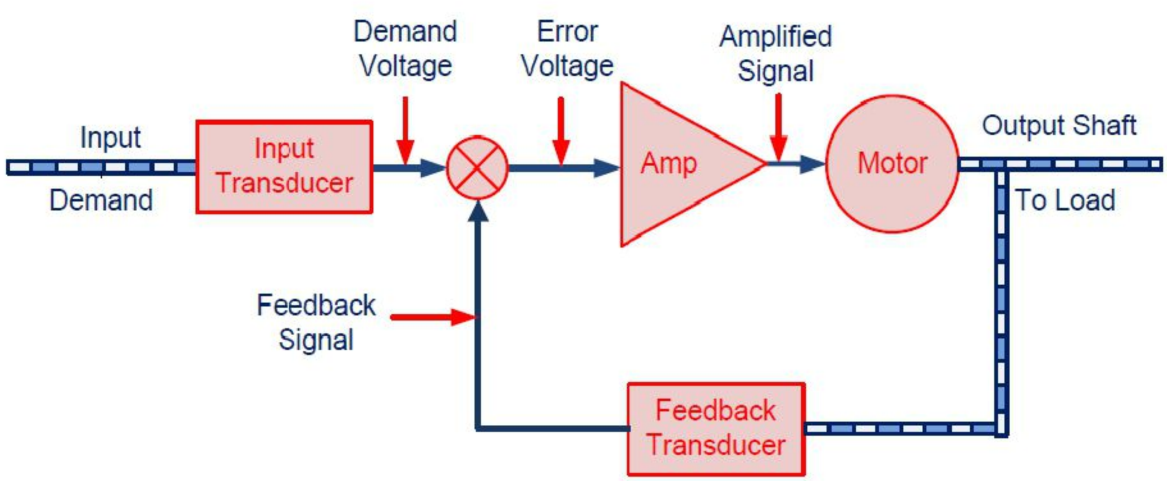

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The essential features of the closed loop system are as follows:

- The feedback of information concerning the behaviour of the load.
- The comparison of this information with the behaviour demanded by the input.
- The production of an error signal proportional to the difference between the desired behaviour and the actual behaviour.
- The amplification of the error signal to control the power into a servomotor.
- The movement of the load by the servomotor in such a direction as to reduce the error signal to zero, at which point the output is the same as that demanded by the input. The block schematic diagram of a basic closed loop control system is illustrated in Figure

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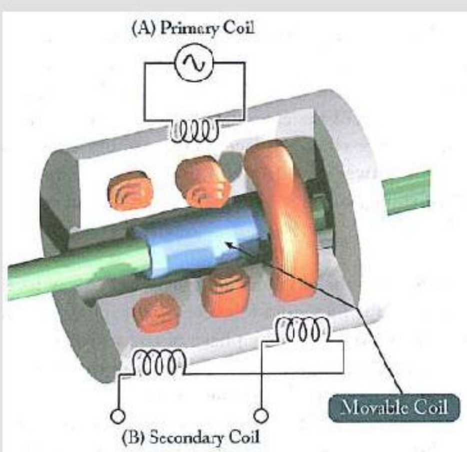
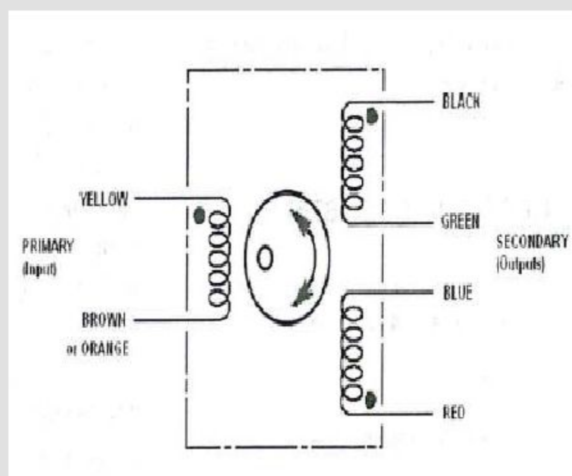
ANALOG TRANSDUCERS

LVDT	RVDT
	

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SYNCHRO SYSTEM

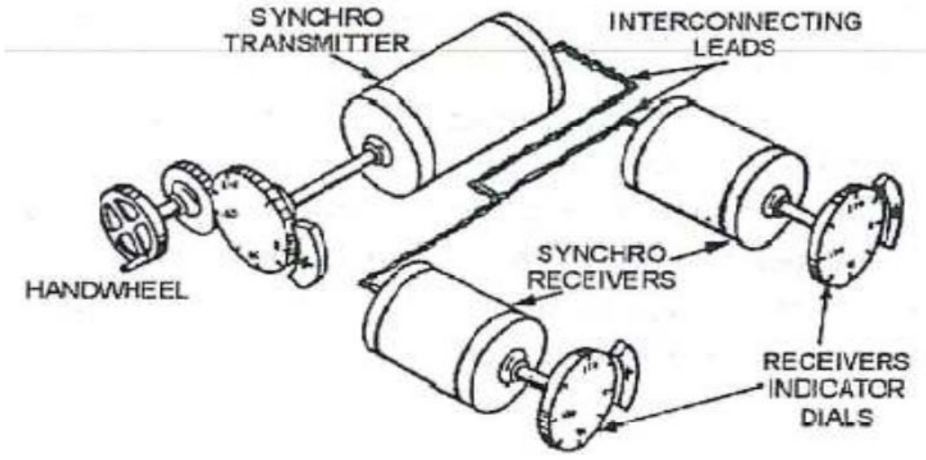

Figure 3-6. Synchonous Transmitter output signal moves receiver indicator dials in unison.

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DC SELSYN SYSTEM

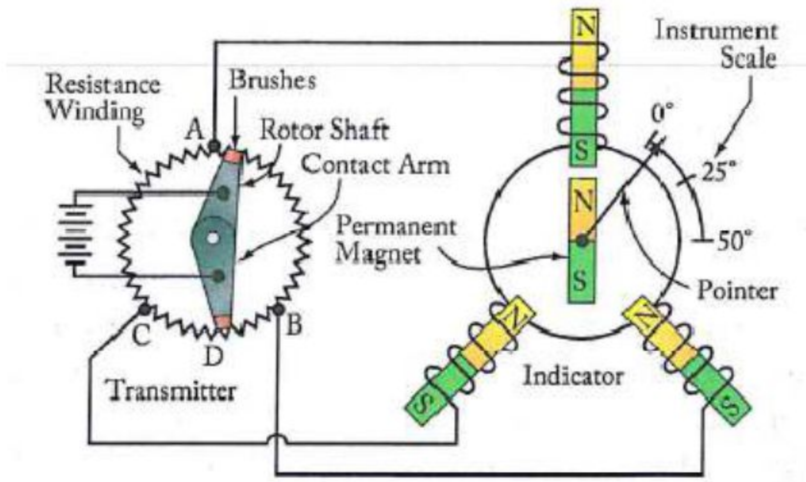

Figure 3-7. A schematic diagram of a DC selsyn synchro remote indicating system.

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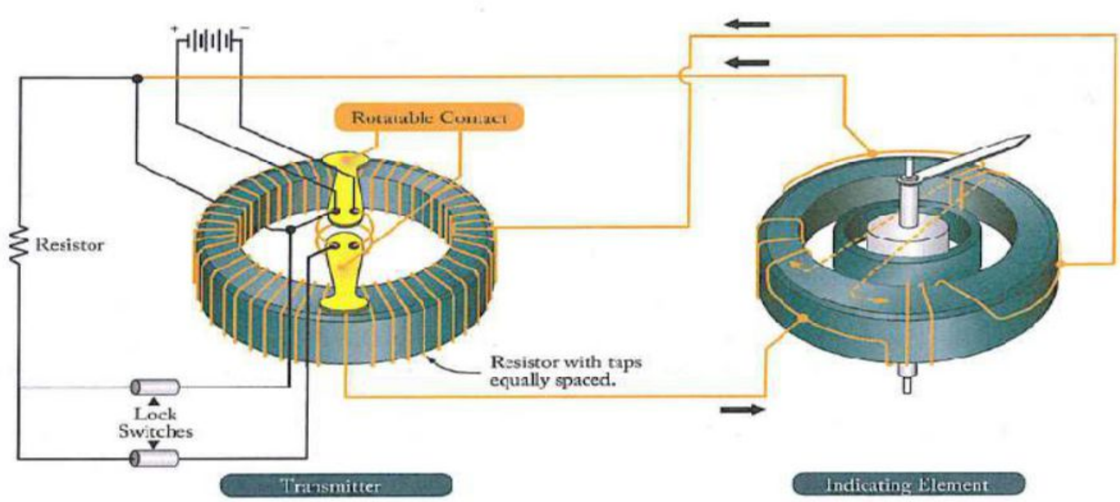

Figure 3-8. A lock switch circuit can be added to the basic DC selsyn synchro system when used to indicate landing gear position and up- and down-locked conditions on the same indicator.

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SYNCHRONOUS TRANSMISSION

- In many servo systems error signals are generated by inductive transducers which are commonly classified under the generic term *'synchro'*. They can be divided into four main categories according to their function:

 Control synchros
 Torque synchros
 Resolver synchros
 Differential synchros

- Whatever form the input transducer takes it must be capable of providing a signal which corresponds in magnitude, and in sign, to the misalignment between input and output shafts. The sensitivity and resolution of the input transducer must be able to operate when only small misalignments occur.
- it should be noted that input transducers are alternatively known in the field of servomechanisms as signal sensors, or more commonly *'pick off'* elements

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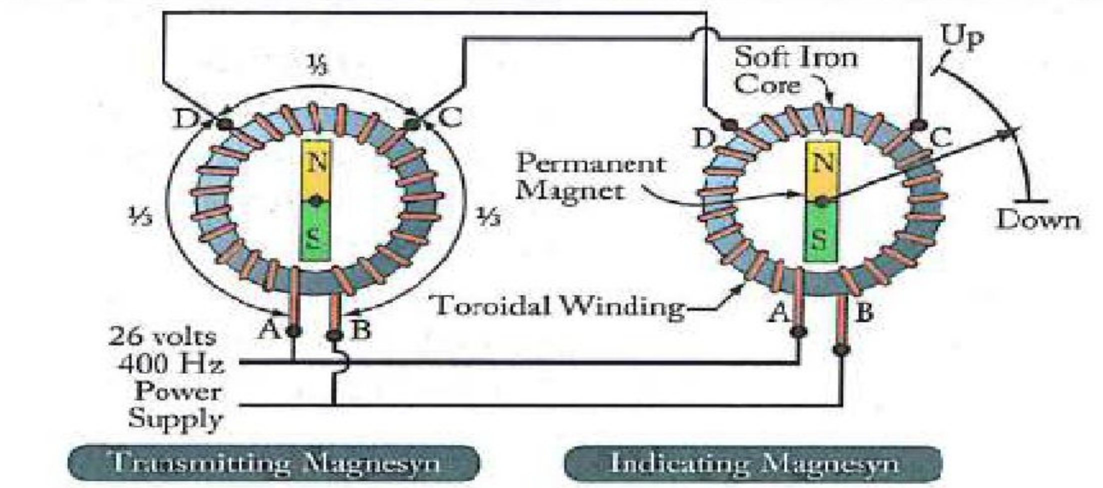
AC SYNCHRO SYSTEM



- A Magnasyn Synchro remote-Indicating System uses AC. It has Permanent magnet rotor in the transmitter and indicator.

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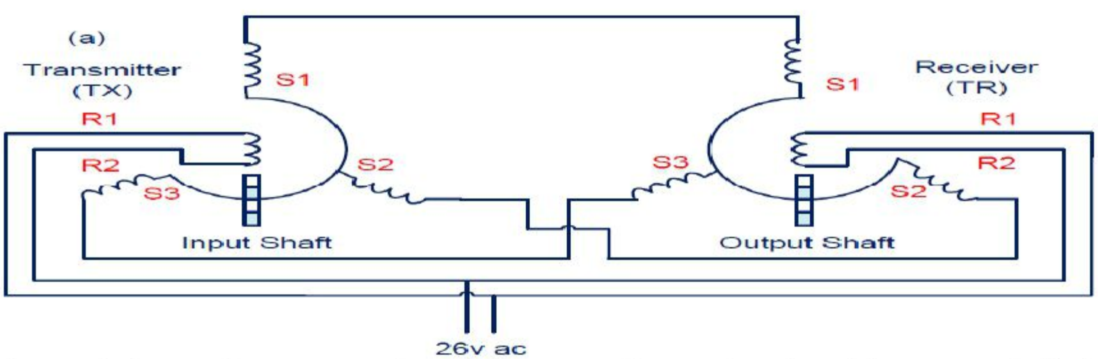
TORQUE SYNCHRO SYSTEM



- AC transmission systems are referred to generally as *'synchros'* because of their synchronous action, ie. any movement of the input shaft connected to the transmitter is exactly reproduced in the angular movement of the remote output shaft connected to the receiver.
- The basic torque synchro system consists of a torque transmitter (TX) and a torque receiver (TR), both of which are similar electrical construction as shown in Figure (a).

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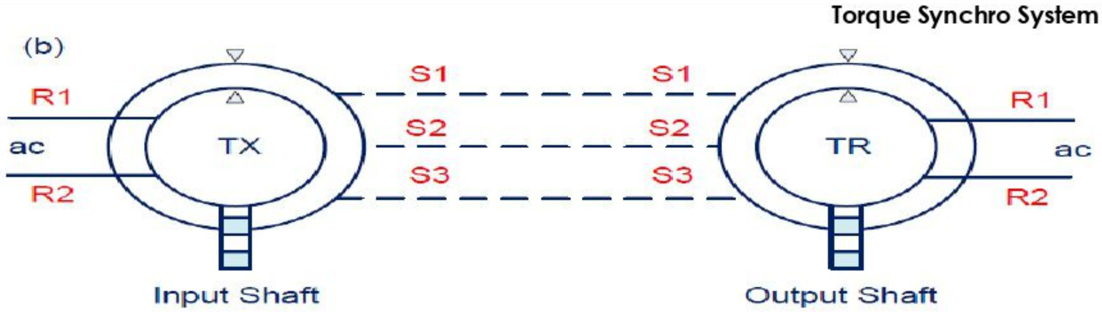

Each consists of a rotor wound with a coil; around the coil are three stator windings arranged with their axes 120 Degree apart. Both rotors are energised from the same AC supply and the corresponding stator connections are joined together by transmission lines. The same arrangement is shown in Figure (b), this time using British Standard symbols.

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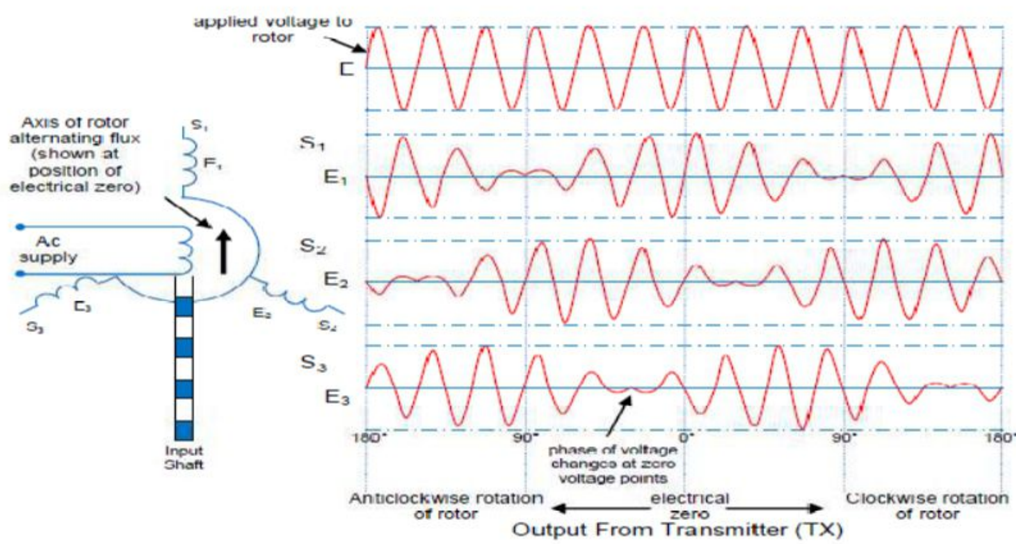
Operation



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CONTROL SYNCHRO SYSTEMS

Introduction

- In the torque synchro system the receiver rotor is aligned by the turning torque exerted upon by the magnetic fields. In a control synchro system there is no torque on the receiver rotor. Instead, the receiver rotor produces an output voltage, called an error signal, which is proportional to the misalignment between the input and output shafts.
- The transmitter or control synchro transmitter (CX) is similar to that used in the torque system and, similarly, is powered from the AC supply.
- The receiver or control transformer (CT) has a stator similar in design and appearance to that of other synchros but with high impedance coils to limit the current through the windings. The CT rotor is not energised and is wound such that it is not subject to any torque when it is out of alignment with the stator field. A control synchro is shown in Figure .

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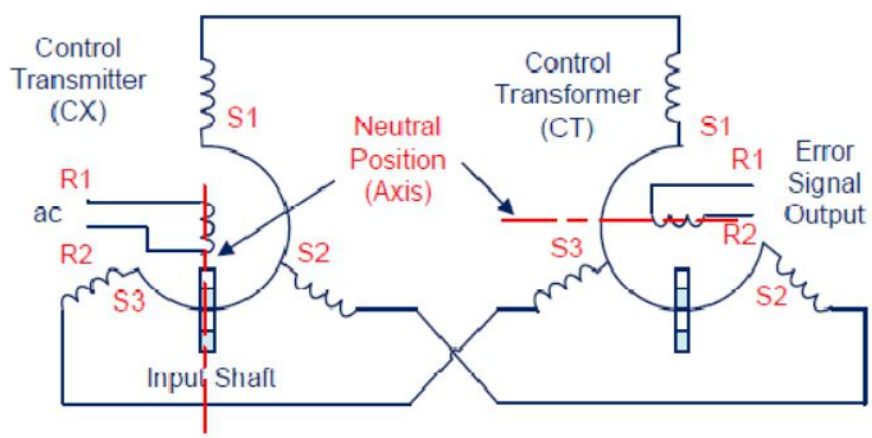
CONTROL SYNCHRO SYSTEMS



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DIFFERENTIAL SYNCHRO SYSTEMS

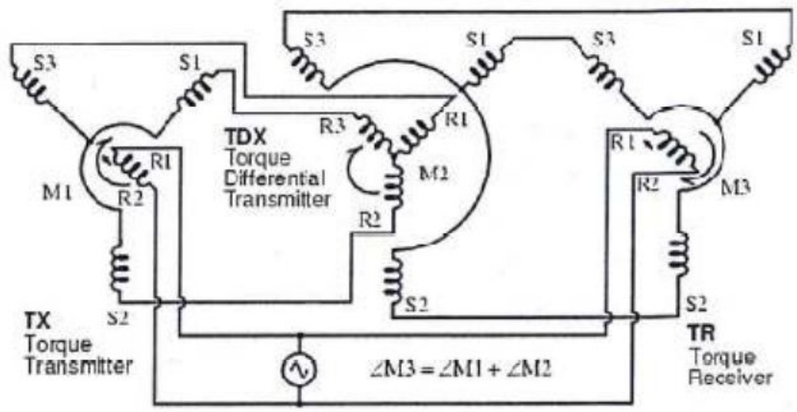


Figure 3-12. A differential synchro system consists of three synchros.

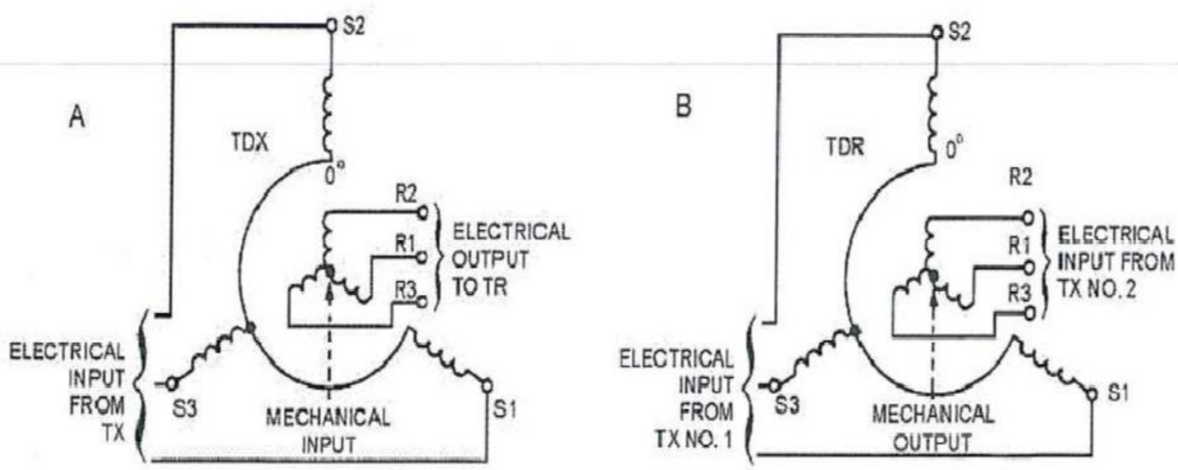


Figure 3-13. The Torque Differential Transmitter receives two inputs and provides one output.

RESOLVER SYNCHRO SYSTEMS

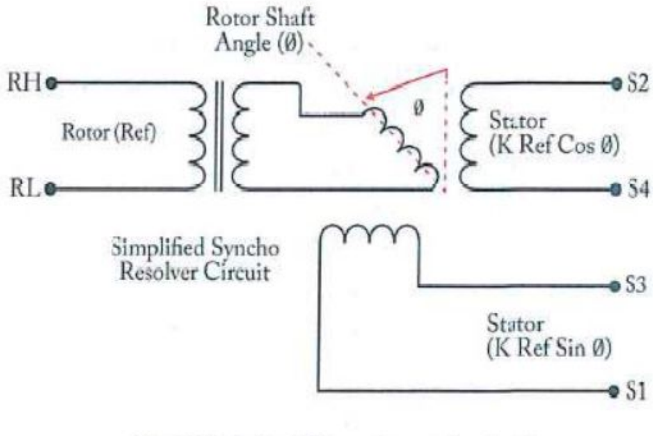
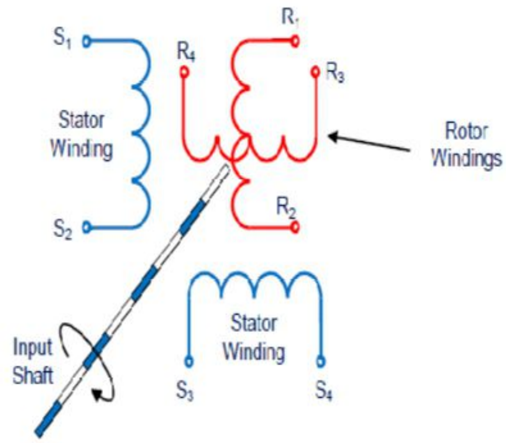


Figure 3-14. A simplified synchro resolver circuit.



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E-I INDUCTIVE TRANSMITTERS SYSTEMS

- The arrangement of this input transducer is shown in Figure . The primary coil is wound around the centre limb of the E-shaped core and it is supplied with the excitation voltage. The outer limbs are wound with secondary coils connected in series opposition.
- The 'I' bar which is pivoted at its centre is connected to the input demand shaft, so that the air gap between it and the outer limbs of the 'E' bar can be varied. When the I bar is deflected through angle θ, the air gaps become unequal, thus changing the reluctance of the magnetic circuit.
- The flux in one outer limb of the 'E' bar will, therefore, increase whilst the flux in the other decreases. These changes will produce an output signal voltage, the amplitude of which is proportional to the 'I' bar deflection.

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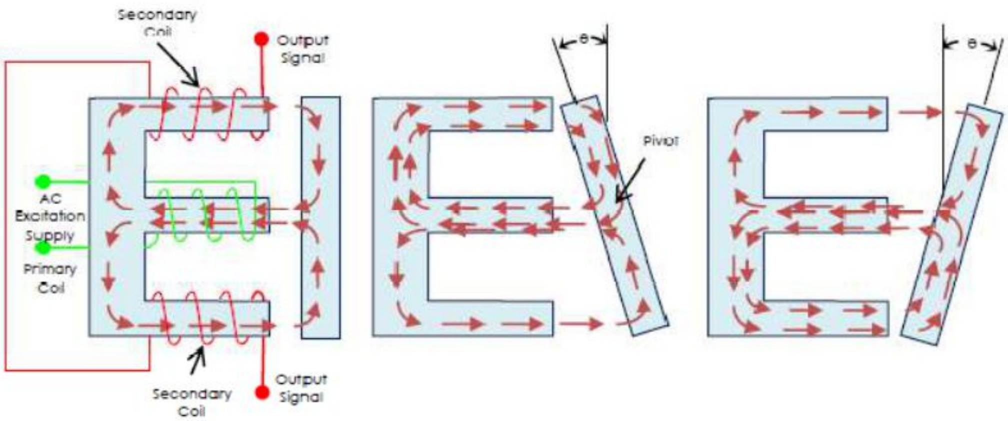

- The direction of the deflection will determine whether the signal voltage is in or out of phase with respect to the supply voltage. When the 'I' bar is in its neutral position, the same magnetic flux flows in each limb since the air gaps are equal. The induced voltages are equal and opposite resulting in no output signal from the coils. The demand shaft, therefore, controls the magnitude and phase of the output signal.

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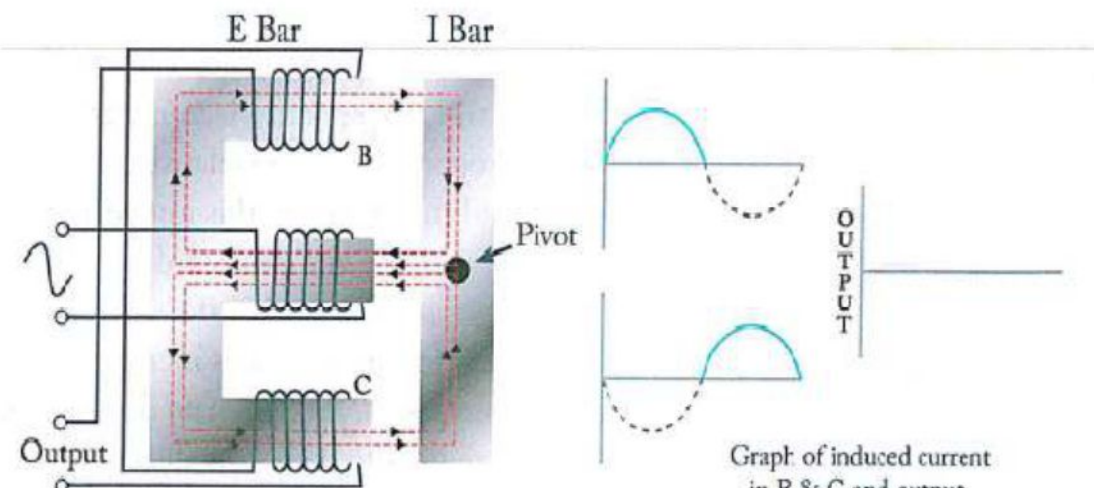

(A) I Bar - Neutral Position.

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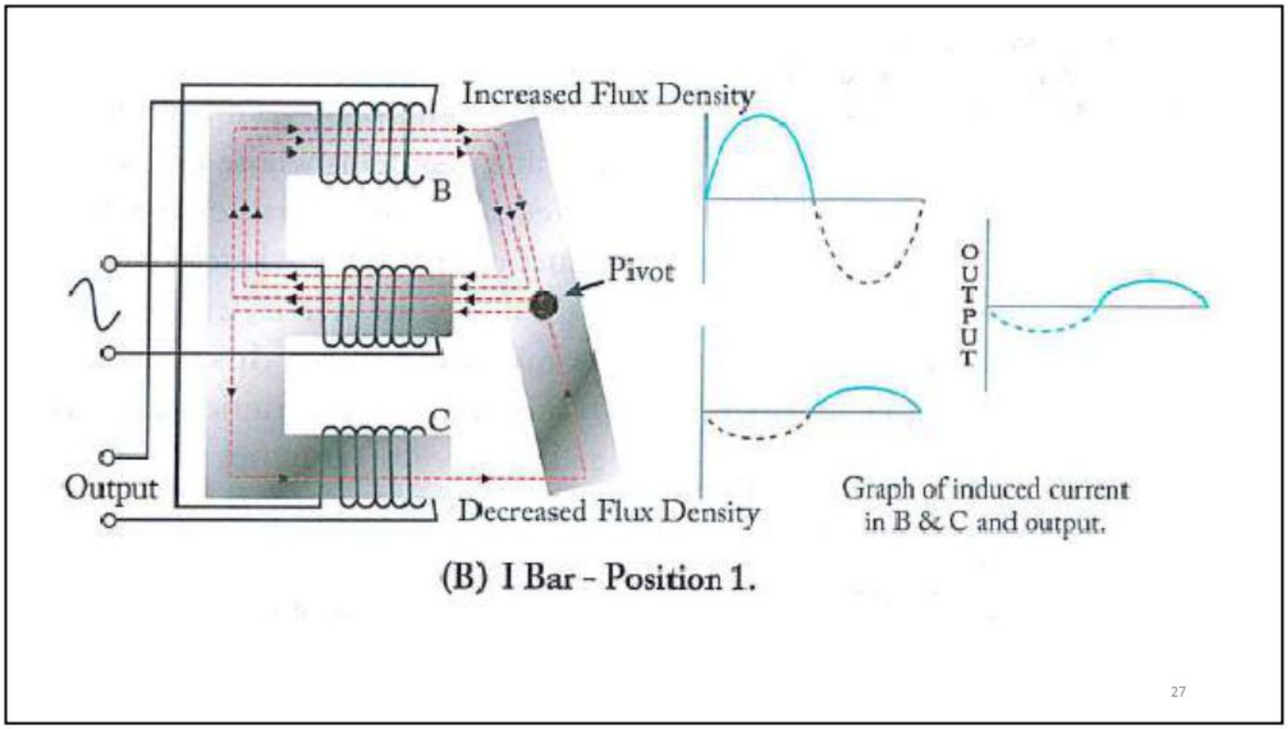
Increased Flux Density
B
Pivot
C
Output
Decreased Flux Density
OUTPUT
Graph of induced current
in B & C and output.
(B) I Bar - Position 1.
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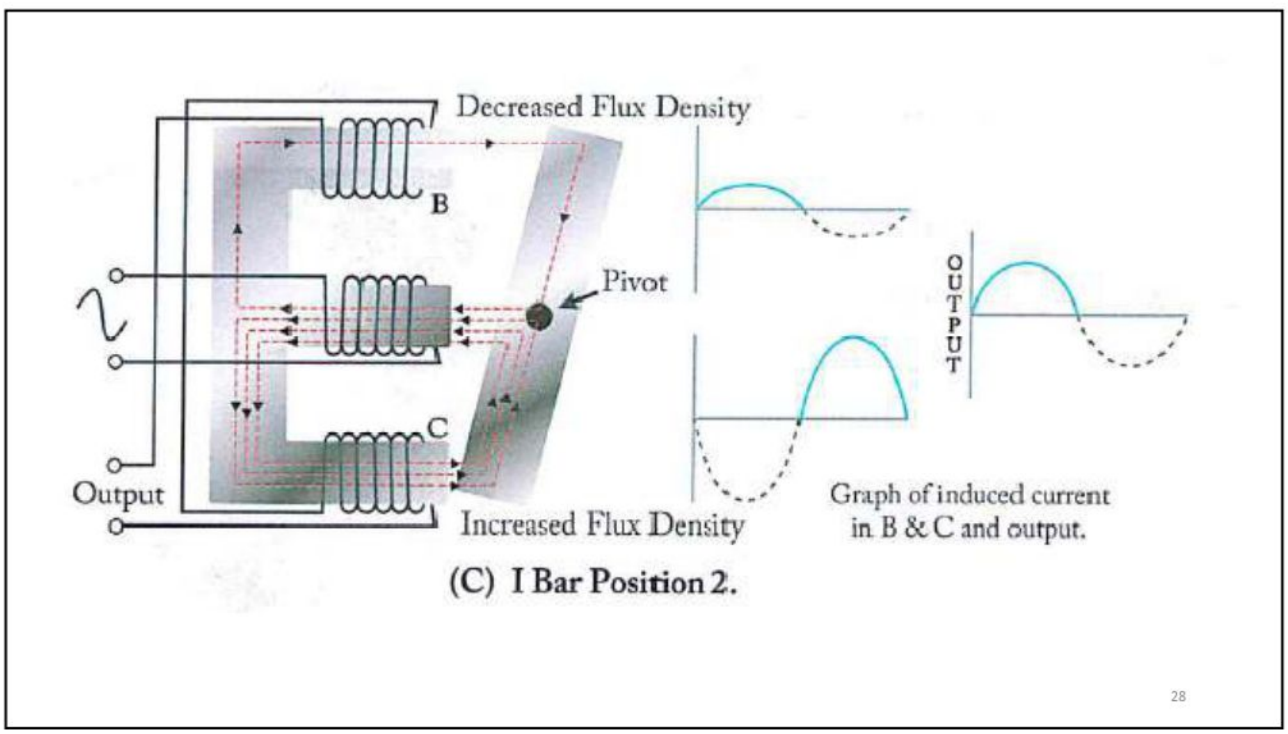
Decreased Flux Density
B
Pivot
C
Output
Increased Flux Density
OUTPUT
Graph of induced current
in B & C and output.
(C) I Bar Position 2.
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CAPACITANCE TRANSMITTERS

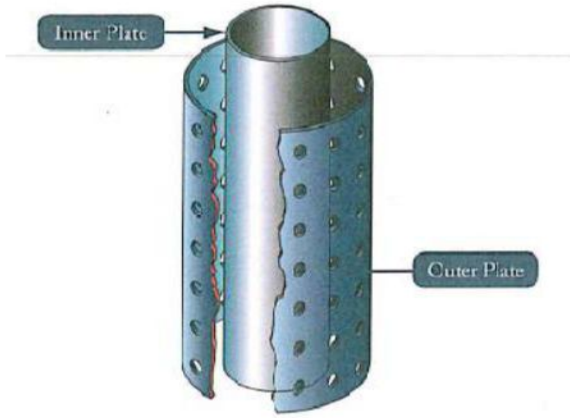

Figure 3-17. The capacitance of tank probes varies in a capacitance-type fuel tank indicator system as the space between the inner and outer plates is filled with varying quantities of fuel and air depending on the amount of fuel in the tank.

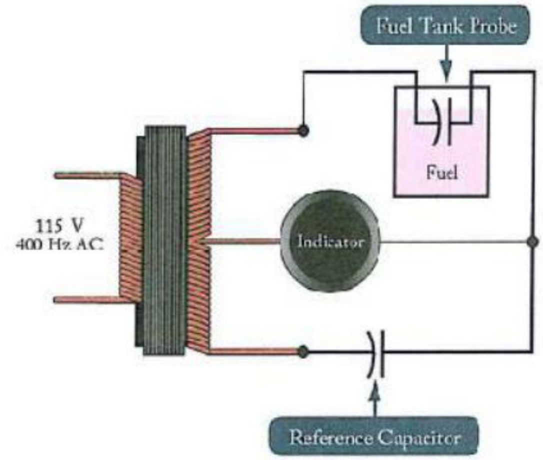

Figure 3-18. A simplified capacitance bridge for a fuel quantity system.

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