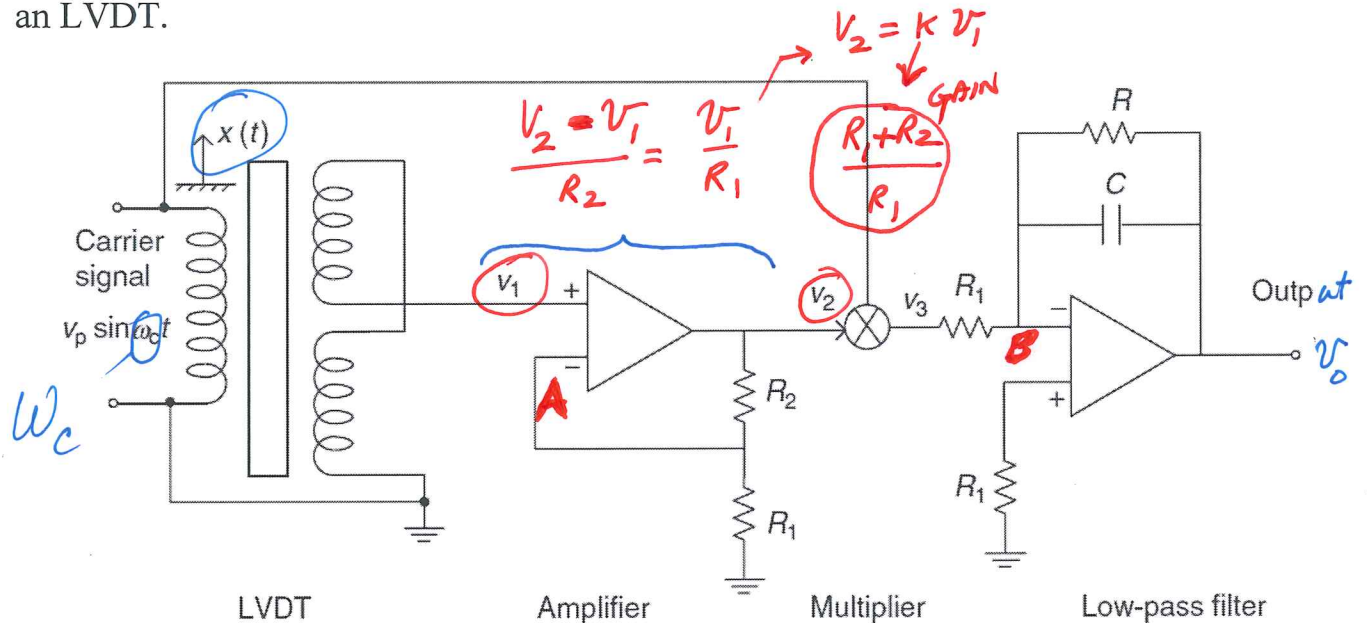


## Signal Conditioning:

- Signal Amplification – increase signal strength so we can interpret it.
- Filtering – need exactly the signals we require for interpreting it properly.
- Improving SNR – filter out unwanted so actual signal quality is better and Noise (unwanted) signal is suppressed.

### Example:

Figure shows a schematic diagram of a simplified signal-conditioning system for an LVDT.

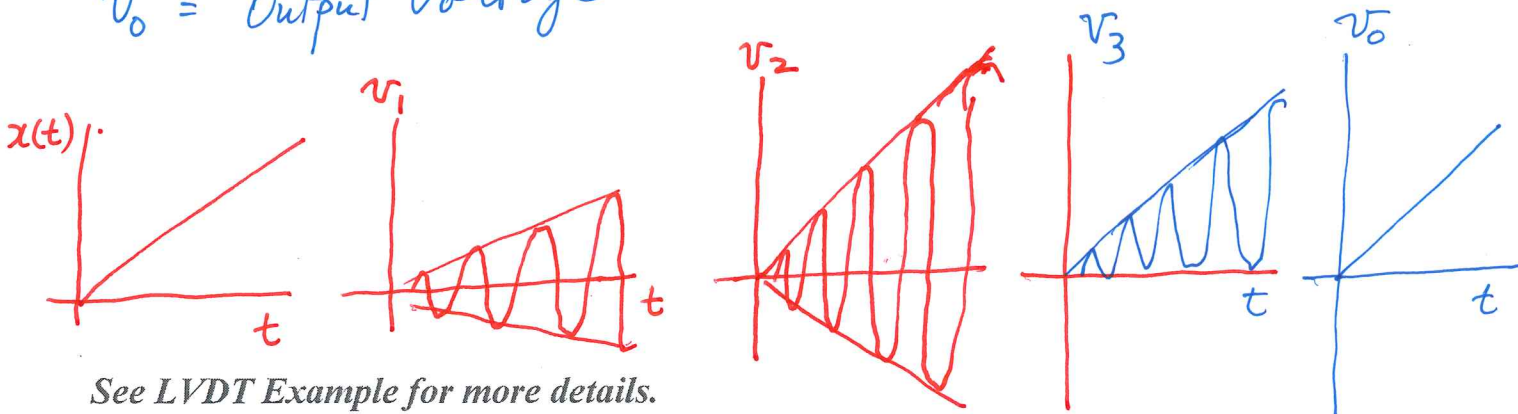


$x(t)$  = Displacement of the LVDT CORE

$\omega_c$  = frequency of the carrier voltage

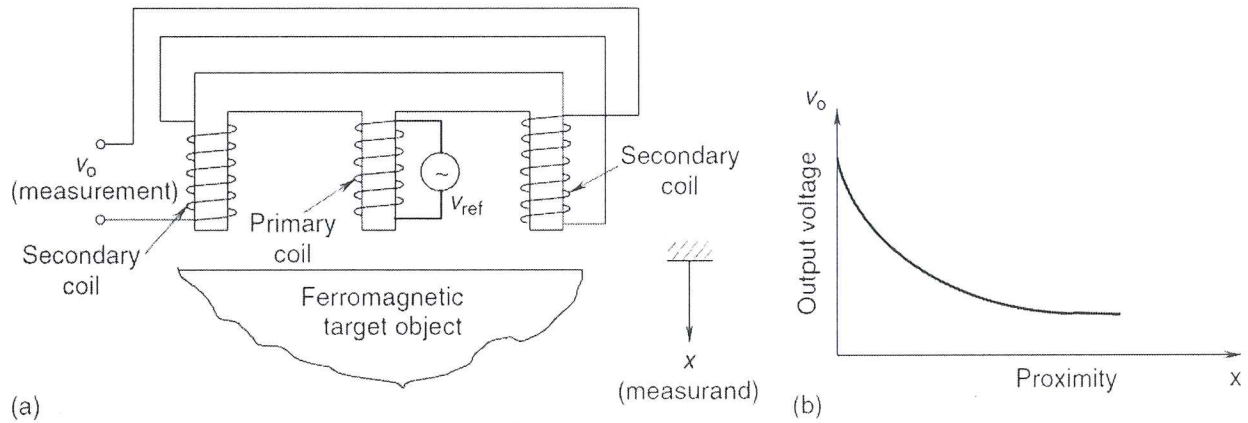
$v_o$  = Output Voltage

$C \times R$  Signal will be filtered out by LPF



See LVDT Example for more details.

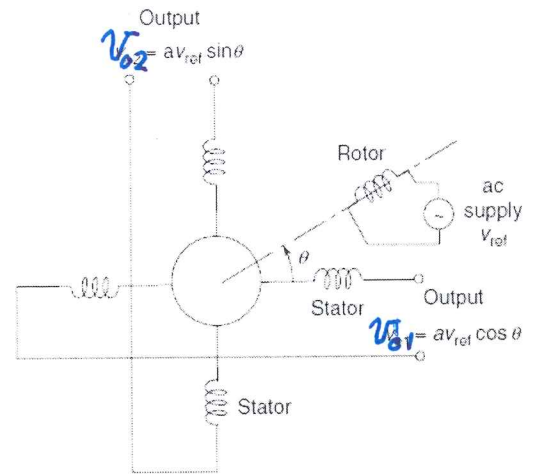
## Mutual Induction Proximity Sensor:



- Displacement transducer also operates on the mutual-induction principle.
- The insulating *E-shaped* core carries the primary winding in its middle limb. The two end limbs carry secondary windings, which are *connected in series*. Unlike the LVDT and the RVDT, the two voltages induced in the secondary winding segments are additive in this case.
- Proximity sensors are used in a wide variety of applications pertaining to non-contacting displacement sensing and dimensional gaging. Few applications are:
  - Measurement and control of the gap between a robotic welding torch head and the work surface.
  - Gaging the thickness of metal plates in manufacturing operations (e.g., rolling and forming).
  - Angular speed measurement at steady state, by counting the number of rotations per unit time
  - Level detection (e.g., in the filling, bottling, and chemical process industries)

**Resolver:** This mutual-induction transducer is widely used for measuring angular displacements.

- Rotor contains the primary coil & It consists of a **single two-pole winding element** energized by an ac supply voltage  $V_{ref}$
- Rotor is directly attached to the object whose rotation is measured.
- **Stator** consists of two sets of windings placed  $90^\circ$  apart.
- If the angular position of the rotor with respect to one pair of stator windings is denoted by  $\theta$ , the induced voltage in this pair of windings is given by:



$$V_{o1} = a V_{ref} \cos \theta$$

Induced voltage in other pair of windings is given by

$$V_{o2} = a V_{ref} \sin \theta$$

→ Amplitude Modulated signals by  $V_{ref}$  (Carrier signal)  
Termed as Quadrature signals.

$a$ : dependant on geometry + Material characteristics of device.

e.g: ratio of # of TURNS IN ROTOR and STATOR WINDINGS.

Any:  $V_{o1}$  or  $V_{o2}$  can be used to determine angular position  $[0, 90^\circ]$

Need Both for displacement: Magnitude and Direction

Example: Angular position  $90 + \theta$ ,  $90 - \theta$  give same SINE  
Direction But  $90 + \theta$ ,  $90 - \theta$  sign will Diff for COSINE  
is Proper Direction.

## Demodulation

- As for differential transformers (i.e., LVDT and RVDT) transient displacement signals of a resolver can be extracted by demodulating its (modulated) outputs.
- This is accomplished by filtering out the carrier signal, thereby extracting the modulating signal.

Revisiting Two output signals from Resolver

$$V_{o1} = a V_{ref} \cos \theta, \quad V_{o2} = a V_{ref} \sin \theta.$$

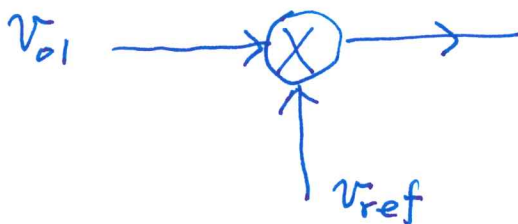
These are called Quadrature signals

$$\text{Using } V_{ref} (C \times R) \text{ Signal} = V_a \sin \omega t$$

$\therefore$  Induced signals will be:

$$V_{o1} = a V_a \cos \theta \sin \omega t$$

$$V_{o2} = a V_a \sin \theta \sin \omega t$$



$$V_{m1} = V_{o1} V_{ref}$$

$$V_{m2} = V_{o2} V_{ref}$$

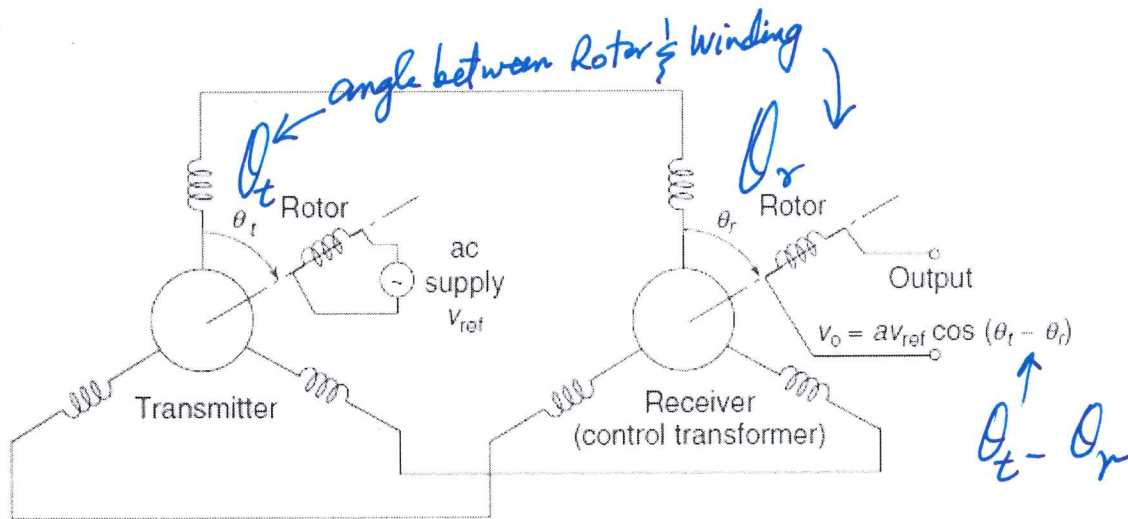
- $V_{m1} = V_{o1} * V_{ref} = a V_a^2 \cos \theta \sin^2 \omega t = \frac{1}{2} a V_a^2 \cos(1 - \cos 2\omega t)$
- $V_{m2} = V_{o2} * V_{ref} = a V_a^2 \sin \theta \sin^2 \omega t = \frac{1}{2} a V_a^2 \sin \theta (1 - \cos 2\omega t)$
- $\omega_c: 2\pi f_c$ : is 10 x Max. frequency content - in. displacement  $\theta$   
use LPF with cutoff  $\omega/10$  and  $V_{m1} + V_{m2}$

$$\therefore V_{f1} = \frac{1}{2} a V_a^2 \cos \theta \quad \text{and} \quad V_{f2} = \frac{1}{2} a V_a^2 \sin \theta.$$

Providing  $\cos \theta$  &  $\sin \theta \Rightarrow$  Magnitude and sign of  $\theta$ .  
Sign of  $\theta \Rightarrow$  direction

## Synchro Transformer:

The "synchro" is somewhat similar in operation to the resolver. The main differences are that the synchro employs two identical rotor-stator pairs, and each stator has three sets of windings, which are placed  $120^\circ$  apart around the rotor shaft.



- Both Rotors have single windings
- One of the Rotors is energized with 'ac'  $V_{ref}$ 
  - This induces voltage in 3 winding segments of cone. stator.
  - 3 diff. Amplitudes → depending on angular pos. of ROTOR.
  - This DRIVE ROTOR-STATOR is called Transmitter.
- Other ROTOR-STATOR is called: Receiver
- Windings of Tx <sup>STATOR</sup> now connected to Rx <sup>STATOR</sup> Windings
  - This induces a voltage  $V_o$  in Rx ROTOR
- If  $\theta_t = \theta_r \Rightarrow$  Receiver ROTOR is aligned with direction
  - $V_o = a V_{ref} \cos(\theta_t - \theta_r)$  will be MAX.
- Synchros are operated near  $\theta_r = \theta_t + 90^\circ$ ;  $V_o = 0$  at this pt.
  - So we define a new angle  $\theta \Rightarrow \theta_r = (\theta_t + 90) - \theta$
  - $\therefore V_o = a V_{ref} \sin(\theta)$
  - $\theta$ : relative displacement between 2 Rotating objects.