A Modern Approach to AC Analog Transducer Testing

The world of avionics today, much as it has been for over 60 years, is reliant on an array of AC analog transducers that serve as part of the electromechanical servo and angle positioning systems of both military and commercial aircraft. Over the years, designers have realized that, coupled with the appropriate electronics, synchros, resolvers, and linear/rotary variable differential transformers (LVDTs/RVDTs) can form the basis of outstanding digital shaft angle and linear displacement measurement and positioning systems. These transducer types are key building blocks in flight control and actuator systems.

Synchros and Resolvers

Synchros and resolvers have traditionally been the transducer of choice where reliability is important, and where difficult environment conditions exist. Systems based on such devices are unsurpassed in reliability and cost effectiveness.

Synchros and resolvers are very similar, and the term synchro is often used to refer to both. Both are rotating, transducing devices used to convert shaft angle position to electrical signals, or the reverse. Synchros are typically three-phase devices with one- or two-phase primary windings and 3 secondary windings, each mechanically oriented 120° apart. Resolvers have 2 secondary windings oriented at 90° to each other. The primary of each is driven by an AC signal. See Figure 1.

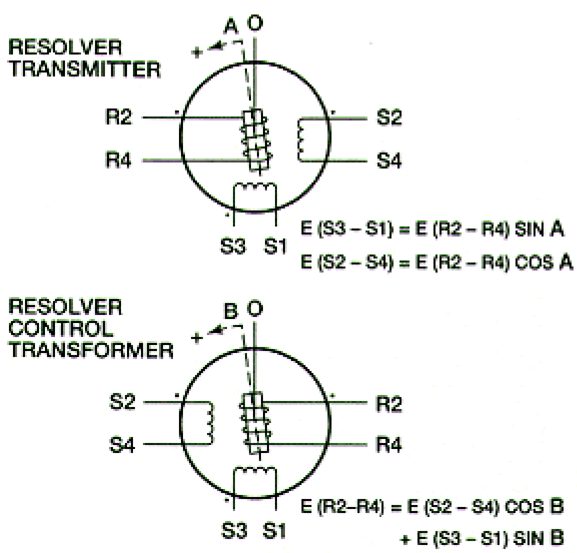

Figure 1: Example of torque synchros and control synchros

While synchros and resolvers are essentially transformers, they are mechanically more like a motor. The primary winding in a synchro can be physically rotated with respect to the secondary windings. The magnitude of the mechanical coupling between the primary and secondary varies according to the position of the rotating element. This, in turn, varies the magnitude of the output voltage. In some systems, a mechanical input, such as a shaft rotation, is converted to a unique set of output voltages. In others, a set of input voltages is used to turn a synchro rotor to a desired position.

Typical synchro/resolver applications include:

- Fire control systems
- Inertial navigation reference units such as a gyro or compass
- Automatic direction finders
- Distance measurement equipment
- Cockpit simulators
- Jet engine control systems
- Antenna pedestal control
- Cockpit indicators
- Landing gear positioning and control
- Flap actuators

Synchro/Resolver Operation

Synchros are designed to operate with AC input voltages from less than 1.0Vrms to 115Vrms, over a wide range of frequencies from 60Hz to 100kHz. There are some standard voltages used such as 11.8, 26, 90, and 115Vrms. They are commonly operated at 26Vrms and below, and at 60Hz or between 400 and 2600Hz.

Depending on the size of the synchro, the input voltage and/or frequency may have to be limited such that excessive input current does not saturate the core. Reducing the size and weight of a synchro reduces the size of its magnetic core. However, a small magnetic core easily saturates when driven with 60Hz. For that reason, for aircraft applications, synchros are commonly excited with 400Hz signal.

Accuracy

The accuracy of a synchro is based on the ability of its output voltages to define the rotor angle. This is probably the most important of all synchro parameters. It is an exact measure of the performance of the synchro. For any given rotor position, the output voltages are designed to provide precise electrical information which corresponds uniquely to that rotor position.

LVDTs and RVDTs

LVDTs and RVDTs are electromagnetic displacement transducers designed to provide output voltages proportional to linear and rotary displacement respectively. These transducers consist of three basic elements: a primary winding, two secondary windings and a movable armature made of a soft ferromagnetic material. See Figure 2. These transducers are commonly used to measure aircraft surfaces (flaps, slats, rudder, and ailerons), landing gear positioning and control, or cockpit motion such as thrust control levers or the control wheel/stick. As differential or ratiometric devices, they are particularly insensitive to common-mode noise and temperature effects and are therefore ideal for harsh aircraft environments.

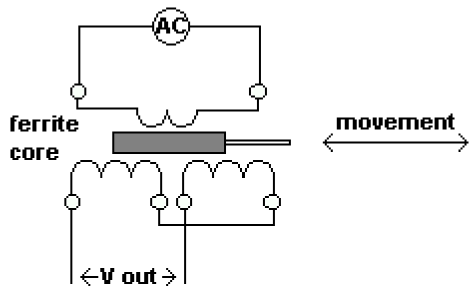

Figure 2: Example of an LVDT

LVDTs and RVDTs, as displacement measurement devices, have penetrated many sectors of industry and research because they are both robust and maintenance free.

Avionics test equipment must be able to both accurately measure and simulate these signal types. Typical racks of test equipment include angle position indicators (APIs), synchro/resolver simulators (SIMs) and phase angle voltmeters (PAVs) to enable measurement or simulation of phase-sensitive signals. LVDT/RVDT signals are usually measured with a phase angle voltmeter.

In-Phase & Quadrature Sinusoidal Components

From trigonometry, we know

$$\sin(A+B) = \sin(A)\cos(B) + \cos(A)\sin(B)$$

And

$$\begin{aligned} x(t) &\triangleq A\sin(\omega t + \phi) = A\sin(\phi + \omega t) \\ &= [A\sin(\phi)]\cos(\omega t) + [A\cos(\phi)]\sin(\omega t) \\ &\triangleq A_1\cos(\omega t) + A_2\sin(\omega t). \end{aligned}$$

From this we may conclude that every sinusoid can be expressed as the sum of a sine function (phase zero) and a cosine function (phase $\pi/2$). If the sine part is called the “in-phase” component, the cosine part can be called the “phase-quadrature” component. In general, “phase quadrature” means “90 degrees out of phase,” i.e., a relative phase shift of $\pi/2$.

It is also the case that every sum of an in-phase and quadrature component can be expressed as a single sinusoid at some amplitude and phase. The proof is obtained by working the previous derivation backwards.

Figure 3 illustrates in-phase and quadrature components overlaid. Note that they only differ by a relative degree phase shift.

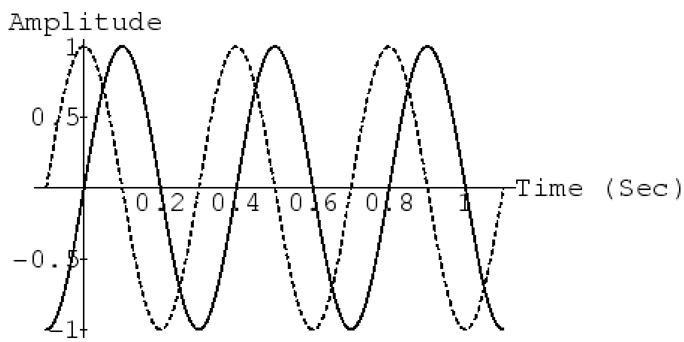

Figure 3: In-phase and quadrature sinusoidal components.

Transducer Testing

Synchro/resolver and LVDT/RVDT signals require specialized test equipment for accurate measurement and calibration. Several parameters need to be considered, as all of these will affect the performance and integrity of the of the avionics system as a whole.

- Accuracy
- Resolution
- Phase shift
- Quadrature
- Dynamic characteristics
- Distortion and noise

Synchro/resolver and LVDT/RVDT signals must be tested using a phase angle voltmeter such as the *XiTRON Technologies* 6250, 6000, or 6010. Key measurements made are typically ratiometric characteristics, voltage linearity and phase shift.

For high accuracy calibration or testing, a phase angle voltmeter, such as the *XiTRON Technologies* model 6250 is required. The PAV is used to measure phase shift, plus total (true rms plus harmonics), fundamental, quadrature and in-phase voltages. The PAV is specifically designed to measure these parameters accurately in the presence of highly distorted and noisy signals (such as those encountered in synchro/resolver systems).

Not only does the *XiTRON Technologies* 6250 provide all of the common standard and ratiometric measurements quickly and accurately, but its DSP-based programmability allows the user to customize measurements to suit their particular needs. The 4-line display (scrollable to 50) allows the user to see multiple readings at once. Alternatively, the user can use one of the *XiTRON Technologies* LabView applications and view *all* of their measurements at once. A full printed measurement listing can be provided at the touch of a single button. The *XiTRON Technologies* 6250 even allows for testing to a limit internally, and will display PASS, HIGH, or LOW as appropriate.

The *XiTRON Technologies* 6250 is actually much more than just a "*voltmeter*." Beyond the typical LVDT/RVDT measurements of phase and voltage, many manufacturers are testing the following parameters in their production acceptance tests.

- Input frequency
- Input current
- Input power
- Impedance
- Resistive component
- Reactive component

Since the *XiTRON Technologies* 6250 is truly a phase angle *multi-meter*, it can be used to measure all of these parameters and many more. The 6250 can be set to measure any single harmonic, or range of harmonics to the 2047th, as well as THD, up to 150kHz. Since the *XiTRON Technologies* 6250 also includes current input terminals, it can be used to measure input current directly without the need for an external resistor. The voltage and current inputs together can be used to measure power and items such as impedance, including resistance and reactance.

Some of these measurements may sound simple. However, if they are not performed using a *XiTRON Technologies* 6250, they can require additional items such as digital voltmeters, AC ammeters, a wattmeter, pencil and paper, plus a calculator! All of these measurements can be easily accomplished, or even mostly automated, when using the *XiTRON Technologies* 6250. We'll even give you a $95 trade-in credit for your calculator!

Conclusion

Synchros, resolvers and LVDT/RVDTs are essential and reliable elements of avionics systems. These important transducers enable navigation and flight surface control feedback. They are also critical elements in many industrial applications. The performance, operational characteristics, and failure mechanisms must be well characterized. Production testing of such devices must be accurate, reliable, repeatable, and they must be done in a timely, cost effective manner.