

Motion Electronics in Avionics

Several transducer types, including synchros, resolvers, linear/rotary variable differential transformers (LVDT/RVDT) are key building blocks in flight control and navigation dynamics. This article will address the systems that utilize these transducers, de-mystify the workings of these AC analog transducers and associated conversion electronics, describe the testing and simulation of these signal types and discuss some common troubleshooting failure mechanisms.

Synchros & Resolvers

Synchros have been used in a wide variety of military and commercial systems for many years. They have traditionally been the transducer of choice where reliability is critical, and where harsh environmental conditions exist. The simplicity of their connection, combined with today's modern (and relatively inexpensive) Synchro-to-Digital and Digital-to-Synchro converter boards (such as those from North Atlantic Industries) make the synchro a very attractive component.

Typical applications include:

- fire control
- inertial navigation reference units (gyro, compass)
- automatic direction finder (ADF)
- omni-range system (VOR, very high frequency omni-directional range)
- distance measurement equipment (DME)
- flight surface positioning
- cockpit simulators
- jet engine control
- antenna pedestal control
- cockpit indicators
- landing gear positioning and control
- flap actuators

In an ADF, for example, the resolver or synchro is used to drive an indicator. As the aircraft turns, the amount of coupling in the transducer changes proportionally as illustrated in figure 1. The analog waveforms generated by these transducers, and their characteristics, are detailed in the ARINC407 specification (ARINC Synchro System Manual), but how do synchros and resolvers work specifically?

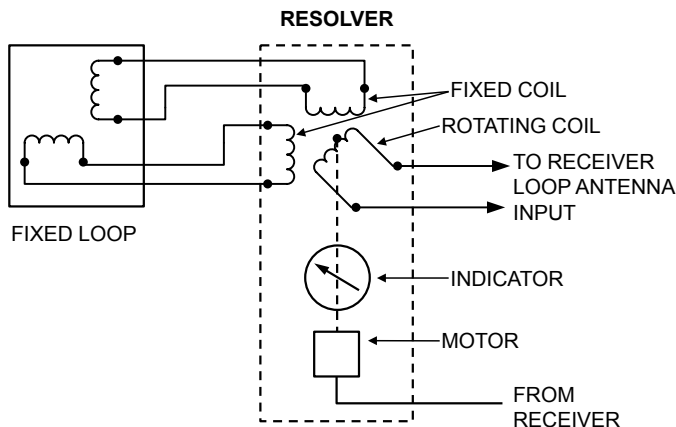


Fig. 1 – Automatic Direction Finder (ADF)

Theory of Operation

Synchros and resolvers are World War II era technology that is still widely used in modern day electronic motion control applications. They are essentially transformers. Just like a traditional transformer, they have a primary winding and multiple secondary windings, and just like a transformer, their primary is driven by an AC signal. Synchros and resolvers are very similar. However, there are some differences. As shown in figure 2, a synchro has:

- 2 primary windings
- 3 secondary windings, with each secondary winding mechanically oriented 120° apart

In contrast, as shown in figure 3, a resolver has:

- 2 primary windings
- 2 secondary windings, which are oriented at 90° to each other

While a synchro and a resolver are electrically very similar to a transformer, they are mechanically more like a motor. The primary winding in a synchro or a resolver can be *physically rotated* with respect to the secondary windings. For this reason, the primary winding is called the rotor. The secondary windings (which are fixed) are called *stators*. Because of this similarity, the term "synchro" will be used to refer to both Synchros and resolvers for the remainder of this article, unless otherwise noted.

Synchros are often used to track the rotary output angle of a closed-loop system, which uses feedback to achieve accuracy and repeatability. A synchro can be turned continuously and, since its secondary winding outputs are analog signals, provide "infinite" resolution output. As the shaft of a synchro transmitter is turned, the angular position of its rotor winding changes with respect to its secondary (stator) windings. The relative amplitude of the resulting AC output signals from the secondary (stator) windings indicates the rotary position of the transmitter's shaft.

A synchro is excited by an AC reference voltage applied to its rotor winding. This reference signal is typically one of two possible voltages:

- 115 VRMS @ 60 Hz or 400 Hz
- 26 VRMS @ 400 Hz

400 Hz signal is used in aircraft applications, where size and weight are important factors. Reducing the size and weight of a synchro reduces the size of its magnetic core. A small magnetic core saturates when driven with 60 Hz. For that reason, small aircraft synchros are excited with 400 Hz signal.

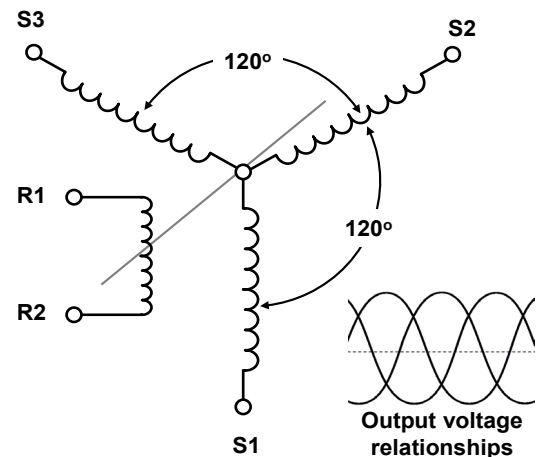


Fig. 2 – Synchro Rotor/Stator Configuration

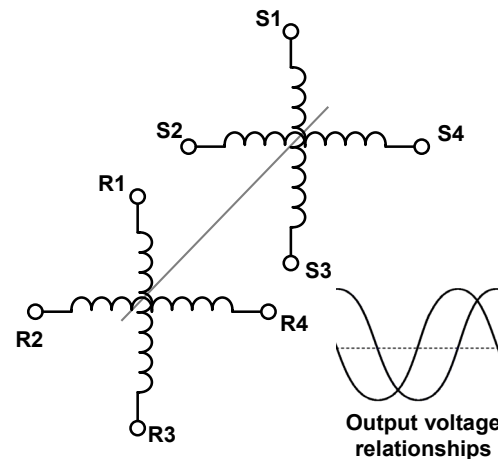


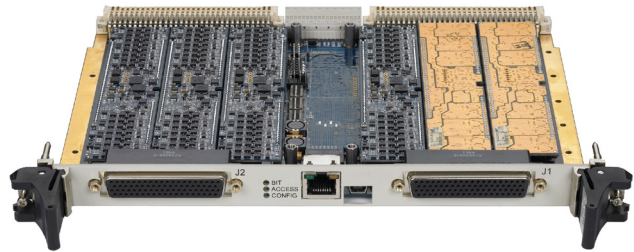
Fig. 3 – Resolver Rotor/Stator Configuration

Synchro-to-Digital Conversion

Synchros generate analog output signals, and those outputs must typically be converted to digital form. This can be accomplished by using a synchro-to-digital converter. It might seem logical to use a set of conventional A/D converters to simultaneously sample the AC voltages on the outputs of a synchro. The relative magnitudes of these samples could then be used to determine the rotary position of the synchro's shaft at the time the samples were taken.

However, this does not work well for several reasons:

- Synchros have inductive characteristics, which must be taken into account
- Synchro output signals can be heavily distorted, due to the nonlinearities in the Synchro
- Synchro output signals often contain a lot of noise because of the environment they work in.



In addition, if the inputs and the outputs of a synchro are not *galvanically isolated* from each other (and from the signal ground) common mode noise can dramatically affect the accuracy of conversion. To avoid these problems, an S/D converter board must employ transformer-isolated inputs and outputs, thus significantly reducing the effects of common mode noise and ground loops.

The **64C2** 6U VME multifunction board contains up to 6 independent module slots, each of which can be populated with a function specific module. The S Module features 4 channels of Synchro-to-Digital conversion; therefore the 64C2 is capable of providing up to 24 channels of Synchro-to-Digital conversion.

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, as illustrated in figure 4. This transducer type would be typical of flight surface measurement (e.g. flaps, slats, rudder, aileron) or landing gear positioning and control. As differential or ratiometric devices they are particularly insensitive to common-mode noise and temperature effects and are therefore ideal for harsh aircraft environments. ARINC608 (Standard Modular Avionics Repair and Test System) describes interface to many signal types including synchro/resolvers and LVDTs.

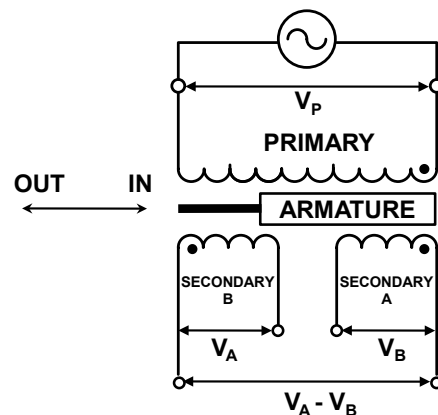
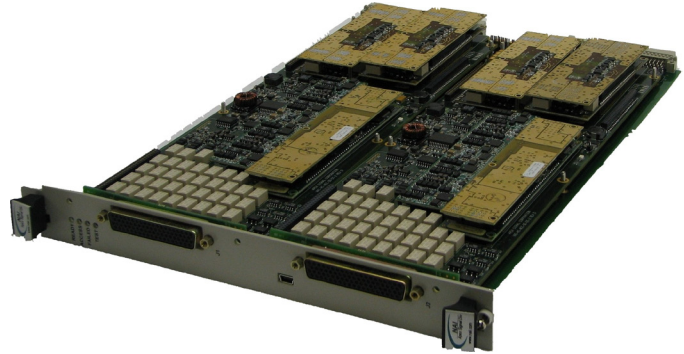


Fig. 4 – LVDT/RVDT Configuration

Avionic Test Equipment must therefore address the means to both measure and simulate these signal types. Typical rack and stack instrumentation might include angle position indicators (API), synchro/resolver simulators (SIM) and phase angle voltmeters (PAV) to enable measurement or simulation of phase-sensitive signals.

Modern ATE has migrated to VXIbus technology with a combination of synchro/resolver measurement and simulation (e.g. NAI model 5390) that may be integrated into an overall instrumentation test stand. Similarly, LVDT signals may be measured by a phase angle voltmeter either rack-and-stack or VXIbus configurations. These signal types may also be configured in a VMEbus environment, common to flight simulators, or a PCbus architecture. Multi-channel implementations are typical and hardware is tailored to meet specific voltage and frequency requirements. Such instruments and cards are essential tools to the measurement, control, simulation and test of motion electronics.



The **65CS4** is a multichannel, Instrument/Embedded Grade single slot VXI "C"-size card. It incorporates up to four Synchro/Resolver-to-Digital conversion channels, as well as 4 channels of Digital-to-Synchro/Resolver simulation.

Testing and troubleshooting

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

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

Accuracy and verification of a synchro/resolver transmitter signals are most easily and best accomplished using an Angle Position Indicator (API) such as the North Atlantic Model 8810A or 8500. These instruments can read the synchro signal directly in degrees and decimal degrees. An API automatically compensates for phase shift, noise and distortion. Due to their transformer coupled inputs, common mode effects are reduced to a minimum.



The **8810A** is a highly accurate Synchro/Resolver Angle Position Indicator (API) used for calibration and test functions of components, assemblies and systems.

For calibration grade accuracy of up to 2 arc seconds a synchro/resolver bridge (such as the Model 540) and Phase Angle Voltmeter (PAV), such as the Model 2250 or 2251 is required. The PAV is also used to measure phase shift and total (rms), fundamental, quadrature and in-phase voltage. 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)



NAI's 2250 Digital Phase Angle Voltmeter presents a new level of accuracy and versatility in AC

To accurately simulate a synchro/resolver signal or to drive a synchro/resolver receiver a standard such as the North Atlantic Model 5330 or 5300 is needed. It is important to understand the load requirements of the unit under test and to make sure that these fall within the output drive capability of the simulator. These instruments are designed to generate signals with enough resolution, speed and drive capability to dynamically and statically test most common devices that accept 3 (synchro) or 4 (resolver) wire inputs.



NAI's 5330A is the latest in Digital Synchro/Resolver Simulation technology. Intelligent DSP design allows all programming via touch-screen or mouse interface.

LVDT/RVDT signals must be tested using a phase angle voltmeter such as the Model 2250 or 2251. Key measurements to be made are ratiometric characteristics, voltage linearity and phase shift. North Atlantic also offers LVDT/RVDT signal generators in VXI, VME and PC based formats.

Conclusion

Synchros, resolvers and LVDT/RVDTs are important and reliable elements of avionics systems. The operation and interface of these transducers enables navigation and flight surface control feedback. Consequently, the operational characteristics, typical failure mechanisms and available equipment for measurement, control, simulation and test of these transducer types are essential elements to the design of on-board systems, flight simulators and ATE.