

## AC/Synchro/Resolver/Phase Definitions

We are required to be familiar with a wide variety of devices, circuits and components to be successful in the modern electronics world. Synchro/resolver and Servo systems are relatively old technology that is still widely used in many modern electronic systems.

You may find the following definitions and general descriptions useful when discussing or describing a synchro/resolver or servo systems or its components.

### General

Synchros and resolvers are electromechanical/rotary transformer devices. As transmission devices they have a primary winding (rotor) and secondary windings (stators). The stators, when specially configured for receiver applications, become the primary transformer windings.

Synchros and resolvers are connected into systems, often called servo systems. A servo system is a closed loop circuit using feedback techniques to achieve accuracy and repeatability. Servo systems using synchro/resolver devices usually involve the reading or transmission of rotation or position information.

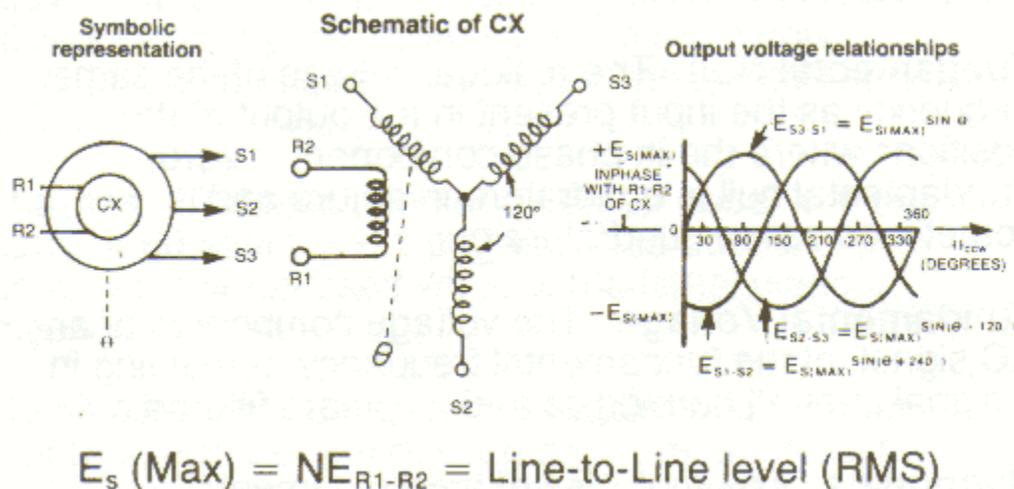


Figure 1

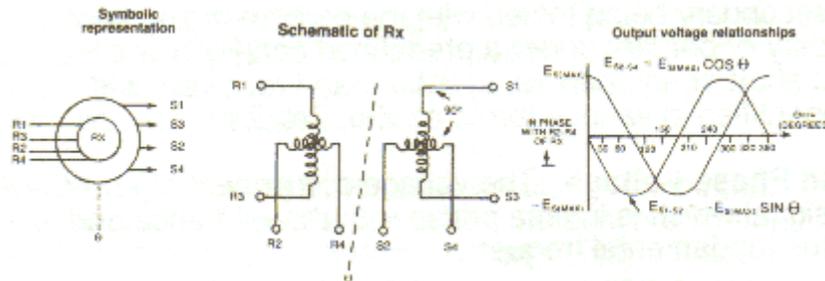


Figure 2 - Click for detail

Synchro/resolver devices (Cx/Rx) are designed to transmit their shaft angular position information (primary rotor windings) to the associated system by causing the amplitude of the signal on the secondary windings (stators) to be changed (Reference Figure 1 and Figure 2). The devices are limited to 360 degrees of rotation. Comparing the amplitude of the stator outputs will give the angular position of the rotor shaft. It can be calculated in degrees, minutes (1/60 degree) or seconds (1/3600 degree), depending on the accuracy required. The amplitude comparison calculation defines the MECHANICAL ANGLE of the synchro/resolver shaft displacement, also known as ANGLE POSITION. See the following definitions:

## DEFINITIONS:

**Accuracy:** The error of the position of the rotor with respect to the electrical angle. It is defined as the output voltage divided by the speed (pole pairs) of the unit, referenced to the starting point of the calibration (usually the electrical zero position). Error is commonly expressed in minutes or seconds of arc maximum from electrical zero, or error spread. Error spread is the arithmetic sum of the absolute values of the maximum positive error and the maximum negative error. Error from electrical zero is the maximum permissible error whether positive or negative.

**Angle Position Indicator:** The API is an electronic bridge that utilizes the characteristics of a Type II servo loop to accurately display the shaft position of a synchro or resolver. The API does not require the use of a phase angle voltmeter to perform its measurement.

**Arc Seconds** (a.k.a. Seconds): The smallest resolution of a degree where 1 sec=1/3600 of a degree or 3600 sec=1 degree. When measuring within a rotational plane, it is also called arc seconds.

**Bridge-Synchro/Resolver:** A nulling type instrument used with a phase angle voltmeter to directly and accurately measure the electrical output of a synchro or resolver. (Also See: **Angle Position Indicator**).

**CDX:** A synchro control differential transmitter.

**CT:** A synchro control transformer, a.k.a. receiver

**CX:** A synchro control transmitter.

**Degrees:** That part of a circular rotation equal to  $1/360^{\text{th}}$  of an arc of rotation or 360 degrees =  $d = \text{circumference of a circle}$ .

**Differential:** A unit with a configuration of equal stators and rotors. Used to dial in correction factors for the servo chain.

**Digital Analyzing Voltmeter:** The DAV is an AC measurement and analysis device that allows phase angle voltmeter component measurement as well as accurate measurement of ratio, THD, frequency and harmonics. The DAV also allows offsets to be programmed to analyze deviations from standards or to analyze errors from an expected result.

**Dividing Head:** A mechanical device to precisely position the shaft of rotary transducers such as synchros, resolvers, RVDT.

**Electrical Error:** The difference between the mechanical angle and the electrical angle. This is also referred to as static electrical error since no velocity errors are included in the stated values.

**Electrical Zero:** The reference point for all measurements and readings. It is the point where the output voltage that is in phase with the input or reference voltage at maximum coupling is at a minimum level or null.

**Excitation:** The input voltage and frequency. The most common voltages are  $26V_{\text{rms}}$  and  $115V_{\text{rms}}$ . The prevalent frequency is 400Hz. Newer designs and system requirements have voltage ranges from  $1V_{\text{rms}}$  to  $115V_{\text{rms}}$ ; and frequencies from 30Hz to 54KHz.

**Functional Error:** The deviation from a true sinusoid of the output voltages. Functional error is usually expressed in percent.

**Fundamental Null:** The residual voltage of the same frequency as the input present in the output at the positions where the in phase component is zero. Fundamental null is quadrature in nature and is sometimes called quadrature null.

**Fundamental Voltage:** The voltage component of an AC signal, at the fundamental frequency, remaining in a signal after all harmonics and noise are filtered out.

**Harmonics:** The multiples of the fundamental frequency.

**Impedance:** The vector reactance, identified by the symbol  $Z$ , which is the algebraic sum of the components: the resistance,  $R$ , and the reactance,  $X$ , having the form of  $R + jX$ . Impedance measurements in synchro systems normally relate to the primary or secondary being tested with the corresponding secondary or primary under a predefined condition of either a short or an open. In synchros and resolvers it is identified in various forms as  $Z_{ro}$ ,  $Z_{rs}$ ,  $Z_{so}$ ,  $Z_{ss}$ ,  $Z_q$ .

**In Phase Voltage:** The voltage component of an AC signal which is in time phase with the reference and at the fundamental frequency.

**Input Current:** The  $V_{\text{rms}}$  value of the input current to the primary when rated voltage at rated frequency is applied with the secondary open circuited. This is also untuned current. Tuned current is the value of input current when the primary is parallel tuned for minimum current.

**Input Power:** The power consumed with rated input voltage.

**Isolation:** A condition of separation, as in separating the output of a device from the influence of the input of another device employing transformer coupling, opto coupling, or any other method which separates both the high and low output of a device from the high and low inputs of a measuring device.

**Line-to-Line:** The  $V_{\text{rms}}$  found on the stator windings of a Synchro or Resolver. Common line-to-line levels are  $11.8V_{\text{rms}}$ ,  $26V_{\text{rms}}$ ,  $90V_{\text{rms}}$ .

**Linear Transformer:** A unit with a single phase stator and single phase rotor designed to provide a linear output voltage that is directly proportional to the rotor input angle. It operates over a range of less than  $\pm 90$  degrees, and is analogous to a potentiometer providing infinite resolution, but without mechanical contact between the elements.

**Loads:** For a transmitting unit, the impedance that the output voltage signal can drive without adversely affecting accuracy.

**Maximum Coupling:** The angle position of the shaft at which the in phase component of the output voltage is at a maximum level, i.e. the line-to-line level in  $V_{\text{rms}}$ .

**Minutes:** The resolution of a degree equal to  $1/60$  parts or  $60$  minutes =  $1$  degree. Also called arcminutes when used within a rotational plane measurement.

**Noise:** Random unwanted signals whose arbitrary nature interferes with desired signal measurement. To insure accurate measurement, the noise must be attenuated such that an acceptable Signal-to-Noise ratio can be maintained.

**Null Spacing Error:** Expressed in minutes, it is a measure of departure from predefined intervals where the electrical null should mechanically appear. For example, a resolver should have windings which are aligned exactly  $90$  degrees apart. Nulls should therefore appear at each  $90$  degree point from electrical zero. The null spacing error would be the deviation from these exact points.

**Null Voltage:** Noise or residual voltage in the output. The residual voltage present when the synchro shaft is at electrical zero or minimum coupling. This voltage is measured using a phase angle voltmeter and is also referred to by a vector description of Fundamental null or Total null.

**Operating Temperature:** The ambient temperature range over which the unit performs its primary function.

**Phase Angle:** The time difference in zero crossings of an AC signal compared to another AC signal (reference) of the same frequency. This difference is expressed not in time but as angular degrees where one cycle of the reference is 360 degrees. If the signal crosses zero at a point + or - x degrees from the zero crossing of the reference signal, the X would be called the phase angle. (Also see **Phase Shift**)

**Perpendicularity:** Resolver windings are mechanically 90 degrees aligned in space. Perpendicularity, usually expressed in minutes, is a measure of the departure from this 90 degree alignment of the electrical outputs.

**Phase Shift:** The difference between the time phase of the fundamental component of the reference voltage and the time phase of the signal voltage, measured at maximum coupling. The lead or lag of the output voltage with respect to the input voltage, usually stated in + or - degrees.

**Quadrature Voltage:** The voltage component of an AC signal which is 90 degrees out of phase with the reference and at the fundamental frequency.

**RC:** A resolver control transformer a.k.a. receiver.

**RDX:** A resolver differential transformer.

**Receiver:** A unit with stators excited by the input, which causes the rotor to drive to the proper mechanical position, giving an electrical null. Also called a CT.

**Resolution:** The smallest increment or least significant decade that a measurement can be displayed or counted. For example, angular resolution of .1 degree = 0.0 to 359.9 degrees displayed with an incremental count of 0.1 such that 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 degrees etc. is the counting sequence. If given as 0.5 degree resolution, the count would be 0.5, 1.0, 1.5, 2.0 degree etc.

**Resolver:** An electro mechanical device used to relate a mechanical angle displacement of a shaft to electrical voltages. A unit with a two phase rotor and two phase stator that is used to create or receive SIN/COS signals.

**RX:** A resolver transmitter.

**Scott-T Transformer:** A bilateral transformer device that converts synchro format signals into resolver signals and visa versa; it consists of two interconnected transformers with mathematically related turns ratios.

**Simulator-Synchro/Resolver:** An instrument that derives its output from a predefined excitation input that allows it to generate an accurate synchro or resolver formatted signal.

**Size:** The maximum outside and minimum inside diameters, length, shaft dimension and mounting configuration.

**Transformation Ratio:** The ratio of the in phase component of the output voltage, at maximum coupling, to the input voltage.

**Transmitter:** A unit with stators that output a signal proportional to the position of its excited rotor.

**Total Null:** The  $V_{\text{rms}}$  value of all the harmonics present in the output, including quadrature at the same points where fundamental null is measured.

**Zro:** The impedance of the rotor at rated frequency with the stator opened circuited.

**Zrs:** The impedance of the rotor with all stator windings short circuited at rated frequency and with a voltage applied to produce the same input current as for Zro.

**Zso:** The impedance of the stator with the rotor opened circuited.

**Zss:** The stator impedance with the rotor short circuited with rated frequency applied and a voltage applied to produce the same current as for Zso.

The following table (Table 1) outlines the type of synchro/resolver test instrument to be used with each type of synchro/resolver.

<b>SYN/RES</b>	<b>Type of Test Equipment</b>
CX or RX	1. Bridge Model 540 with DAV Model 2250 2. API Models 800, 801, 8500, 8800, 8810 3. PAV or DAV
CT or RC	Simulator Model 5300, 530, 5310, 5330 with a PAV or DAV
CDX or RDX	1. Bridge Model 540 with DAV Model 2250 2. API Models 800, 801, 8500, 8800 3. Simulator Model 5300, 530, 5310, <a href="#">5330</a>

North Atlantic Instruments also provides a full complement of VXIbus instruments to perform these functions.

## SYNCHRO AND RESOLVER CONVENTIONS

North Atlantic Instruments designs its equipment to conform with electro-mechanical conventions based on MIL-S-20708 (Synchro) and MIL-R-21530 (Resolver). The mathematical relationship is as follows.

### Synchro Convention:

$$\begin{aligned}E(S3-S1) &= NE(R1-R2) \sin \theta \sin \omega t \\E(S2-S3) &= NE(R1-R2) \sin (\theta + 120^\circ) \sin \omega t \\E(S1-S2) &= NE(R1-R2) \sin (\theta + 240^\circ) \sin \omega t\end{aligned}$$

Where N is the transformation ratio of the Synchro and  $\theta$  is positive for CCW rotation from electrical zero as viewed from the shaft end.

### Resolver Convention:

$$\begin{aligned}E(S3-S1) &= NE(R2-R4) \sin \theta \sin \omega t \\E(S2-S4) &= NE(R2-R4) \cos \theta \sin \omega t\end{aligned}$$

Where angles are based upon a transmitter excited R2 (HI) and R4 (LO).

## MIL-T-28800D Environmental Standards

North Atlantic Instruments designs its commercial equipment to conform with MIL-T-28800, Type III, Class 5 and 6. The following table (Table 2) outlines some specific characteristics and the qualified acceptance criteria.

Characteristic	Qualification	Class 5	Class 6
Temperature	Non-Operating	-55°C to 75°C	-55°C to 75°C
	Operating	0°C to 50°C	10°C to 40°C
Relative Humidity	Non-Condensing	95%	95%
Altitude	Non-Operating	12,000 m	12,000 m
	Operating	3,050 m	12,000 m
Vibration	Limit	2g max	2g max
Shock	Limit	30g	30g

### Notes:

1. Fungus resistance is required
  2. No requirements for explosive atmosphere, sand and dust resistance.
  3. All equipment must have shock mounts or rear supports if mounted by front panel only in order to pass shock test.
-