

## USER MANUAL THE RESOLVER

ICPE Department 4 has developed and produced a wide range of transmitter – type resolvers for military and industrial applications. From a mechanical viewpoint, these products have been developed in two design shapes: with housing, bearings and without housing. From an electrical viewpoint, these rotary induction transducers change a rotational motion into a cartesian system of electric voltages and there are the following operational categories: transmitter, differential, transformer, synchro-resolver. The resolvers are designed in accordance with the requirements of the military standards MIL-R-23417 and MIL-STD-202. The mechanical design is developed within the overall sizes: 0.6inch...5inch (housing outside diameter).

On demand, the specialists in ICPE SA- Department 4 can deal with all the operational types having other overall sizes than these.

### Mechanical configuration.

The magnetic circuit consists of stamped and glued lamination stacks; the material from which the laminations, are stamped is: iron-silicon alloy or iron-nickel alloy (depending on the application). The stator lamination stack is introduced into the housing made of 10Cr130 stainless steel and the rotor stack is fixed on the hub made of the same alloy; on demand, there can be used titanium-based stainless steel. At the user's request, there can be delivered resolvers only with wound magnetic circuits (Fig. 1.1)-the sizes are in millimetres-pancake design. The winding is of the distributed mono-two-phase type and is made of enamelled copper wire, class H.

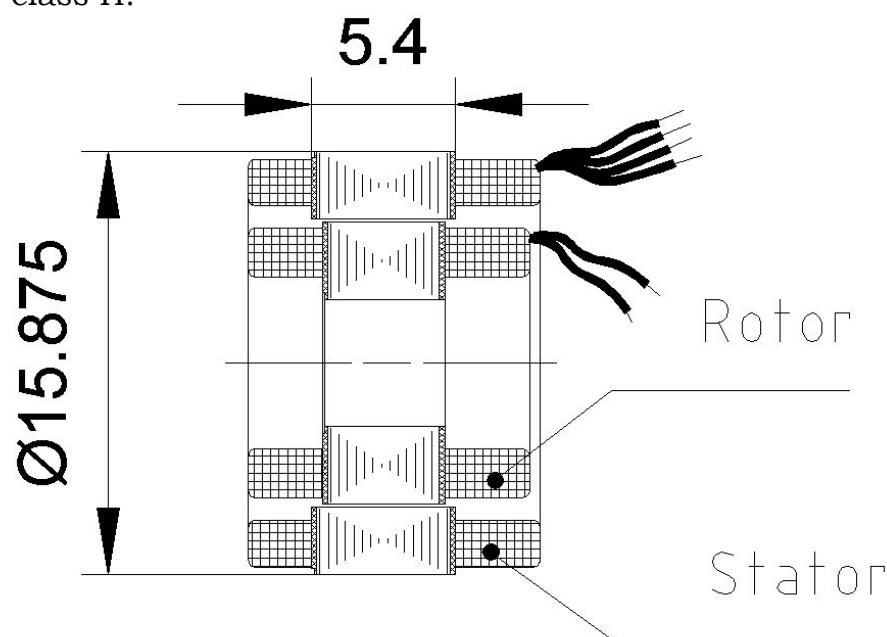


Fig. 1.1 Cross section of a pancake design

The lead wires are of the multicore type, are flexible, teflon-insulated according to MIL-W-16878. This design is requested by application in which the load shaft performs a limited rotational motion ( $\pm 90^\circ$ ).

For the applications in which the load shaft performs a continuous rotational motion (more than  $\pm 360^\circ$ ), the design is with housing, bearings and the resolver supply is carried out through a rotary transformer (Fig. 1.2).

This consists of a stator magnetic circuit (the primer), massive (without slots) equipped with a toroidal coil to which the excitation voltage is applied; the rotor circuit has the same magnetic structure as that of the stator and represents the resolver supply source. These magnetic circuits are made of ferrite-martensitic steel or iron-nickel alloy.

This mechanical design is delivered with the overall size of 0.8 inch; on demand, there can also be performed other overall sizes.

The use of the rotary transformer has the advantage that it removes the collecting rings-brushes subassembly and the operation time and rotational speed increase considerably.

In general, both designs can be performed with a number of pole pairs larger than or equal to one.

As to the pancake design, in the case in which the application requests high performances (residual voltage and reduced static electrical error), the alloy from which the laminations are stamped is of the iron-nickel type. In this case, the user has to take into consideration that the thermal expansion coefficient of the system connecting piece should be compatible with that of iron-nickel alloy. At the same time, if the resolver mounting place is an intense electromagnetic field, the user has to consult the manufacturer in order to choose the most efficient screening methods.

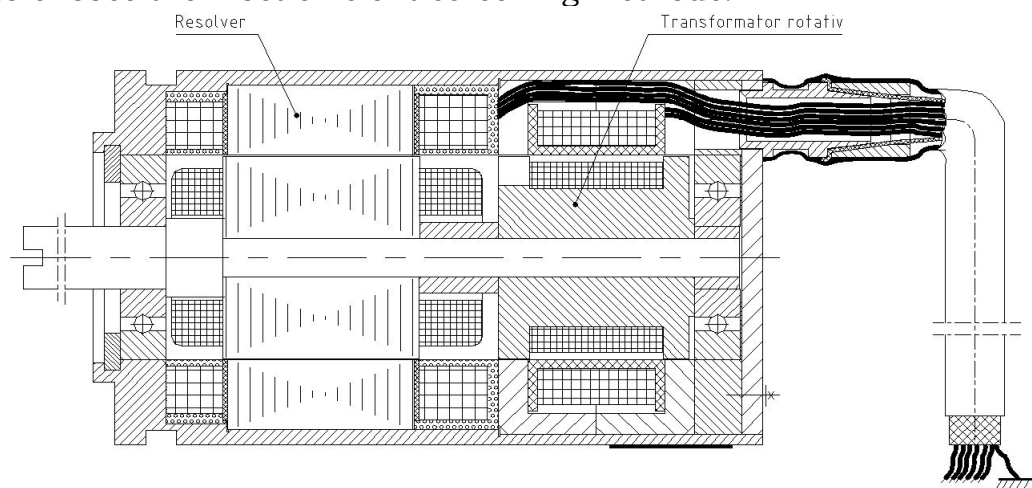


Fig. 1.2 Cross section of a design with bearings

## 2. Operation.

In the quasi-stationary regime, the resolver operation is based on the transformer theory. According to Fig. 2.1, if the voltage at the primary

winding terminals is  $E_{IN}$ , then the voltage at the secondary winding terminals ( $E_{IE}$ ) is:

$$E_{IE} = E_{IN} \cdot \frac{N_1}{N_2}$$

where:  $N_1$ ,  $N_2$  respectively, represent the turn number of the two windings.

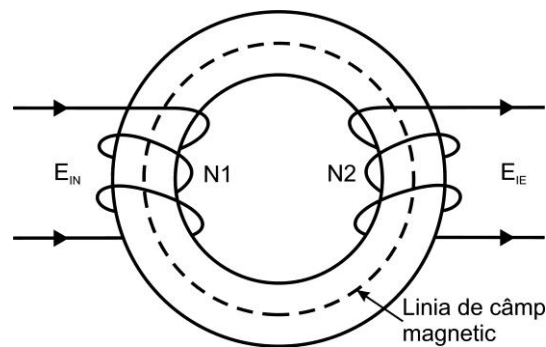


Fig. 2.1

In a resolver, the two magnetic circuits are inductively coupled as it is shown in Fig. 2.2

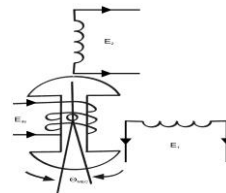


Fig. 2.2

The amplitude of the secondary voltages is modulated by the relative position between the two magnetic circuits.

The two windings of the stator magnetic circuit are galvanically separated and spatially distributed one against the other at an electric angle of  $90^\circ$ .

In this way, at a complete rotation of the rotor magnetic circuit, the two secondary voltages are amplitude modulated according to the sine function, cosine respectively, with a period depending on the number of the pole pairs with which the windings are performed. Fig. 2.3 shows the amplitude variation of the two secondary voltages function the relative position ( $\theta_{MEC}$ ) between the windings of the stator and the rotor.

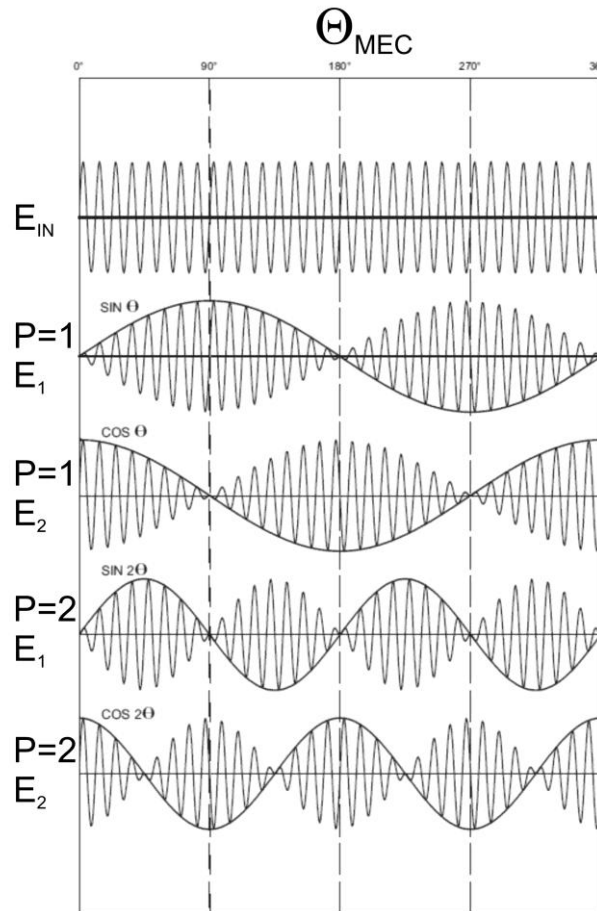


Fig. 2.3

For a stationary position of the rotor, the magnetic field, generated by the primary winding, excited by the time variation of voltage  $E_{in}$ , induces two voltages,  $E_1$  and  $E_2$  in the stator windings, amplitude modulated function the mechanical angle  $\theta_{MEC}$  between the axis of the rotor winding and that of the stator winding (sine).

$$E_1 = KE_{IN} \sin \theta_{MEC}$$

$$E_2 = KE_{IN} \cos \theta_{MEC}$$

Where:  $K$  is the ratio transformation.

For a resolver which is built with  $p$  pole pairs ( $p$  – speed number) the above equations become:

$$E_1 = KE_{IN} \sin (p\theta_{MEC})$$

$$E_2 = KE_{IN} \cos (p\theta_{MEC})$$

The electric angle is defined by the following relation:

$$\theta_{ELEC} = \arctan \left( \frac{E_2}{E_1} \right)$$

The most important parameter is the electrical error defined as the difference between the electric and mechanical angles .ICPE SA Department



4 owns equipment specialized in the establishing of this parameter: standards, angular position indicator, digital analyzing voltmeter and performs resolvers with the electrical error between 25 sec. arc and 30 min.arc.

### 3. Electrical characteristics.

The resolver is defined by the following electrical characteristics:

*Input voltage (excitation) and frequency:* the preferable voltage level for the pancake resolvers ranges between  $1V_{RMS} \dots 26 V_{RMS}$  and the frequency from 400Hz to 20kHz. At user's request, ICPE SA Department 4 has developed a wide range of windings in order to avoid the magnetic circuit saturation.

*Sensitivity:* represents the value of the voltage at the sine winding terminals corresponding to a displacement of the rotor with a degree in comparison with the electrical zero position. This parameter which is also called voltage gradient can be calculated by the following relation:

$$GT = \frac{E_{IN} \cdot \sin \theta_{MEC}}{\theta_{MEC}} \cdot 1000 \quad [\text{mV} / \text{grad}]$$

were:

$E_{IN}$  – input voltage in rotor in root mean square value;

$K$  – ratio transformer;

$\theta_{MEC} = 1^\circ$  (rotor displacement);

$p$  – number of pole pairs (speeds).

*Electrical zero (EZ):* is that position of the rotor winding axis compared to the sine winding axis, for which the voltage induced in this winding is minimum; if the rotor moves from *EZ* in the rotation positive direction (CCW), the root mean square value of the voltage  $E_1$  increases and is in phase with the voltage  $E_{IN}$  and the root mean square value of the voltage  $E_2$  decreases and is in phase with the voltage  $E_{IN}$ .

*Residual voltage ( $U_{REZ}$ ):* this voltage is defined in *EZ* and has three components:

- Residual voltage ( $U_{REZ}^{IF}$ ) in phase with  $E_{IN}$  – it has the value of the order  $10^{-4}$  mV, measured in *EZ*, for the fundamental frequency of the voltage  $E_{IN}$ ;
- Residual voltage ( $U_{REZ}^{QF}$ ) in quadrature of phase with  $E_{IN}$  – it is measured in *EZ* for the fundamental frequency of voltage  $E_{IN}$ , its value is function the resolver overall size;
- Total residual voltage ( $U_{REZ}^T$ ) – it is measured in *EZ* and represents the total voltage between the fundamental component value of the residual voltage and the values of the components induced in the winding by the other temporal harmonics of the primary magnetic field; its value depends on the number of pole pairs with which the windings are performed. Usually with a resolver with a pair of poles, its value is 1mV...3mV for a volt from the maximum secondary voltage; with a resolver with several pole pairs, its value is 0.2mV...0.5mV for a volt from the maximum secondary voltage.



$U_{REZ}^{QF}$  and  $U_{REZ}^T$  are measured in both secondary windings: for the sine winding in  $EZ$  and 180 electrical degrees and for the cosin winding at 90 and 270 electrical degrees. In specifications it is given as maximum value.

*Impedances, Absorbed current, Consumed power.* Usually, the winding impedances are given in the complex phase form:

$$\underline{Z} = R + jX$$

where:  $R[\Omega]$  includes  $R_{DC}$  of the winding and the magnetic circuit loss resistance – for the minimization of the losses, ICPE SA Department 4 uses, for the carrying out of the lamination stacks, great permeability magnetic materials – of nickel-based alloy type.

$X[\Omega]$  represents the winding reactance, which has a powerfully inductive character

Impedances are measured at the values of the current and the rated voltage in  $EZ$ ; the resolver is defined by the following impedances:

- $\underline{Z}_{RO}$  – Rotor winding impedance (primary), with the no-load secondary windings;
- $\underline{Z}_{SS}$  – Sine winding impedance (secondary), with the other short-circuit windings;
- $\underline{Z}_{SO}$  – Sine winding impedance (secondary), with the other no-load windings;
- $\underline{Z}_{RS}$  – Rotor winding impedance (primary), with the other short-circuit windings (it is measured on demand).

*The absorbed current intensity and the consumed power value* are defined by the following relations:

$$I_{IN} = \frac{E_{IN}}{Z_{RO}} \quad [A]$$

$$P_{IN} = I_{IN}^2 \cdot R$$

[W]

*The ratio transformer (TR):* it is determined as the ratio of  $E_2$ ,  $E_1$  respectively to the excitation voltage for  $EZ$  and 90 electrical degrees respectively, in the positiv rotation direction. For the bipolar resolver, the usual values are: 1; 0.454; 0.5; it is proportional to the  $\frac{N_2}{N_1}$  ratio.

*The phase shift ( $\Phi$ ):* it is determined in the rotor first angular position in  $EZ$  corresponding to the maximum coupling. It can be approximated by the following relation:

$$\Phi = \arctan (R_{DC} / X_L)$$

where:  $X_L$  – is the inductive component of impedance  $\underline{Z}_{RO}$ .

*The static regime electrical error ( $\epsilon_{EL}$ ):* it is the most important electrical parameter of the resolver and it represents the accuracy with which the mechanical angle changes into electric angle. This is determined in  $\Delta\theta_{MEC} = 1^\circ; 5^\circ; 10^\circ; 15^\circ$  on  $360^\circ$ . In a multipolar resolver, the electrical error is determined by means of the following relation:

$$\varepsilon_{EL} = \frac{1}{p} \cdot \arctan\left(\frac{E_{\sin i}}{E_{\cos i}}\right) - \theta_{MEC,i} \quad [\text{min.arc}]$$

where:  $I$  is the measuring angular interval ( $\Delta\theta_{MEC}$ ).

Fig. 3.1 shows a static electrical error typical curve of a multipolar resolver.

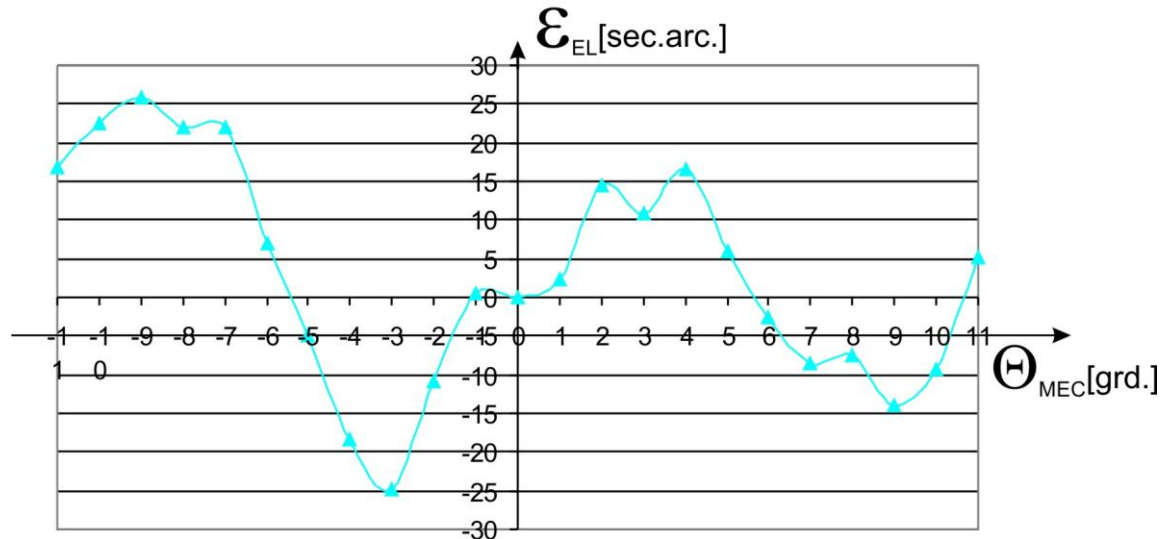


Fig. 3.1

Fig. 3.2 shows the static electrical error typical curve of a bipolar resolver.

#### 4. Load effect

In the case in which the secondary windings are connected to an analog-to-digital converter with an input impedance of the 250kΩ order, the load effect on the static electrical error is negligible.

If the value of the load impedance (purely) resistive character is: 10kΩ...20kΩ, then the load effect on the static electrical error is quite important especially in the case of the bipolar resolvers. For a ratio of the load resistance value ( $R_L$ ) to the resolver output impedance value ( $Z_{SS}$ ), the additional error is presented in Table 4.

$\frac{R_L}{Z_{SS}}$	Unbalance of the two loads [%]	Additional static electrical error [sec.arc]
10	0,5	50
	0,1	10
20	0,5	20
	0,1	4

Tab.4

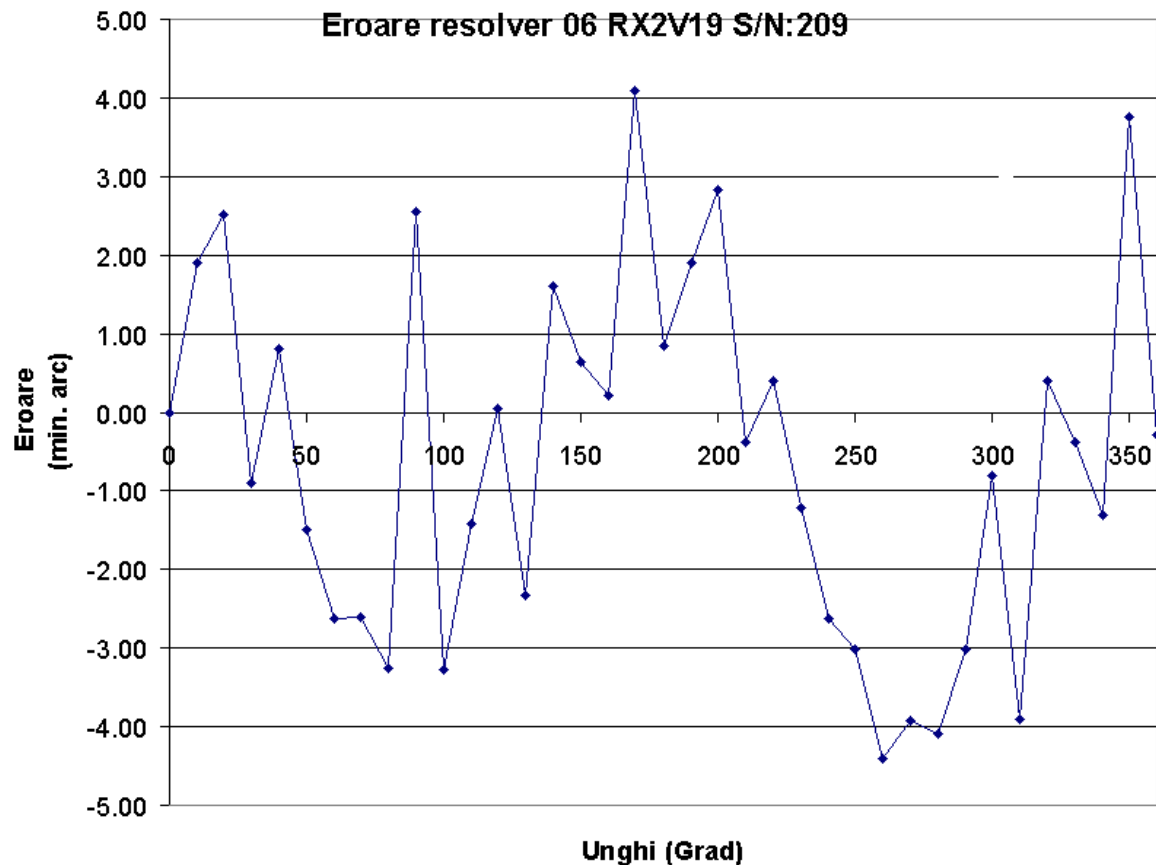


Fig. 3.2

In this case, one notices the unbalance influence of the two loads connected to the sine, cosine, respectively, windings.

5. Insulation resistance and dielectric rigidity. These tests certify the quality of the electroinsulating materials which ensure the electrical insulation among the windings and the windings as against the lamination stacks. ICPE SA Department 4 uses, for the resolver construction, high performance electroinsulating materials which ensure the product operation in the environment hostile conditions.

The test to the insulation resistance is performed at: 250V DC; 500V DC  $R_{IZmin.} = 100M\Omega$

The test to the dielectric rigidity is performed at: 250V AC; 500V AC /50Hz  $I_{Leakage max.} = 2mA$ ,  $t=1minute$