8. Controlling direction, position and rotation speed of EMRAX motors

a) Drive control with sensor:

- For controlling <u>direction</u>, <u>position</u> and <u>rotation speed</u> of the motor a sensor should be used. Sensor types that can be used are: resolvers, encoders or hall sensors.

- Sensors must be used for e.g. electric vehicles and propellers that have to stop at the exact position (glider planes, where the propeller has to be put into the fuselage).

- Resolver/encoder has to be precisely mounted onto the motor by a special bracket. Hall sensors have to be mounted in the motor during assembly of the motor. Sensors with brackets can be ordered from the EMRAX Company, where they are also mounted. If sensors are not mounted in the EMRAX Company no warranty applies.

!Note:

- It is important that auto tuning (synchronising the electrical and mechanical motor angle) and pre-setting of controller software is done first. Here is a video, which shows auto-tuning EMRAX motor with Unitek controller: https://youtu.be/yuyPS_RCWQ8

- For every motor one sensor (encoder/resolver/hall) is needed if the motor is used with one controller. When one motor is used with two controllers (2 sequences of motor phase connectors – 2xUVW) then two sensors should be used (e.g. tandem resolver). This is when a very high motor current has to be ensured.

- For the EMRAX TWIN application two sensors (tandem resolver mounted on the second motor) and two controllers are needed. Some controllers (rare controllers) have an option to split the signal from two controllers in only one sensor (usually encoder), which is mounted on the second motor.

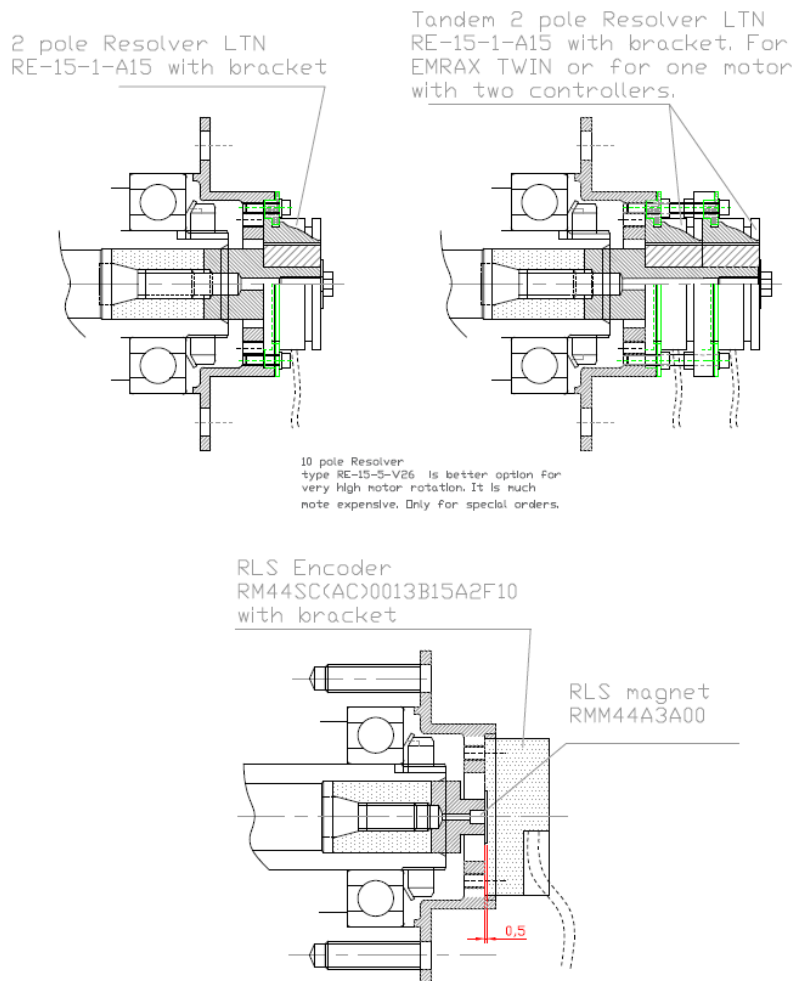- For more information about sensors, please consult with the controller producers.

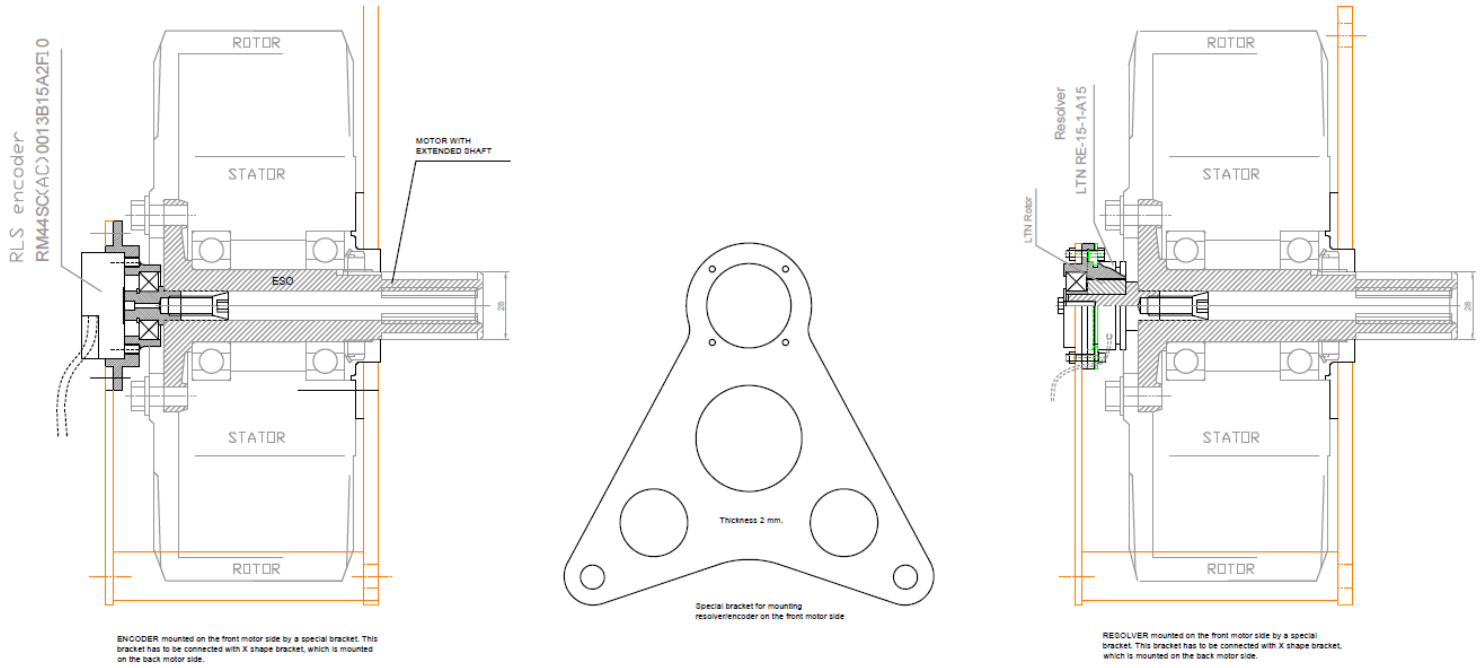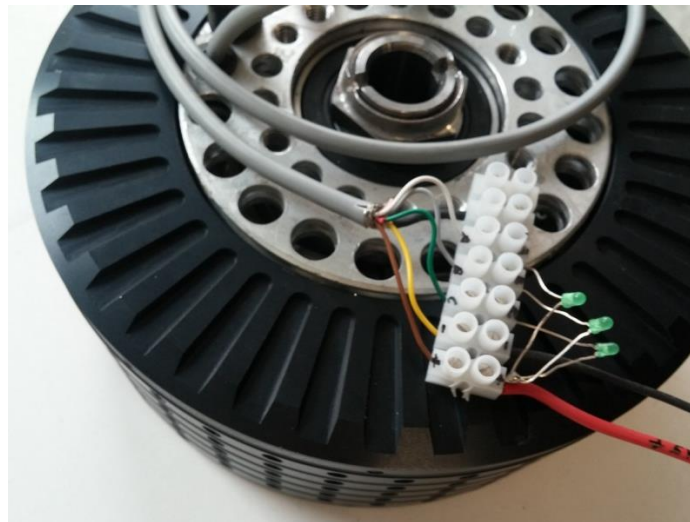**Figure 1: Resolver / encoder on back motor side**

Figure 2: Resolver / encoder on front motor side

Figure 3: Encoder with bracket

Figure 4: Resolver with bracket

Hall sensors type:	SS411P

Power supply wires:	
BROWN	+ 5 V
YELLOW	- 5 V

Hall sensors signal wires:	
WHITE	A
GRAY	B
GREEN	C

Figure 5: EMRAX with hall sensors

b) Drive control without sensor (sensor-less):
- Direction of motor rotation (clockwise/counter clockwise) can also be defined without a sensor, if the controller has a sensor-less option. It can be defined by pole reversal, which can be achieved by a change of two motor phase cables. Three phase power connectors UVW are shown below in this Item. Position and rotation speed cannot be defined without a sensor.
- Sensor-less can be used for e.g. boats, airplanes and for applications that do not need a high torque at the start (applications with propellers).
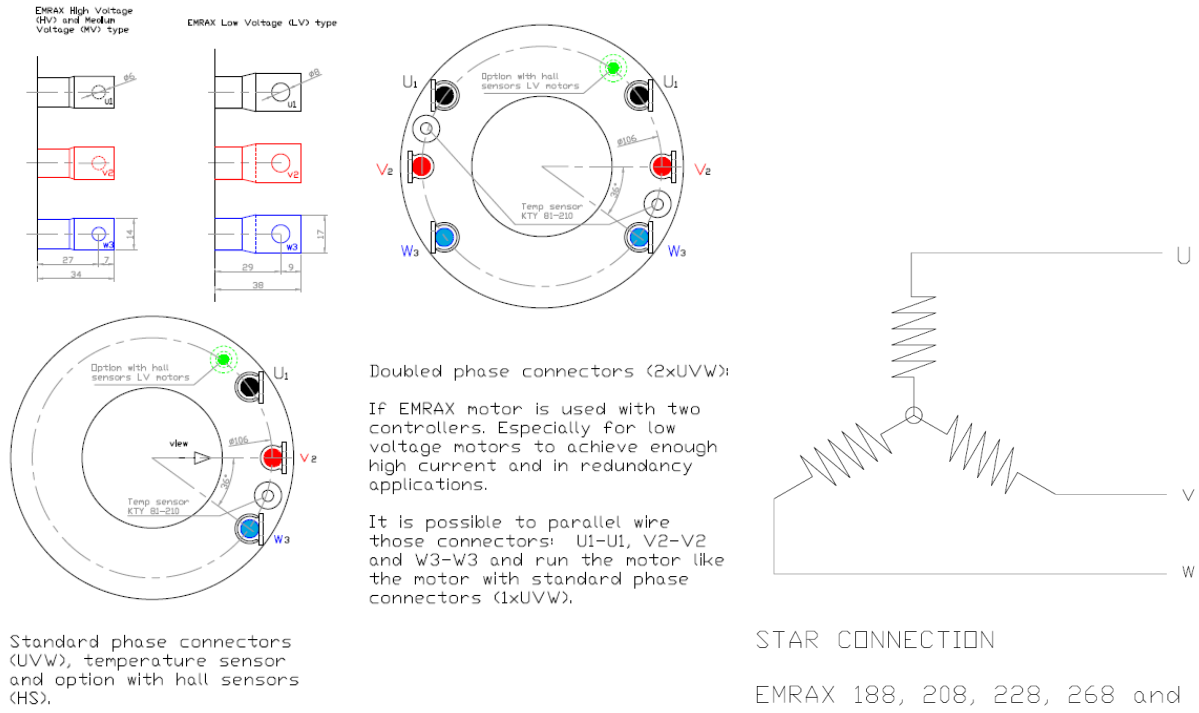
Doubled phase connectors (2xUVW):

If EMRAX motor is used with two controllers. Especially for low voltage motors to achieve enough high current and in redundancy applications.

It is possible to parallel wire those connectors: U1-U1, V2-V2 and W3-W3 and run the motor like the motor with standard phase connectors (1xUVW).

Standard phase connectors (UVW), temperature sensor and option with hall sensors (HS).

STAR CONNECTION

EMRAX 188, 208, 228, 268 and 348

Figure 6: Motor phase connectors – normal (UVW) and doubled (2xUVW)

9. Suitable controllers for EMRAX motors

Controllers have to be bought directly from the producers. The most suitable controllers for EMRAX motors are from the following companies:

- Unitek GmbH, Germany
- Emsiso d.o.o., Slovenia
- Sevcon Ltd., United Kingdom
- Reinhart Motion Systems LLC (RMS), USA

The controller has to be selected according to the Technical Data Table of each motor (high motor current and voltage is very important). For some EMRAX motor types it is difficult to find a suitable controller even in the global market. It is especially difficult to find a controller with enough high current, which enables low voltage motors performances listed in the Technical Ddata Tables. If the motor current is not high enough, then performances are inferior to the performances in the Technical Data Tables. For this reason two controllers can be used with one motor, therefore the motor can perform with its full performance. In this case the motor windings are wind in two phase sequences (2xUVW). The customer has to order doubled phase connector sequences on one motor when placing an order.

EMRAX motors should be used with the **sinusoidal commutation** controllers. If the controller with trapezoidal commutation is used, the motor would not work at its best performance, and it would also be louder.

Every motor is tested with the Unitek Bamocar D3 controller before dispatch. Stator windings are tested at 1500 Vac.

In the table below controllers are listed that are recommended for each motor type (performances of the motor should be calculated according to controller characteristics – current, voltage!):

Motor type	Recommended controller
EMRAX 188 High Voltage	Unitek; Sevcon
EMRAX 188 Medium Voltage	Emsiso emDrive 500 Unitek; Sevcon
EMRAX 188 Low Voltage	Emsiso (2x emDrive 150 or 1x emDrive 500)
EMRAX 208 High Voltage	Unitek (Bamocar D3 400 V) Emsiso (emDrive H300) Sevcon; RMS
EMRAX 208 Medium Voltage	Unitek (Bamocar D3 400 V) Emsiso (emDrive H300) Sevcon; RMS
EMRAX 208 Low Voltage	Emsiso (emDrive 500) Sevcon; RMS
EMRAX 228 High Voltage	Unitek (Bamocar D3 700 V) Sevcon; RMS
EMRAX 228 Medium Voltage	Unitek (Bamocar D3 400 V) Emsiso (emDrive H300) Sevcon; RMS
EMRAX 228 Low Voltage	Emsiso (emDrive 500) Sevcon; RMS
EMRAX 268 High Voltage	Unitek (Bamocar D3 700 V) Emsiso (emDrive H300, for up to 450Vdc - for high torque at lower RPM) Sevcon; RMS
EMRAX 268 Medium Voltage	Unitek (Bamocar D3 700 V) Emsiso (emDrive H300) Sevcon; RMS
EMRAX 268 Low Voltage	Emsiso (emDrive 500 - only up to 130 Vdc→lower RPM→lower power or 2x emDrive H300)

	Unitek (2x Bamocar D3 400 V) Sevcon, RMS
EMRAX 348 High Voltage	Unitek (2x Bamocar D3 700 V) Sevcon; RMS
EMRAX 348 Medium Voltage	Emsiso (emDrive H300 - only up to 450 Vdc◻lower RPM◻lower power) Unitek (2x Bamocar D3 700V) Sevcon; RMS
EMRAX 348 Low Voltage	Emsiso (2x emDrive 500 - up to 1200 RPM)

!Note: For the correct type of the controller consult with the controller producer – especially for Sevcon and RMS controllers.

Most controllers use sensors for controlling position, direction and rotation speed of the motor. If the controller has the sensor-less option, then a sensor is not needed, but in this case only the direction of motor rotation can be defined (by changing positions of two phase cables). More information about sensors is written in Item 8.

Recommended sensors for different controllers:
- Most controllers can drive the EMRAX motor with encoder, 2 poles resolver or hall sensors. Sensors that are available from the EMRAX Company are (they are mounted on the motor by a special bracket or in the motor):
- **LTN RE15_1_A15** (2 poles resolver) for Unitek Bamocar D3 controller
- **TLTN RE15_1_A15** (2 poles tandem resolver) for two Unitek Bamocar D3 controllers; when using two controllers with one motor (doubled phase connectors - 2xUVW are needed) or for EMRAX TWIN
- **RLS RM44SC** (encoder) for Emsiso emDrive 500 and emDrive H300
- **RLS RM44AC** (encoder) for Sevcon controllers
- **HS SS411P** (three hall sensors; possibility of doubled hall sensors) for Emsiso controllers
- Some controllers (e.g. RMS) require 10 poles resolvers, which are more accurate and can deliver a better signal to the controller. Then the controller can deliver a better current commutation to the motor. These sensors are especially required for higher speeds. The 2 poles resolver can be replaced by the 10 poles resolver by using the same resolver bracket. 10 poles resolvers are more expensive than 2 poles resolvers.

For more information about suitable sensors, consult with the controller producer.
Every sensor has to be mounted on the motor by a special bracket. If the resolver / encoder is bought from the EMRAX Company it is already precisely mounted on the motor by a special bracket when the customer receives the motor. Hall sensors are mounted in the motor during the motor assembly.

!Note:
- Controllers can usually deliver very high peak power and lower continuous power, especially if the controller is air cooled.
- Performance of the motor also depends on the controller boost current and voltage (especially peak).
- Batteries should have very high C (Current) rating – very high boost discharging current from the batteries at high motor load.
- For EMRAX TWIN application two sensors (tandem resolver mounted on the second motor) and two controllers are needed. Some controllers (rare controllers) have an option to split the signal from two controllers in only one sensor (usually encoder), which is mounted on the second motor.
- Separated EMRAX motors which are not connected together mechanically (are not on the same shaft), cannot be driven with one controller.

Motor RPM depends on battery DC voltage and magnetic field weakening:
Maximal battery DC voltage delivers maximal motor RPM which should not be exceeded. Take a look at specific load speed in the Technical Data Table – RPM/1Vdc. In the case of using the magnetic field weakening option in the controller settings the maximal motor RPM can be achieved even at lower DC voltage from the batteries.

Achieving higher RPM with magnetic field weakening (MFW):
Most controllers have an option to set the magnetic field weakening in the controller software program. This setting enables the motor to achieve higher RPM at the same battery voltage. All EMRAX motors can weaken the magnetic field up to 100%. In this case the rotation speed increases, but the power stays at the same level. Torque is lower at higher speed. Efficiency drops only for 1-2 %.

Magnetic field weakening can be set in the controller software. EMRAX motors have 10 pole pairs, therefore it is recommended to weaken the magnetic field 15-20% to achieve the best performance. With higher % of magnetic field weakening the motor can run faster with very good efficiency, which drops only for 1, 5% at 80% MFW. We recommend MFW only for a short time (few min in case of full motor power), because of a very high current phase between the motor and controller.

!Note:
- Maximal motor RPM should not be exceeded. Maximal motor RPMs are listed in the Technical Data Tables for each motor type.
- EMRAX motor has 10 pole pairs, which results in very high motor rotation frequency, especially at higher motor speed. Therefore the controller for an EMRAX motor has to be made for high rotation frequencies.
For example: at 6000 RPM the rotation frequency is 1000 HZ. Consequently, the controller must deliver a stable and smooth signal even at a high rotation frequency with high PWM. $RPM = 60 * Hz/PP$.