SMARTsolver

Instruction Manual

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Introduction

For decades, Attwood Electronics have serviced industrial equipment, including motor drives, CNC machines and other equipment with power electronics.

Encoders are often seen in such machines for measuring rotational or linear position.

Traditional incremental encoders are still common, but now they compete with the likes of resolvers and digital encoders that work very differently. Examples of common digital encoders now include EnDat, Sick HIPERFACE® and other high speed protocols.

The problems with encoders and Servo motors.

Like any precision mechanical device, Encoders deteriorate due to wear and stress from vibration or misalignment. Encoders can be pretty reliable while environmental conditions remain good. During assessment they are cleaned up, and tested for missing pulses or signs of signal instability due to wear.

Typical industrial machines are packed with permanent magnet servo motors. Each has an encoder buried inside. Together with computerised control they provide agile, accurate and high-torque capabilities to machine designers.

Servo motors use an internal encoder to provide angular feedback to the drive electronics. When the drive knows the current shaft angle, it will create the best moving magnetic field for maximum torque and efficiency.

What is less well-known is that servo motors have a fixed rotational relationship between the motor shaft and the encoder shaft. If this angle is disturbed the motor will not perform well, if at all. Servo motors will draw a high current when they're out of alignment, even by just a few degrees.

Any motor servicing technician that is unaware of this relationship is in trouble from the moment they dismantle a PM (permanent magnet) servo motor. As soon as the relationship between motor and encoder is disturbed, the chances of the motor working again are very slim.

Our Solution

In the past, servo motors and encoders were physically marked to record their static relationship. It worked, but was time-consuming. This procedure also ran the risk of having marks disappear during motor cleaning and refurbishment.

What if there were a way to electrically test a motor to determine the angle relationship to its encoder?

Furthermore, imagine a device that can prove the integrity of the encoder, capture the angular calibration, *and* guide someone through reassembly and recalibration once refurbishment is complete.

The Attwood Electronics SMARTsolver kit.

Test functions (Separate interface modules):

- Incremental Encoders (up to 6 signals including A, B & Z)
- Resolvers (6 wire transformer with rotatable secondary)
- EnDat Encoders (digital signal protocol)
- Hiperface Encoders (digital signal protocol with sin/cos outputs)

Features:

- Capture motor / encoder calibration angle.
- Guide and assist with motor / encoder reattachment and recalibration.
- Ability to brake / stop the motor shaft at the correct calibration position.
- Incremental Encoder functions:
    - Supply encoder power (5V, 12V, 24V)
    - Detect / confirm quadrature and index signals
    - Detect bearing wear, signal jitter
    - Determine signal type (NPN, Line, Push-pull, PNP)
- Powered from internal AA batteries, or from USB-C charger / power bank.
- Operating on internal battery puts the SMARTsolver in low-power mode:
    - The display backlight remains off
    - If no buttons are pressed for a while, the unit beeps a few times
    - If no buttons have been pressed, the unit enters sleep mode
    - Occasional snoring sound invites someone to turn off the power switch

Important Information:

- Before an encoder / resolver can be tested, the following must first be known:
    - Power connections and voltage (resolvers don't need power)
    - Signal connections. Online datasheets, and machine wiring diagrams can be helpful
- Encoders, Resolvers and motors cannot be tested unless they are electrically disconnected from all external circuits.
- Encoders, Resolvers and motors must be mechanically free to turn by hand (disable brake).
- Reading motor calibration involves hand-spinning the shaft. A seized motor cannot have its calibration read.
- The mechanical process of removing an encoder must be well documented / photographed to inform the process of re-attachment and alignment.

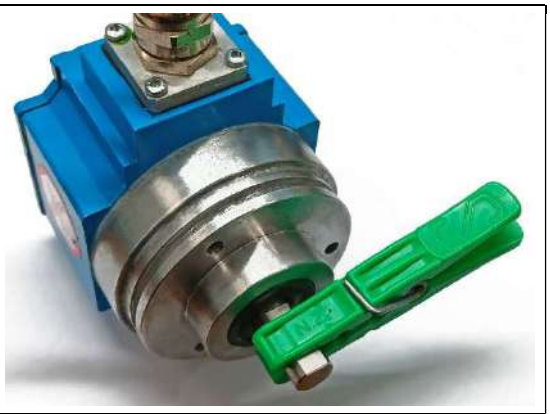
Connectors & Controls

Helpful Tips

Hand-spinning handle:

SMARTsolver tests require the encoder / motor shafts to be turned smoothly by hand.

For encoder shafts we suggest using a plastic clothes-peg. This should be light enough to avoid rotation caused by gravity.



For motor shafts, we recommend making a crank-handle from a 300mm length of stiff welding wire and a suitable hose-clamp.

Firstly, protect the motor shaft by wrapping it with a couple of layers of insulation tape.

Bend the welding wire like the one in the photo. Make sure the bend radius is big enough to put an index finger through.

Use the hose-clamp to secure the handle to the shaft.

Power supply

The SMARTsolver offers two options for its power.

Depending on your location, running the unit on internal batteries (4 x AA) may be convenient.

The SMARTsolver may be powered externally via the USB-C port. The power rating must be 10W or greater. (2A at 5V).

The cable must have USB-C connectors at **both** ends.

Interface cable

The cable that links the SMARTsolver to interface modules is subject to wear and damage if not treated with care.

Remember to squeeze both side-latches when removing this connector.

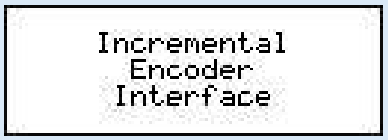
This cable is available from;

Mouser (www.mouser.com) code 517-4926-0101

DigiKey (www.digikey.com) code 3M12129-ND

Testing an Incremental Encoder

Start by plugging in the Incremental encoder interface and then the signal and power wires.

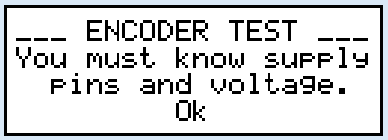


Setup, Step 1

Find out the connection details and supply voltage.

Often there are details visible on the body of the encoder.

If you see a brand and model number, you have a reasonable chance of finding details online.



Setup, Step 2

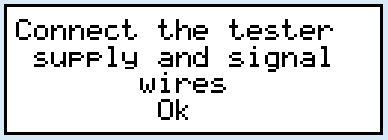
Use wires and clips from the 8-way connector to the encoder pins.

Make sure the supply pins are correct.

There are 6 channels for signals A, B, Z, /A, /B, /Z

Best practice: Use Ch1 for A, Ch2 for B, Ch3 for Z.

If you're unsure which signal is which, the SMARTsolver will attempt to work it out.

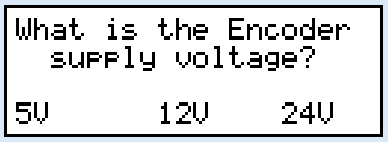


Setup, Step 3

Encoders are often marked with their supply voltage, or a range of voltages. Choose between 5V, 12V, and 24V.

IMPORTANT: Incorrect polarity or over-voltage can damage the encoder under test!

You will be asked to confirm this selection.



Setup, Step 4

Find a way to slowly and smoothly spin the shaft clockwise.

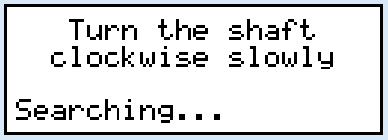
Hint: Many motors have a thread in the shaft. A thread tap and handle is very convenient for this purpose.

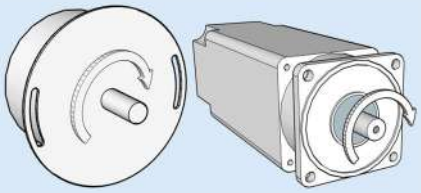
The SMARTsolver will monitor the signals and try to identify them.

C, N, or P identify the type of signal output from the encoder

Q confirms it has recognised a quadrature waveform.

Z confirms it has identified a Z pulse





Setup, Step 5

This screen appears, showing the status of each channel, and the signal.

If either A or B signals don't appear:

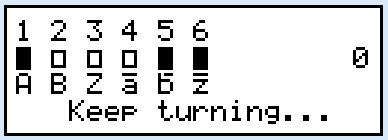
- The shaft may have been turned too fast
- The initial movement may have been the wrong direction
- The encoder may be faulty.

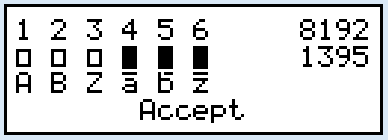
Turn off the tester and begin the process again.

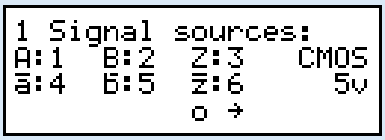
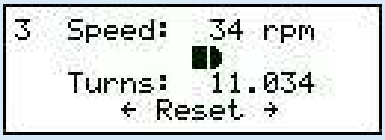
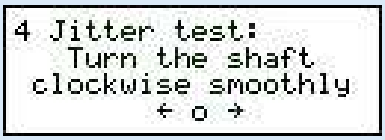
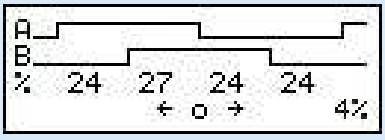
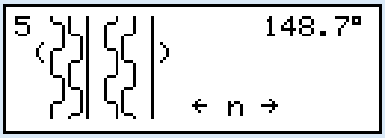
If the analysis is successful, a number will appear in the top right corner. This shows the pulses per revolution.

The number beneath it is the current position count.

If it looks Ok, press Accept

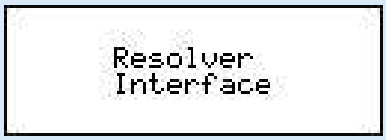




Page 1 displays the results of the signal analysis. It shows you the channels where A, B and Z were found. In this example, the encoder outputs are CMOS (push-pull) and the chosen voltage was 5V. Press right button for Page 2	
Page 2 is a live display of the encoder position. The bar should move smoothly in both directions. If the top number changes, this may indicate a missing pulse issue.	
Page 3 displays shaft speed and counts the turns. Press reset to zero the turn counter. This is useful for counting gear ratios for motors with a gearbox.	
Page 4 offers you a Jitter test. This test provides a reasonable indication of mechanical wear in an encoder. If you want to do the test, spin the shaft smoothly and note the percentage figure at the bottom-right corner. A new encoder will typically show 4% jitter or less. Consider replacing an encoder if jitter approaches 10%.	 
Page 5 has a live display of all 6 encoder channels as the shaft is turned. The strip between the brackets shows you the signal states for the current angle. In this example the left two channels display the quadrature signature. When the shaft is at 0° you should see the Z pulse. Hold the centre button to see the channel numbers.	
Press the right button to see the motor calibration menu.	

Testing a Resolver

Start by plugging in the Resolver interface and then the signal wires.



Useful information:

Traditional resolvers have 6 wires and can be likened to a two-piece transformer. (Stator & Rotor)

Terminals R1 / R2 are like a primary winding. This excites the resolver.

Terminals S1 / S3, and S2 / S4 are offset secondary windings. These signals provide positional information.

Before you can test a resolver, the following conditions are needed

- The resolver must be disconnected electrically from any other device.
- You need to know the designations for the resolver wires.
- A working resolver will know its position without needing to find the index position.

Figure 1

Typical 2-piece resolver with stator and rotor. Occasionally resolvers are enclosed, and look just like encoders (body + shaft).

If the wire designations are unclear, a resistance meter will help you. Of the three independent windings, two should have the same resistance (S1/S3 & S2/S4). The remaining circuit will be R1/R2
You may find the wire colours written on the body of the resolver or in machine wiring diagrams.

Here is a common colour scheme for resolvers:

Signal	Colour	(German)
R1	White	Weib
R2	Violet	Violett
S1	Red	Rot
S2	Yellow	Gelb
S3	Black	Schwarz
S4	Blue	Blau

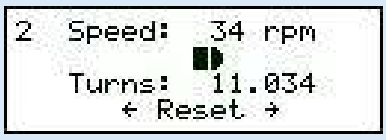
When testing, always record which test wire is connected to each pin/wire on the resolver.

Page 1 shows the screen when a resolver has been connected.
You will see the graphic change as you turn the shaft.

Clockwise rotation should make the graphic move to the right.
If the angle is unstable, go to the diagnostic page on page 3.

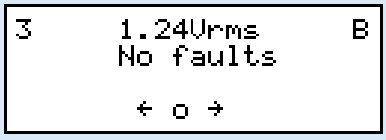
Page 2 displays shaft speed and counts the turns.

Press the middle button to reset the turn count. This is useful for counting gear ratios for motors with a gearbox.



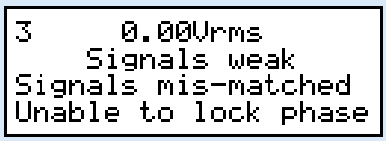
Page 3 is the resolver diagnostic page.

At the top it shows the return signal strength.
Depending on the type of resolver, a 'B' may appear at the top corner. (Boost)

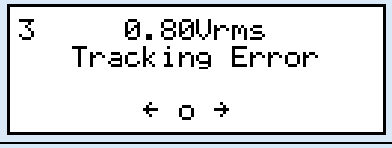


These faults imply that R1 or R2 are not connected.

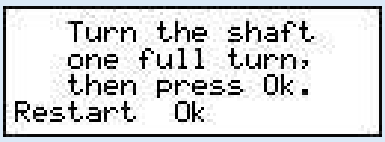
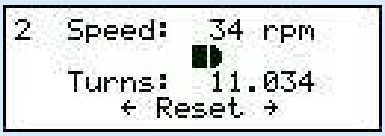
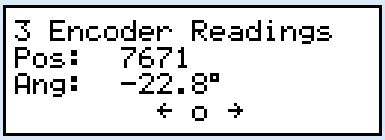
It could also mean that the S signals are mixed up, or the stator is not fully fitted around the rotor.

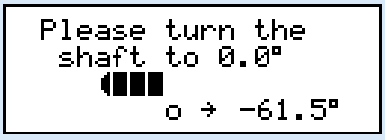
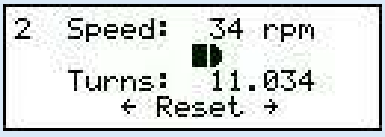
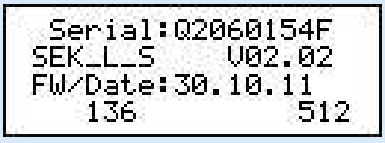


This message is typical of a case where one of the S signals is disconnected. Note that the signal strength is not zero



Press the right button to see the motor calibration menu.

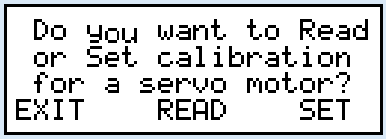
Testing an EnDat Single Turn Encoder Start by plugging in the EnDat encoder interface and then the signal and power wires. Note: EnDat Multi Turn encoders cannot be tested yet	
Setup, Step 1 Turn the shaft about one turn. It helps if you have a handle or a mark on the shaft before you start. This tells the SMARTsolver the correct resolution of the encoder. Anything other than one turn will give you false results.	
Page 1 shows the screen when an EnDat encoder has been connected. You will see the graphic change as you turn the shaft.	
Page 2 displays shaft speed and counts the turns. Press the middle button to reset the turn count. This is useful for counting gear ratios for motors with a gearbox.	
Page 3 shows parameters that are recorded inside the EnDat encoder. 'Pos' shows the count position. 'Ang' is the current shaft angle.	
Press the right button to see the motor calibration menu.	

Testing a Hiperface Single Turn Encoder Start by plugging in the Hiperface encoder interface and then the signal and power wires. Note: Hiperface Multi Turn encoders cannot be tested yet	
Setup, Step 1 First, we need to synchronise the two types of signals in the encoder by moving the shaft to 0.0°	
Page 1 shows the screen when an Hiperface encoder has been synchronised. You will see the graphic change as you turn the shaft.	
Page 2 displays shaft speed and counts the turns. Press the middle button to reset the turn count. This is useful for counting gear ratios for motors with a gearbox.	
Page 3 shows parameters that are recorded inside the encoder. The bottom line shows the current count and the Maximum count.	
Press the right button to see the motor calibration menu.	

Reading (capturing) calibration from a servo motor

Please note: These instructions apply to both encoders and resolvers. In this section, both will be referred to as encoders.

If the encoder is inside a motor, we can easily capture the calibration setting (Cal) by pressing the READ button.

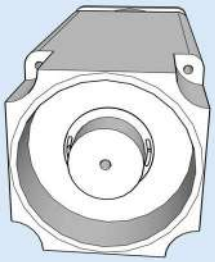


If you remove the back cover of the motor, you will see an encoder inside.

Do NOT disturb the encoder yet.

Look for any information on the encoder.

Take photos where possible.

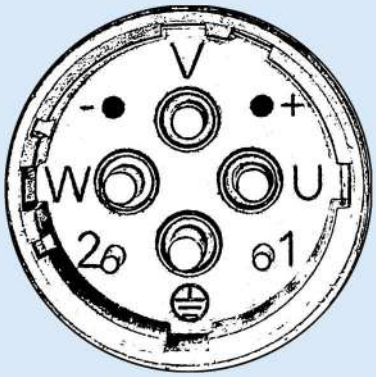


The main motor connector will have at least four pins. Use a meter to identify the Earth pin. You do not need to connect to earth.

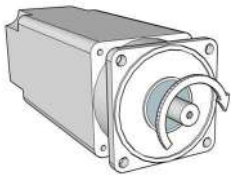
The 3 motor pins should have low resistance between them for the windings. If the plug is marked with labels (like this example), connect U, V and W to the SMARTsolver UVW.

If there are no markings, assume U, V & W move counter-clockwise around the Earth pin. It's Ok to do this, as long as you clearly record the connections for when you recalibrate the motor.

The motor in this graphic has no brake, but if there is one, you will need to apply power to release it.



Turn the motor shaft clockwise slowly, (about one revolution per second).



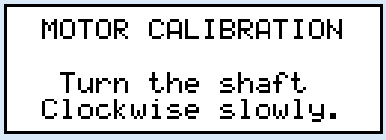
The SMARTsolver will monitor the U, V and W signals and tell you if they are Ok to analyse.

If you continue turning and there is a signal missing, check the U, V and W connections.

When SMARTsolver has found "Cal" position, the unit will beep. You may want to keep turning to ensure the reading is taken at a speed close to 30rpm.

Write down the number on the test sheet. Also record the connections to the encoder and the windings connector.

Press the left button to continue.



At this point you may remove the encoder carefully.

If possible, use photos to record each stage of disassembly.

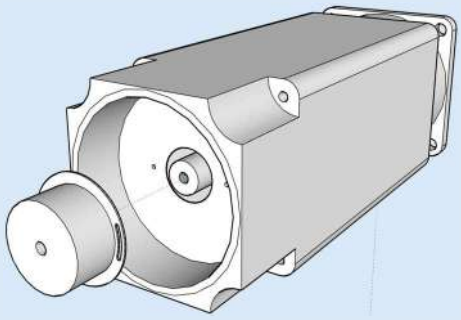
A datasheet for the encoder can be very useful at this stage as it may have mounting details / removal instructions specific to the model.

Typically, there is a screw through the encoder to the motor shaft.

One, two or three screws around the outside of the encoder body are usually in a slotted disk for fine adjustment. For now, they will need to be loosened or removed.

Be sure to protect the encoder and its wires, they are fragile.

You may now refurbish the motor.



Setting encoder calibration for a servo motor

These instructions relate to Incremental, EnDat and Hiperface encoders, and one-piece resolvers.

Most resolvers have two separate parts, and the instructions are different. Please go to page 13 of this manual if you are refitting a two-piece resolver.

At this point you will have the following:

1. The repaired / refurbished motor.
2. A record of the calibration angle (Cal). Hint: If you have Cal from an *identical* motor, you may use that, but only if there is no other option.
3. All test wiring is exactly as it was when calibration was read.
4. The Encoder shaft will be free to turn.

Navigate to page 4 and press the SET button to begin recalibration.

```
 Do you want to Read
 or Set calibration
 for a servo motor?
EXIT    READ    SET
```

```
Before refitting the
  Encoder, you MUST
 know the Cal value
         Ok
```

At this point you tell the SMARTsolver the calibration value for this motor.

Set the 100's, press the middle button

Set the 10's, press the middle button

Set the 1's, press the middle button

The left button allows you to reset to 000 if you need to. A second press will escape back to the previous menu.

```
4
     Set hundreds
      Cal=300
     000  ->  +100
```

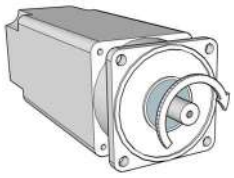
```
4
     Set tens
      Cal=330
     000  ->  +10
```

```
4
     Set ones
      Cal=330
     000  Ok  +1
```

As you turn the motor shaft clockwise it will stop at different pole positions.

If you feel the motor turn beyond the braking point, press RETRY to have another go at it. Perhaps more slowly.

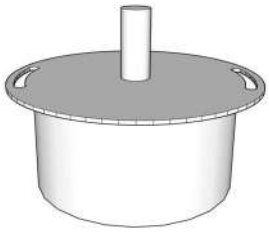
When you are happy with the position, press the YES button.



```
Turn the MOTOR shaft
  CLOCKWISE gently
   until it stops
```

```
Did it stop sharply?
   (no overshoot)

RETRY    YES
```

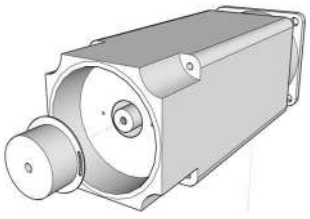


Carefully rotate the shaft of the encoder and watch the Enc value as it approaches 0°

The Ok prompt will appear when the encoder shaft is within a degree either side of 0.

Press the Ok button to continue.

```
  Turn the Encoder
 shaft to 0 degrees
        Enc=   0°
         Ok
```



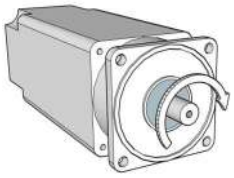
The number at the bottom right of the screen shows the live encoder reading.

Keep the encoder body in the correct orientation whilst bringing the two shafts together. The encoder reading should not change much during this process.

Hold the motor shaft as you tighten the shaft screw.

```
Secure the encoder
to the motor shaft.
Keep reading near 0
        Ok        0
```

Because the motor shaft may have turned while the encoder shaft screw was being tightened, we need to reposition the shaft.



Turn the motor shaft to read -20°, push Ok, then turn it clockwise until it stops.

If you feel the motor turn beyond the braking point, press RETRY to have another try.

When you are happy with the position, press the YES button.

```
Turn the motor
 shaft to read
 -20 degrees.
      Ok      -4
```

```
Turn the MOTOR shaft
 CLOCKWISE gently
  until it stops
```

```
Did it stop sharply?
   (no overshoot)

RETRY     YES
```

Encoder mounting systems usually have provision for fine rotational adjustment.

When the position is 0.0°, tighten the clamping screw(s).

You will have the opportunity to recheck the calibration against your recorded setting.

In RECHECK mode you can fine-tune the position if necessary.

To make a fine adjustment:

- Loosen the encoder body clamp while in RECHECK mode.
- Spin the shaft clockwise about 30rpm while rotating the encoder body until you get the desired calibration point.
- Re-tighten the encoder clamp when you are finished.

```
Turn the body of the
 Encoder until the
  reading is 0.0
      Ok      1.2
```

```
Now do up the clamp
 and re-check your
   calibration.
      Ok      0.0
```

Setting resolver calibration for a servo motor

These instructions relate to 2-piece resolvers only.

Please go to page 11 of this manual if you are refitting an encoder or one-piece resolver.

At this point you will have the following:

1. The repaired / refurbished motor
2. A record of the calibration angle (Cal). Hint: If you have Cal from an *identical* motor, you may consider using that, but only if there is no other option.
3. All wiring is exactly as it was when calibration was read.

Navigate to page 4 and press the SET button to begin recalibration.

```
 Do you want to Read
 or Set calibration
 for a servo motor?
EXIT    READ    SET
```

```
Before refitting the
 Resolver, you MUST
 know the Cal value
         Ok
```

At this point you tell the SmartSolver the calibration value for this motor.

Set the 100's, press the middle button

Set the 10's, press the middle button

Set the 1's, press the middle button

The left button allows you to reset to 000 if you need to. A second press will escape back to the previous menu.

```
4
    Set hundreds
     Cal=300
    000  ->  +100
```

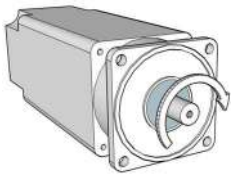
```
4
    Set tens
     Cal=330
    000  ->  +10
```

```
4
    Set ones
     Cal=330
    000  Ok  +1
```

As you turn the motor shaft clockwise it will stop at different pole positions.

If you feel the motor turn beyond the braking point, press RETRY to have another go at it. Perhaps more slowly.

When you are happy with the position, press the YES button.



```
Turn the MOTOR shaft
  CLOCKWISE gently
   until it stops
```

```
Did it stop sharply?
   (no overshoot)

RETRY     YES
```

Mount the resolver rotor on the motor shaft if it isn't already on.

Place the stator ring over the rotor and carefully rotate it until you find 0.0° on the display. Be very careful not to stress the wires to the stator.

Clamp the stator ring in place.

Press the Ok button to continue.

If the calibration is not exactly correct:

Loosen the stator clamp while in RECHECK mode.

Spin the shaft clockwise while rotating the stator until you get the desired calibration point.

Retighten the clamp screws when you are finished.

```
  Fit the resolver
    rotor to the
    motor shaft.
        Ok      108
```

```
Fit the stator ring.
  Turn it until the
   reading is 0.0
        Ok     11.7
```

```
Now do up the clamp
 and re-check your
   calibration.
        Ok
```

SPECIFICATIONS

Attribute	Conditions	Values	Units
INCREMENTAL INTERFACE			
Encoder Channels		6	
Device output types		CMOS / Push-pull Line Driver PNP NPN	
Minimum cycle time		35	µs
Encoder supply voltage outputs (Vo)		5 / 12 / 24	V_{DC}
Device supply current:	Vo = 5V Vo =12V Vo = 24V	600 400 125	mA
Incremental voltage limits at inputs:		-0.7 .. +24	V_{DC}
RESOLVER INTERFACE			
Exciter Frequency		10.0	kHz
Exciter Voltage (nominal)		2.4	V_{RMS}
HIPERFACE INTERFACE			
Single Turn Encoder operation			
Serial Transfer Rate		9600	Baud
SINCOS Functionality		Yes	
EnDat INTERFACE			
Single Turn Encoder operation			
EnDat versions		EnDat01 EnDat 2.1 EnDat 2.2	
Serial Transfer Rate		1.0	Mbaud
MOTOR CALIBRATION			
Measurement Resolution	2 Pole 3 Pole 4 Pole 5 Pole	± 0.50 ± 0.33 ± 0.25 ± 0.25	°
POWER SUPPLY REQUIREMENTS			
-Internal	Non-rechargeable	4 x AA	
-External	USB-C	10 (5V, 2A)	W
PHYSICAL PROPERTIES			
Weights	Base unit + batteries	430	grams
	Interface units	73	grams
Dimensions	Base unit	113w 137d 68h	mm
	Interface units	67w 80d 27h	mm

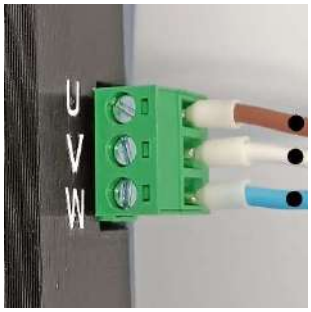
Job Ref:		Date:	
Customer:		Tested by:	

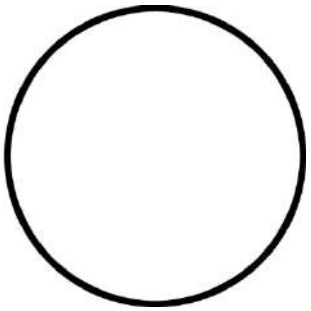
SMARTsolver Test Record Sheet

(Test / Motor Calibration details)

Motor model		Serial #:	
Encoder brand:		Encoder model	
Supply voltage:		Encoder type	Incremental / Resolver / EnDat / Hiperface
Cal Value	°P		

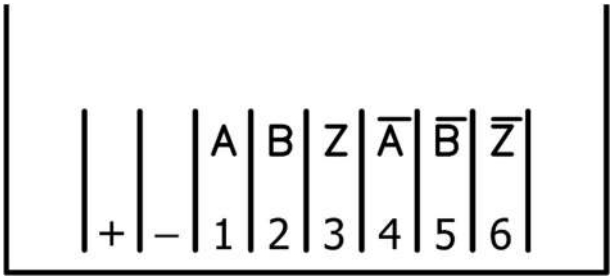
Windings:
Draw connections from U, V & W on the SMARTsolver to the pins on the connector.





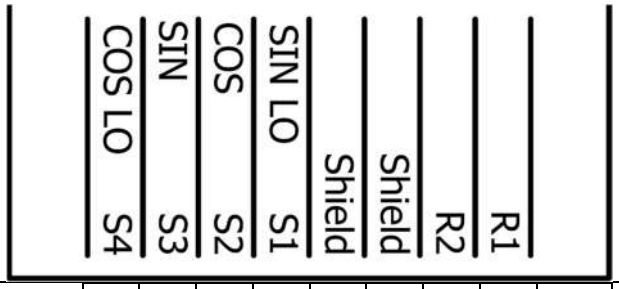
(Draw notches + pins)

Incremental Encoder



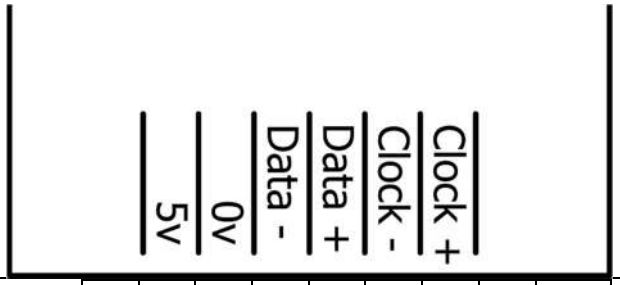
Colour									
Pin #									

Resolver



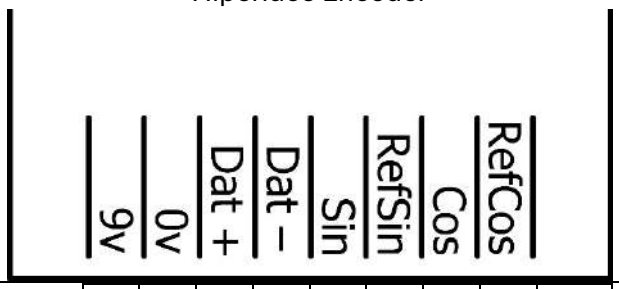
Colour									
Pin #									

EnDat Encoder



Colour									
Pin #									

Hiperface Encoder



Colour									
Pin #									

Notes: