



Precision in the Extreme



# IncOder™ Product Guide

## Inductive Angle Encoders

Revision 4.11 August 2015



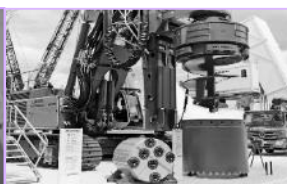
- ☒ No contacts
- ☒ No bearings
- ☒ No couplings
- ☒ No maintenance
- ☒ Absolute
- ☒ Compact
- ☒ Easy installation
- ☒ Accurate
- ☒ Robust
- ☒ Integral electronics
- ☒ >100 Million product options
- ☒ Economical
- ☒ Global support



.....they tick all the boxes.



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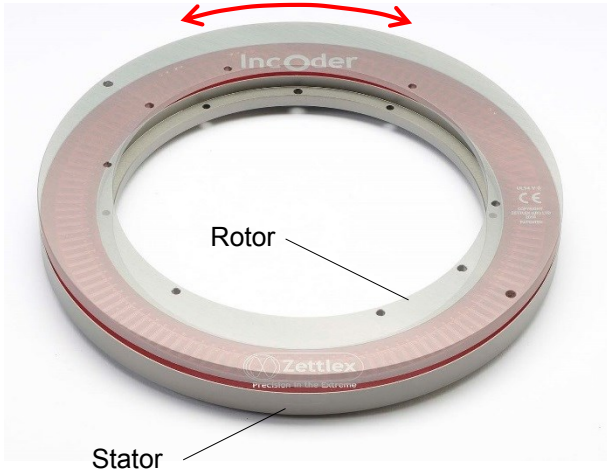
# 1. Introduction

Zettlex IncOders are non-contact devices for precision angle measurement. They use an inductive technique, similar to that used by electrical transformers. IncOders may be considered as an inductive encoder.

IncOders are well suited to harsh environments - where potentiometers, optical or capacitive devices may be unreliable.

IncOders have two main parts each shaped like a flat ring: a Stator and a Rotor. The Stator is powered and measures the angular position of the passive Rotor.

A big bore and low axial height allows easy integration with through-shafts, slip-rings, direct drive motors, optical-fibres, pipes or cables.



IncOder technology is proven technology – tried and tested in tough conditions on land, sea and in the air.

IncOders require no service or maintenance and may be considered as ‘fit and forget’ devices.

**They are designed and built so they won't let you down when the going gets tough.**

IncOders make it easy to achieve high precision, high reliability angle measurement.

There is no need to consider bearing alignment, seals or wearing parts.



Whereas optical or capacitive sensors can be unreliable in harsh conditions – notably with condensation or dust - IncOders are generally unaffected by foreign matter and IP68 rated versions are available.

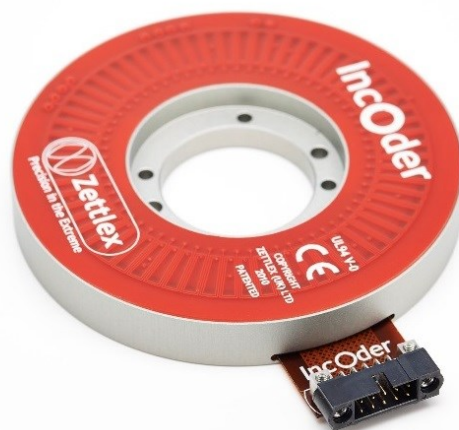
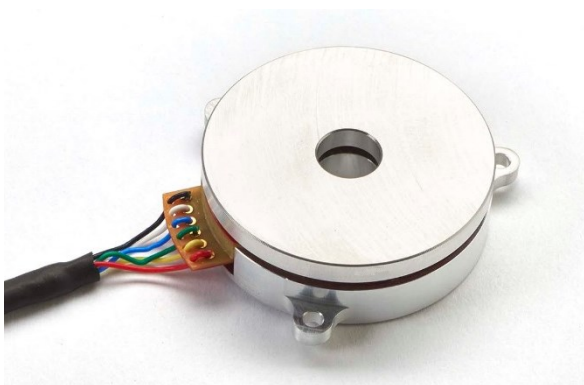
Unlike capacitive devices, there is no need to earth the Rotor or Stator.

Robust, hard-anodized aluminium alloy housings and monolithic constructions are used throughout.



The Stator contains all the electronics to receive power and output a signal. The output signal shows the position of the Rotor relative to the Stator.

Absolute and incremental outputs are available as standard options with various electrical outputs. The absolute devices are truly absolute which means that they need no motion at power up to determine position.



Compliant or special couplings are not required, so the Rotor & Stator can simply be screwed, dowelled, clamped or glued to the host product.

Precise mechanical mounting is not necessary to achieve high measurement performance and there are no bearings.

The measurement performance stated in this Product Guide is guaranteed provided that the IncOder is installed as per its installation tolerances.

IncOders have a solid track record in demanding applications such as heavy industrial machinery, airborne equipment and weapons systems. IncOders are designed and built in ISO-9001 accredited facilities in the United Kingdom; contain no ITAR restricted components and do not require an export licence unless they are >1000mm diameter.

Applications include :-

- Rotary joints & gimbals
- Actuator servos & motor encoders
- Electro-optical & infra-red camera systems
- Heliostats & solar equipment
- Robotic arms & CNC machine tools
- Test & calibration equipment
- Light & heavy calibre weapons systems
- Targeting systems & range finders
- Antenna pointing devices & telescopes
- Packaging & laboratory automation
- Medical scanners & surgical equipment
- Cranes & telescopic manipulators.



The IncOder range offers more than 100 million possibilities from the permutation of options. **The right product for your application can be specified using the IncOder Product Option / Part Number (see Section 8).** Each IncOder contains one Stator and one Rotor. Stators & Rotors are not matched pairs – in other words, either element may be swapped out for replacement, if necessary. The range of options are:-

**Mechanical Format** : mechanical formats include screw mount, servo clamp, external mount & duplex stators as well as plain, screw mount and set-screw rotors – see Section 5.

**IncOder Size** : stated as outer diameter: 37, 58, 75, 100, 125, 150, 175, 200, 225, 250 & 300mm – see Section 5.

**Resolution Options** : 10 to 22bits or any integer number of pulses - see Section 6.

### Communication Interface Options:

Synchronous Serial Interface – see Section 6.4 for various formats (Product Options SSI1-8)

Asynchronous Serial Interface – see Section 6.5 (Product Option ASI1)

Serial Peripheral Interface – see Section 6.6 (Product Option SPI1)

Digital + 1V sin/cos – see Section 6.7 (Product Options SSI1V-8V, ASI1V, SPI1V)

Analogue Voltage Interface – see Section 6.8 (Product Option V0360, W3601, X0270 etc.)

A/B/Z pulses – see Section 6.9 (Product Option ABZ1 etc.)

**Connection Options** : radial and axial connections as well as integral cables – see Section 5.12-13.

**Voltage Options** : 5, 12 or 24VDC.

**Extended Range Options** : these options are only intended for ultra high-reliability applications which may require extended thermal stress screening, bake-out, high shock/vibration constructions, use of conductive surface finishes, leaded solder or very low operating temperatures – see Section 5.14.

A range of Accessories is also available (see Section 9) including:

**Cables** : various shielded cables with connector.

**Servo Clamp** : to suit Servo Clamp Stators.

**Spacer Ring** : an aluminium ring to space Stators from host equipment and provide a protective cavity for the Rotor.

**Rotor Shaft Clamp** : a device for connecting Screw Mount Rotors to shafts.

**Shims** : plastic shims for loosely toleranced installations.





## 3. Customised Products

Zettlex often modify IncOders to specific OEM requirements. Potential changes include :-

- size (up to 570mm outer diameter)
- mechanical mounts and materials, including stainless steel
- voltage supplies
- electrical outputs
- measurement performance (up to 24 bit resolution per rev.)
- connectors, cables & immersion protection
- surface finish – black-anodized, natural, painted or Surtec650
- temperature range – notably to -100Celsius and below
- low weight or low inertia
- ATEX certified.

Consult Zettlex or your local representative for further information. Typically, customised products are an economical option in volumes of >50 units/year. Engineering/tooling charges may apply depending on order quantity. Some examples of customized products are shown below:-



End of shaft unit with black-anodized custom housing & military connector for fighting vehicles.



Custom housing with chromate surface finish & integral cable for remotely controlled gimbal.



Ultra lightweight unit for airborne application.



Electrically duplex lightweight encoder with collar clamp.



Large diameter unit for slip ring in off-road vehicles.



Duplex 'back to back' device with tangential shell connector.



## 4. Manufacturing & Quality

IncOders are designed, made, tested and shipped by Zettlex's facility in Cambridge, UK. Commercial and technical support is provided by the same site or through our global network of partners.



IncOder manufacturing processes are well established, having been perfected over years and the production of thousands of products. Every IncOder is serial numbered and tested according to a rigorous acceptance test procedure before dispatch. Detailed test records for every IncOder are stored by Zettlex.



Certificates of conformity are available as well as a RoHS compliance certificate and a REACH statement. IncOders are not ITAR restricted and use no ITAR components. A UK government export license is typically not required for the devices specified in this Product Guide.

All design, manufacturing and commercial processes operate under a comprehensive ISO-9001:2008 quality management system, developed by Zettlex engineers. The quality management system is subject to regular internal and external audit – including an annual audit by a UKAS accredited, independent authority. Zettlex is also certified for the design and manufacture of intrinsically safe (ATEX) sensors under BS EN 13980.

A copy of our ISO-9001 and ATEX certificate is available on [www.zettlex.com](http://www.zettlex.com).

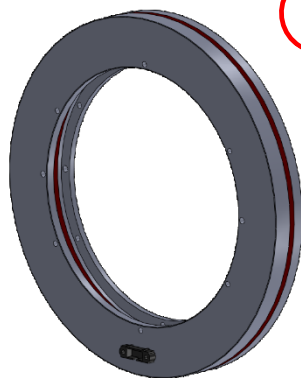




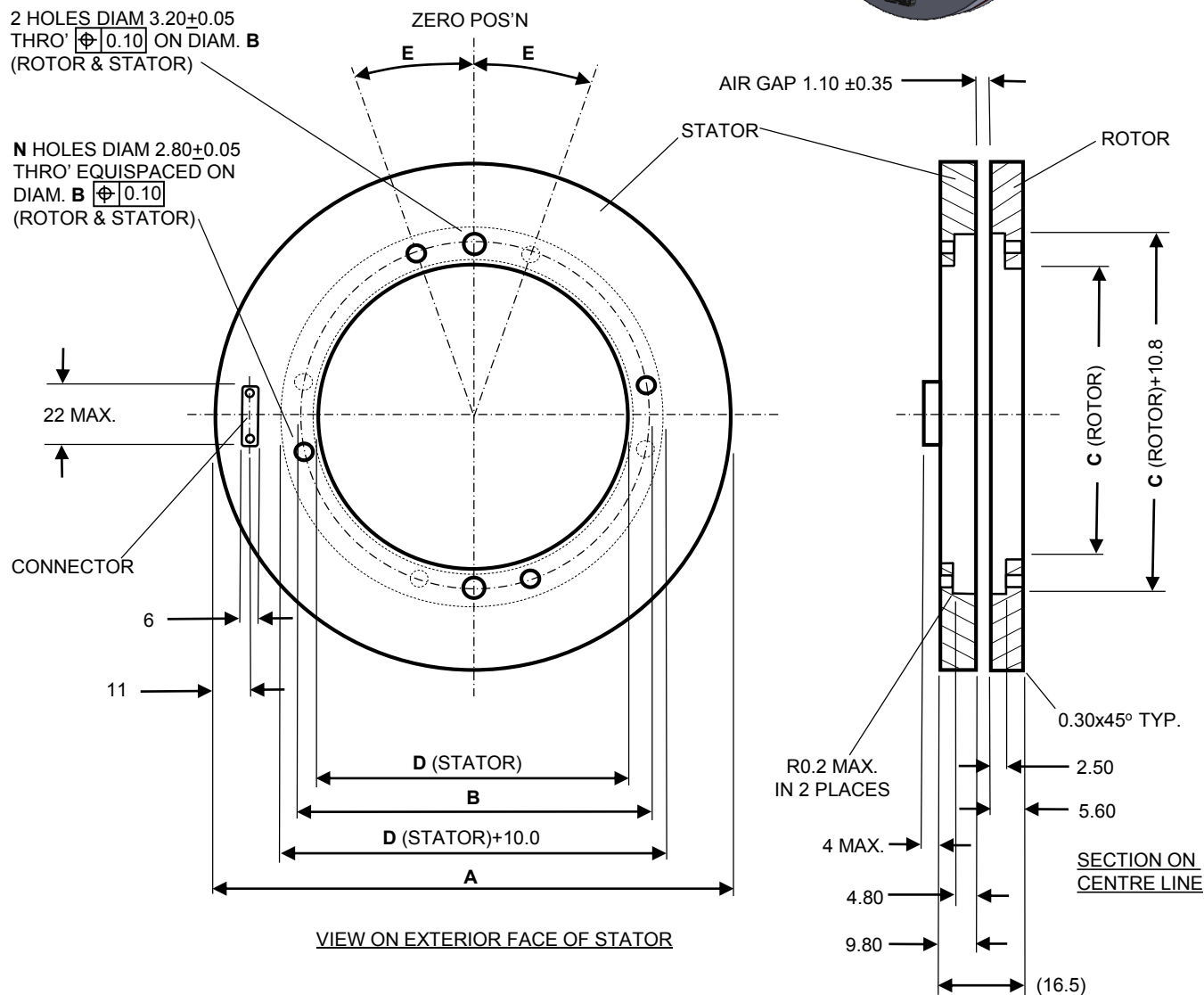
# 5.1 $\geq 75\text{mm}$ Screw Mount Stator & Screw Mount Rotor Format - Product Option INC-3

## NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEX.COM](http://WWW.ZETTLEX.COM)
2. UNIT SHOWN WITH AXIAL CONNECTOR (AC1)
3. ALL DIMS IN mm – DO NOT SCALE
4. 3<sup>RD</sup> ANGLE PROJECTION
5. TOLERANCES:- 0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



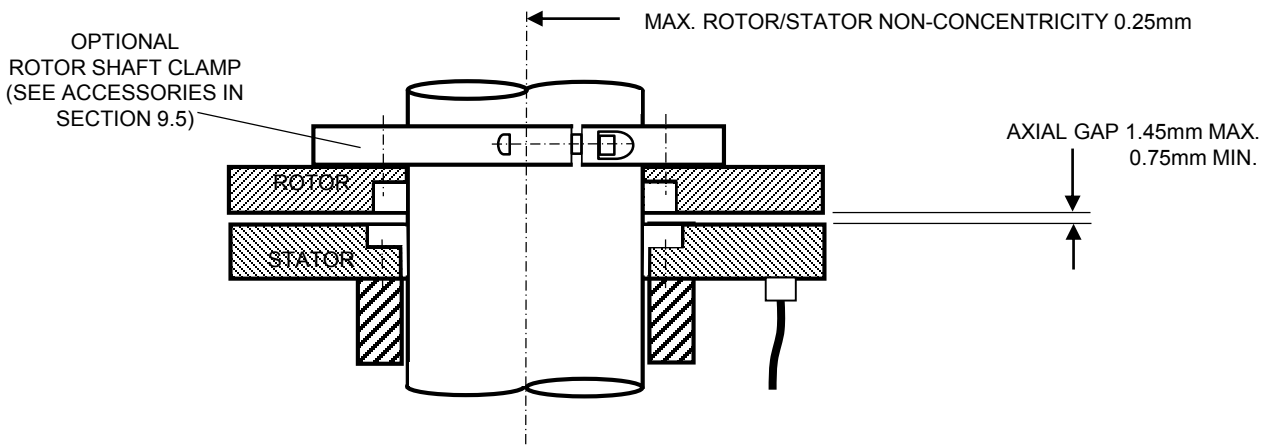
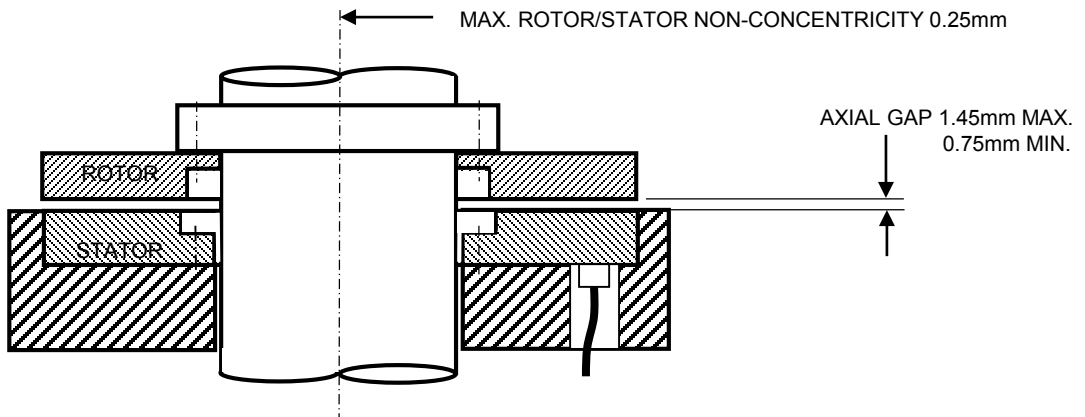
Most popular  
format



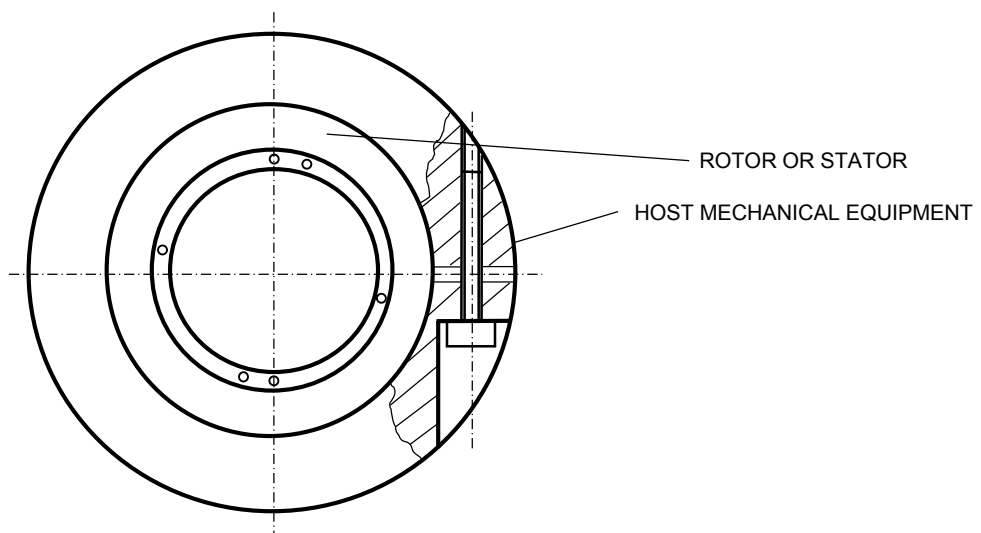
	INC-3-75	INC-3-100	INC-3-125	INC-3-150	INC-3-175	INC-3-200	INC-3-225	INC-3-250	INC-3-300	
Dim. A - Stator / Rotor Body O.D.	75.00	100.00	125.00	150.00	175.00	200.00	225.00	250.00	300.00	mm
Dim. B - Pitch Circle Diameter	30.50	55.50	80.50	105.50	130.50	155.50	180.50	205.50	255.50	mm
Dim. C - Rotor I.D.	25.00	50.00	75.00	100.00	125.00	150.00	175.00	200.00	250.00	mm
Dim. D - Stator I.D.	25.80	50.80	75.80	100.80	125.80	150.80	175.80	200.80	250.80	mm
Dim E - Offset Angle from T.D.C.	30	30	30	30	30	30	30	20	20	degrees
N Number of screw clearance holes	4	4	4	6	6	6	6	8	8	
Max. radial misalignment	0.25									mm
Rotor & stator fixings	Steel screws cap head M2.5 & steel dowels M3									

## 5.1 $\geq 75\text{mm}$ Screw Mount Stator & Screw Mount Rotor Format - Product Option INC-3

Screw Mount Format IncOders can be installed in various ways and the following sketches show a few examples. Provided the axial gap and concentricity tolerances are maintained, then the stated measurement performance will be met.



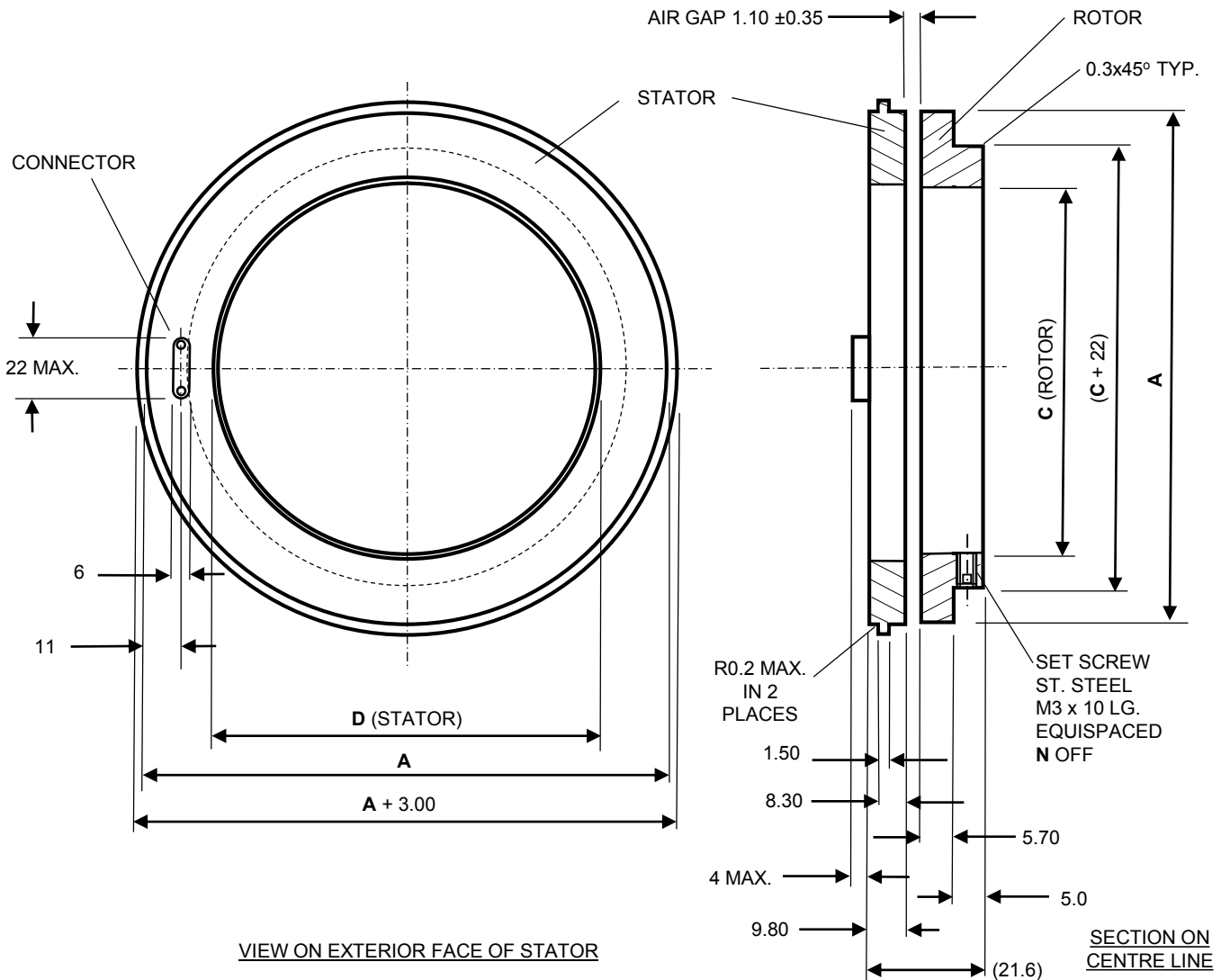
All formats of IncOder can be installed using a circumferential clamp in the host equipment. This applies to Rotor or Stator. Preferably the C-ring's gap is closed by at least one screw.



# 5.2 $\geq 75$ mm Servo Clamp Stator & Set Screw Rotor Format - Product Option INC-4

## NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. UNIT SHOWN WITH AXIAL CONNECTOR AC1
3. SEE SECTION 9.3. FOR CORRESPONDING SERVO CLAMPS
4. ALL DIMS IN mm – DO NOT SCALE
5. 3<sup>RD</sup> ANGLE PROJECTION
6. TOLERANCES:- 0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$

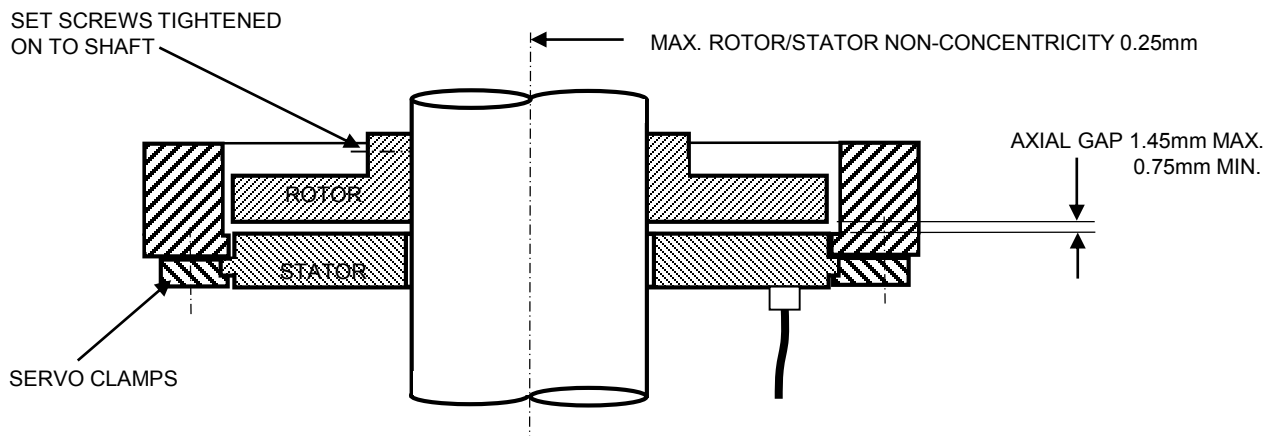
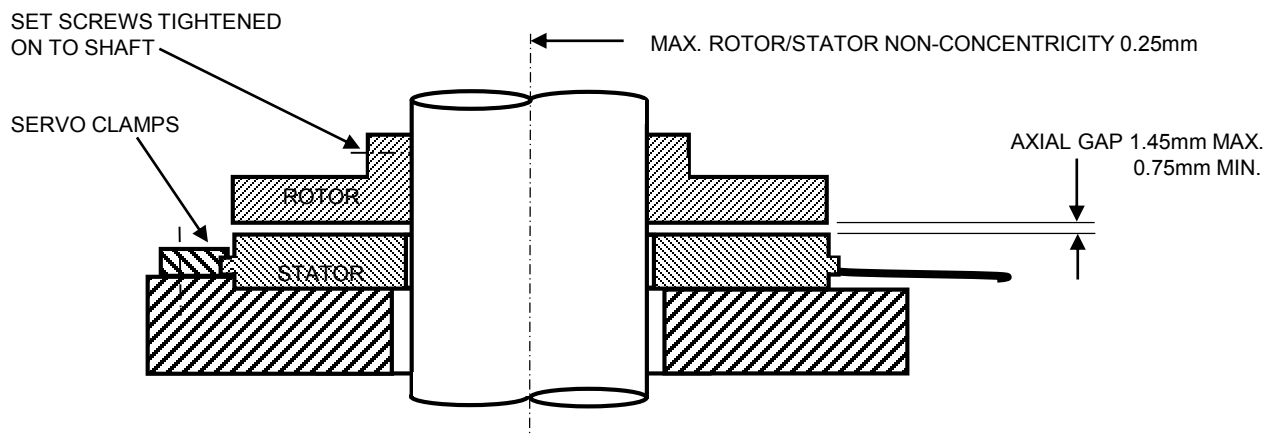
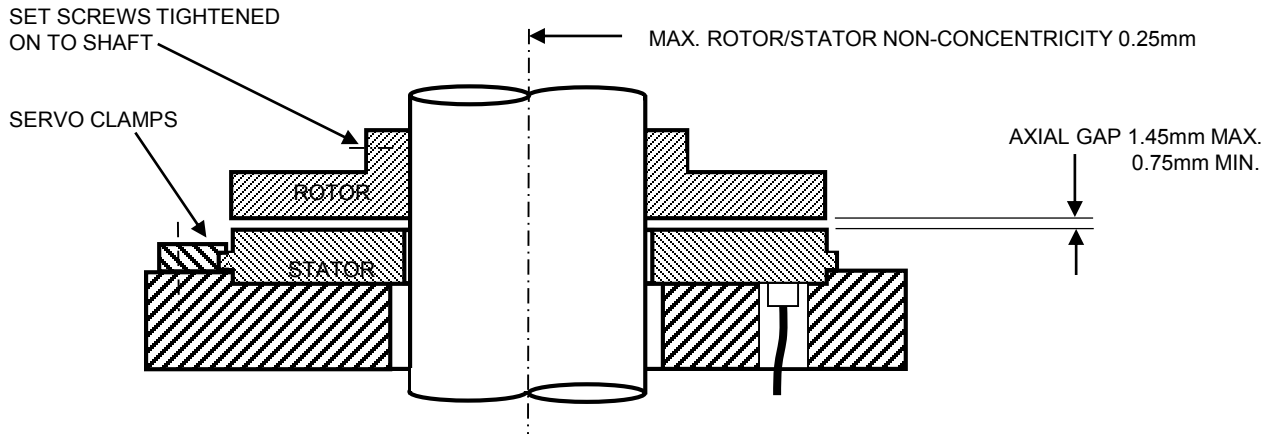


	INC-4-75	INC-4-100	INC-4-125	INC-4-150	INC-4-175	INC-4-200	INC-4-225	INC-4-250	INC-4-300	
Dim. A - Stator / Rotor Body O.D.	75.00	100.00	125.00	150.00	175.00	200.00	225.00	250.00	300.00	mm
Dim. C. - Rotor I.D.	35.00	60.00	85.00	110.00	135.00	160.00	185.00	210.00	260.00	mm
Dim. D. - Stator I.D.	35.80	60.80	85.80	110.80	135.80	160.80	185.80	210.80	260.80	mm
N Number of Set Screws	3	3	3	3	4	4	6	6	8	
Max. radial misalignment	0.25									mm
Rotor & stator fixings	Rotor by Set Screws St. Steel (supplied). Stator by Servo Clamps (see Accessories) or host equipment									



## 5.2 $\geq 75\text{mm}$ Servo Clamp Stator & Set Screw Rotor Format - Product Option INC-4

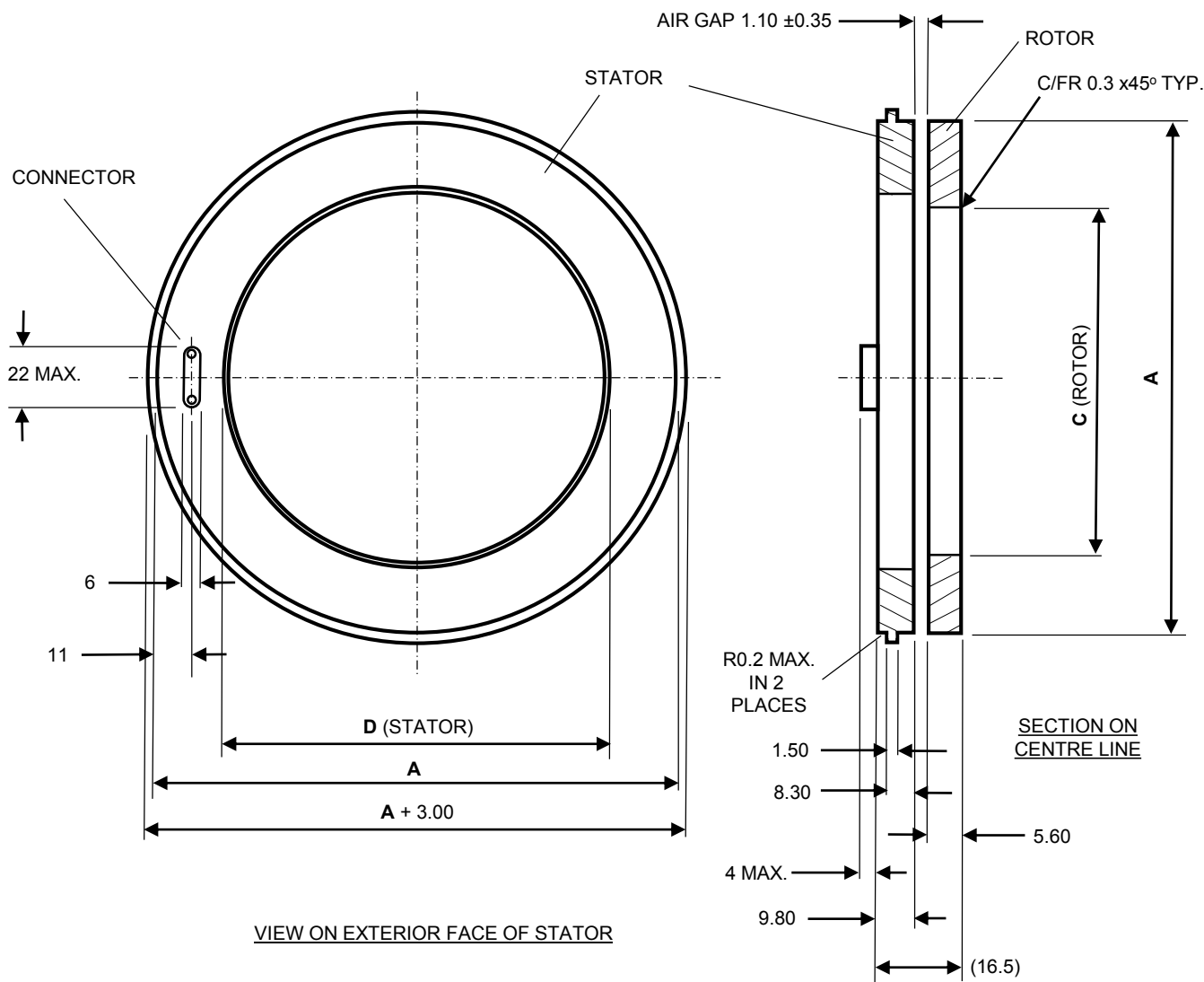
Servo Mount Format IncOders can be installed in various ways and the following sketches show a few examples. Provided the axial gap and concentricity tolerances are maintained, then the stated measurement performance will be met.



## 5.3 $\geq 75$ mm Servo Clamp Stator & Plain Rotor Format - Product Option INC-6

### NOTES

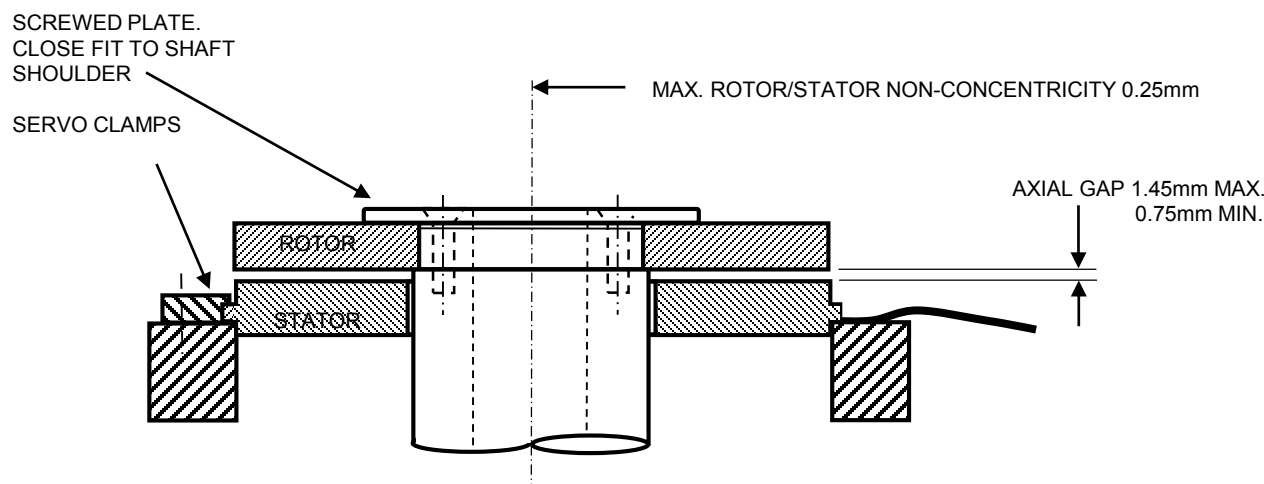
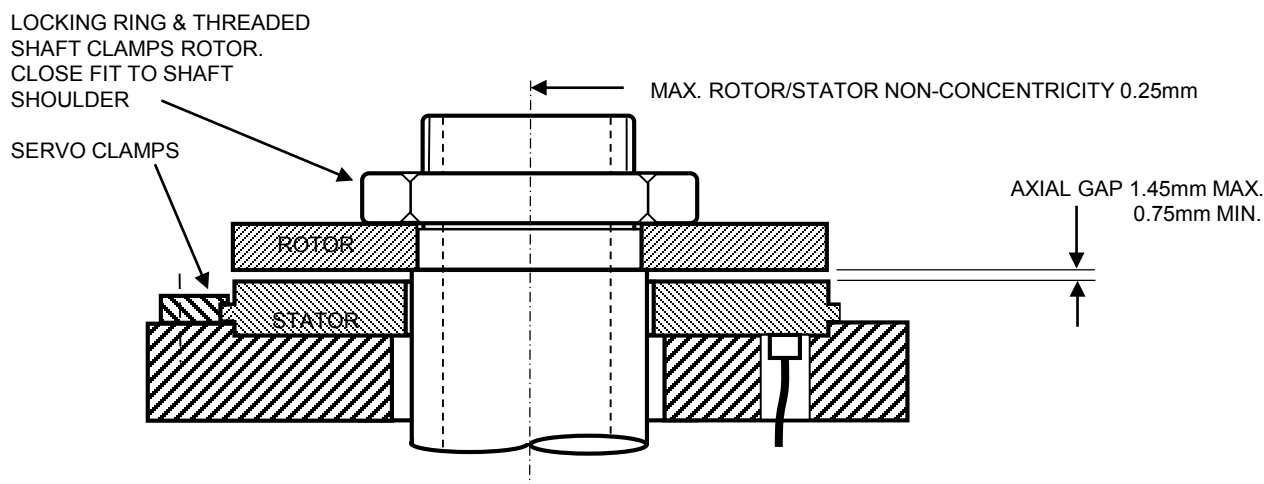
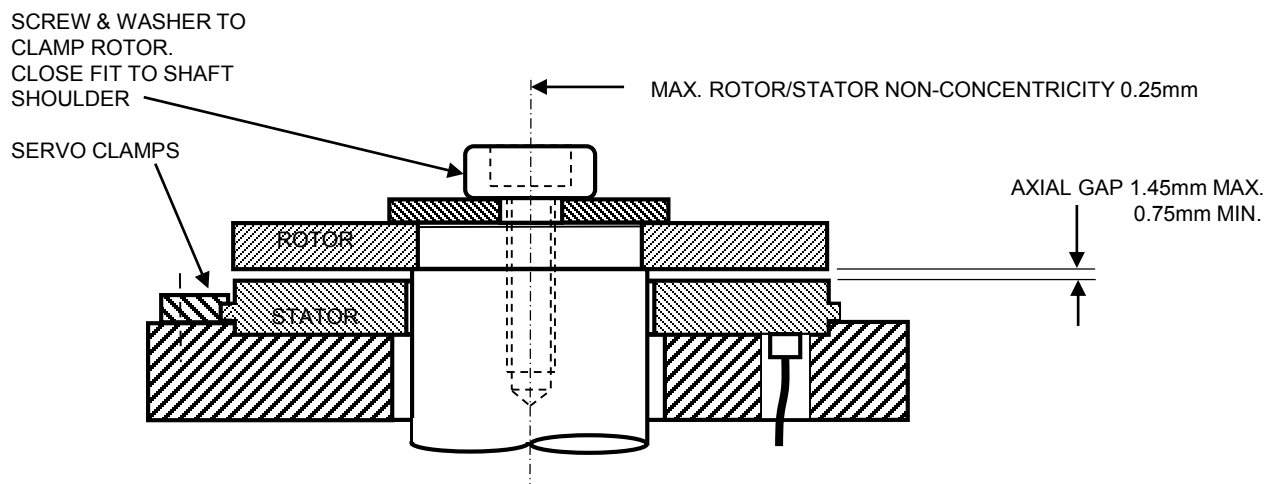
1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. SEE SECTION 9.3 FOR CORRESPONDING SERVO CLAMPS
3. UNIT SHOWN WITH AXIAL CONNECTOR AC1
4. ALL DIMS IN mm – DO NOT SCALE
5. 3<sup>RD</sup> ANGLE PROJECTION
6. TOLERANCES:- 0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



	INC-6-75	INC-6-100	INC-6-125	INC-6-150	INC-6-175	INC-6-200	INC-6-225	INC-6-250	INC-6-300	
Dim. A - Stator / Rotor Body O.D.	75.00	100.00	125.00	150.00	175.00	200.00	225.00	250.00	300.00	mm
Dim. C. - Rotor I.D.	30.00	55.00	80.00	105.00	130.00	155.00	180.00	205.00	255.00	mm
Dim. D. - Stator I.D.	35.80	60.80	85.80	110.80	135.80	160.80	185.80	210.80	260.80	mm
Max. radial misalignment	0.25									mm
Rotor & stator fixings	Rotor by host equipment and Stator by Servo Clamps (ordered separately - see Accessories) or host equipment									

## 5.3 $\geq 75\text{mm}$ Servo Clamp Stator & Plain Rotor Format - Product Option INC-6

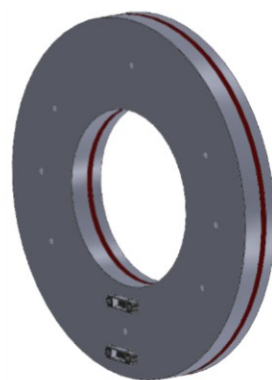
IncOders with Servo Clamp Stators & Plain Rotors can be installed in various ways and some examples are shown below. Provided the axial gap and concentricity tolerances are maintained, then the stated measurement performance will be met.



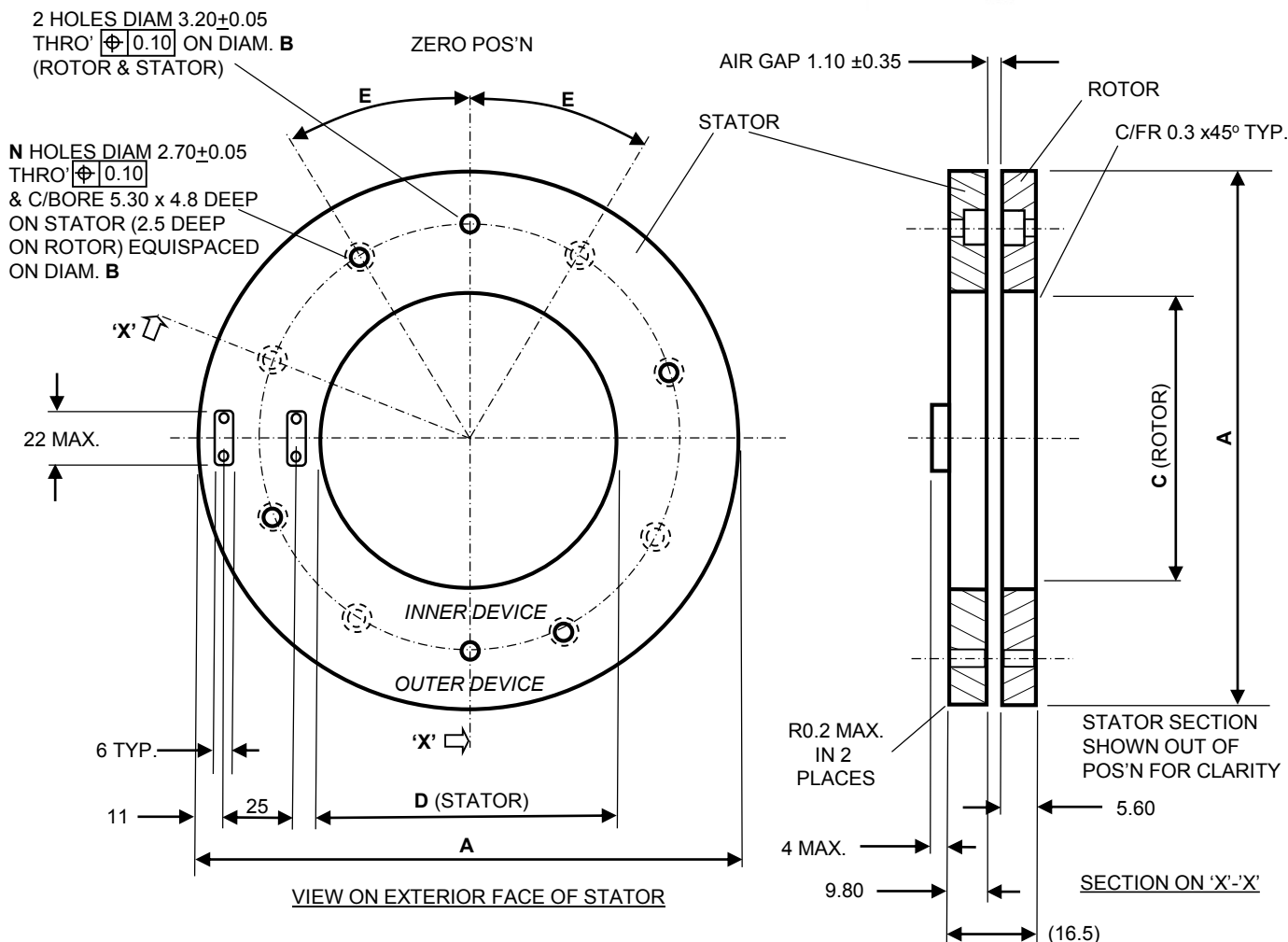


## NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. UNIT SHOWN WITH AXIAL CONNECTOR AC1
3. ALL DIMS IN mm – DO NOT SCALE
4. 3<sup>RD</sup> ANGLE PROJECTION
5. TOLERANCES:- 0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



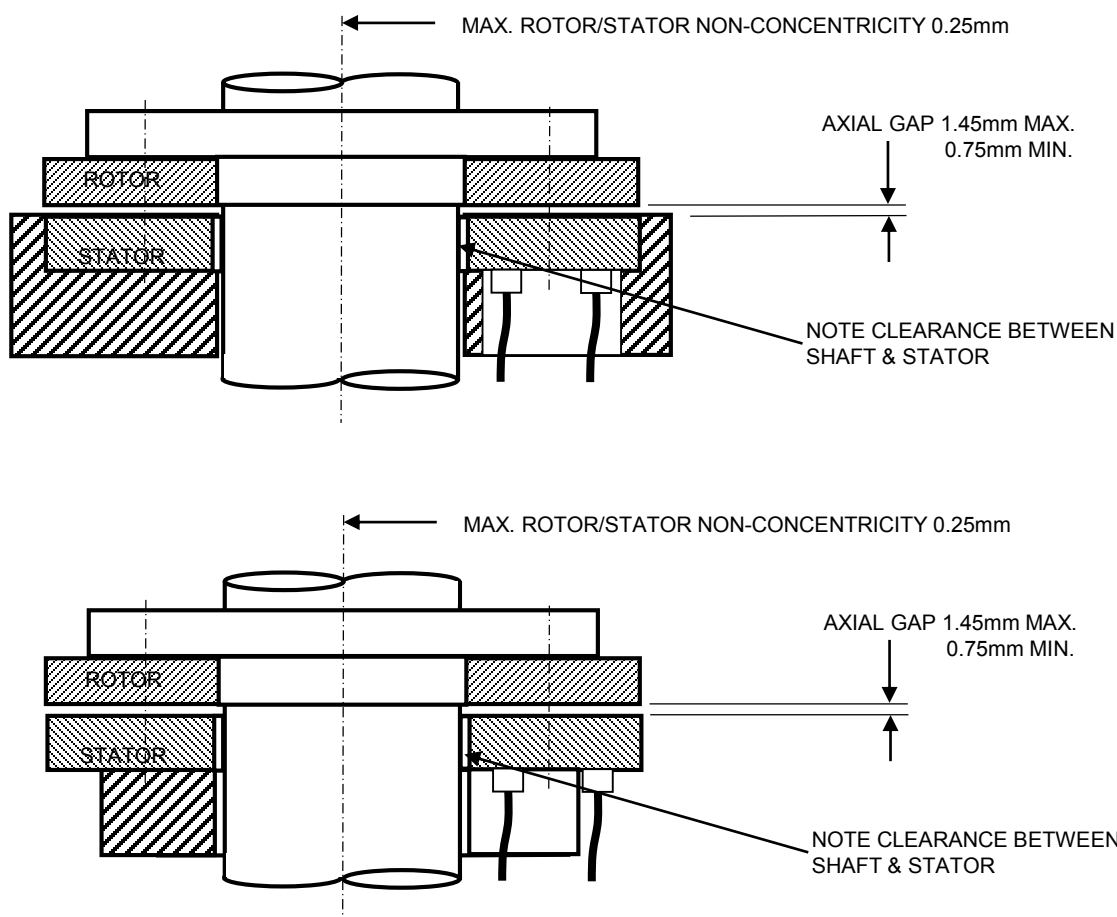
Electrically  
Duplex



Duplex IncOders are electrically redundant:- 2 electrically independent IncOders in 1 package – the first on the outer annulus, the second on the inner. The range starts at an O.D. of 125mm with axial connections (AC1) or integral flying leads (AFL1-5). Note - measurement performance is quoted for the outer annulus device.

	INC-10-75	INC-10-100	INC-10-125	INC-10-150	INC-10-175	INC-10-200	INC-10-225	INC-10-250	INC-10-300	
Dim. A - Stator / Rotor Body O.D.	n/a	n/a	125.00	150.00	175.00	200.00	225.00	250.00	300.00	mm
Dim. B - Pitch Circle Diameter	n/a	n/a	80.50	105.50	130.50	155.50	180.50	205.50	255.50	mm
Dim. C - Rotor I.D.	n/a	n/a	35.80	60.80	85.80	110.80	135.80	160.80	210.80	mm
Dim. D - Stator I.D.	n/a	n/a	35.80	60.80	85.80	110.80	135.80	160.80	210.80	mm
Dim E - Offset Angle from T.D.C.	n/a	n/a	30	30	30	30	30	20	20	degrees
N Number of screw clearance holes	n/a	n/a	4	6	6	6	6	8	8	
Max. radial misalignment	n/a	n/a	0.25							mm
Rotor & stator fixings	n/a	n/a	Steel screws cap head M2.5 & steel dowels M3							

Duplex IncOders can be installed in various ways and some examples are shown below. Provided the axial gap and concentricity tolerances are maintained, then the stated measurement performance will be met.



### 5.4.1 Part Numbering for Duplex IncOders

The default for Duplex (INC-10 format) IncOders is that the inner & outer devices have identical electrical interfaces.

A Duplex IncOder may be specified with differing electrical interfaces for the inner and outer devices. This is a requirement in some applications such as:

- an absolute encoder for a gearbox output shaft and a pulse encoder for the motor driven input shaft
- safety requirements for two different sensing technologies to avoid common failure modes.

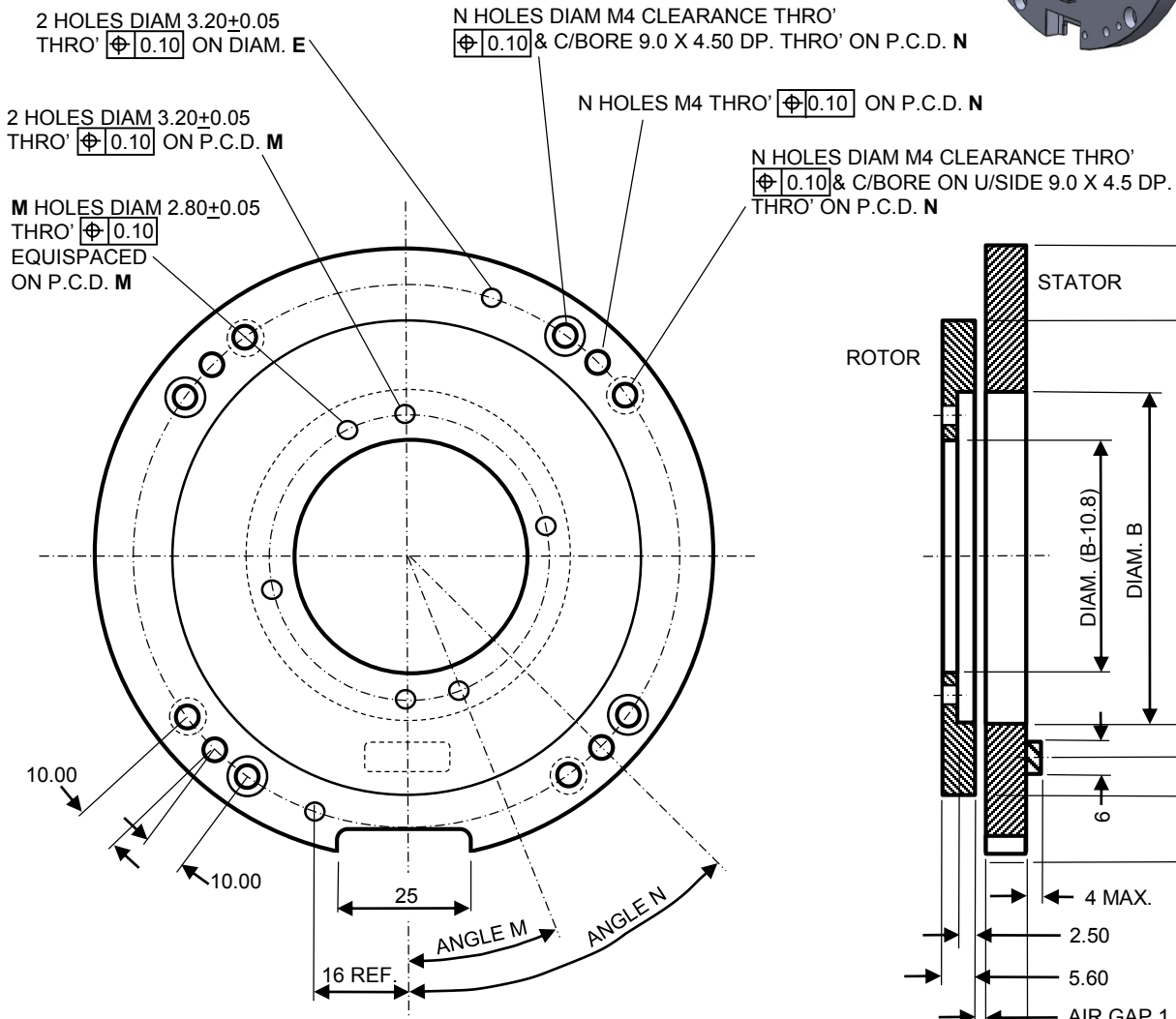
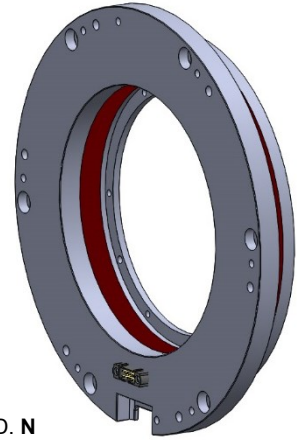
If differing electrical interfaces are required, please specify the outer device using the standard Product Options as per Section 8 and add a note on electrical aspects (only) for the inner e.g., INC-10-250-140101-SSI1-AC1-12-AN OUTER with 140101-SSI3-AC1-24 INNER.

Note that the performance of the outer device will be as stated for any IncOder of the same (outer diameter) size and the performance of the inner device will be as stated as for a proportionately smaller device (outer diameter – 50mm).

# 5.5 $\geq$ 75mm External Mount Stator & Screw Mount Rotor - Product Option INC-13

## NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. VIEW SHOWN WITH AXIAL CONNECTOR (AC1)
5. UNLESS STATED, TOLERANCES:-  
0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$

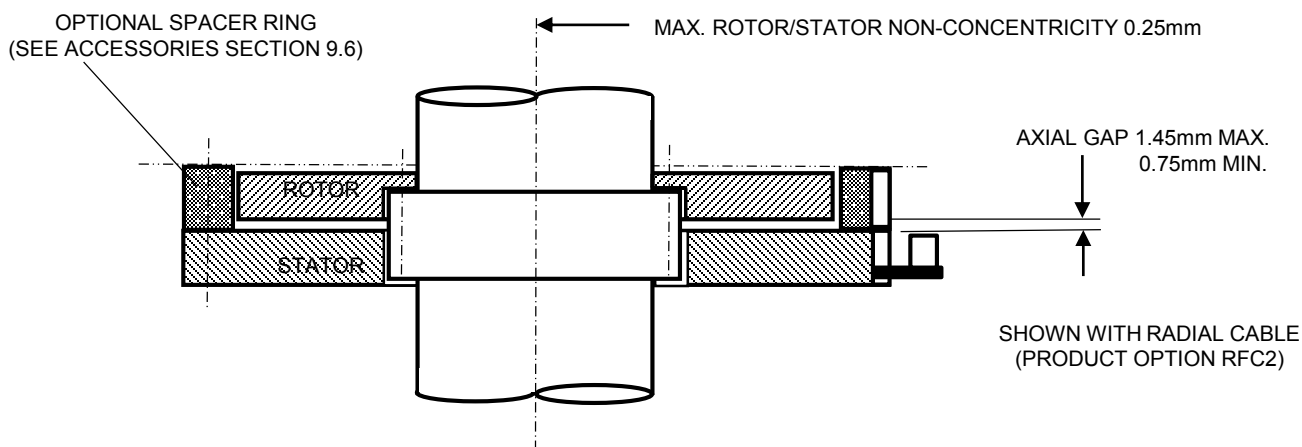
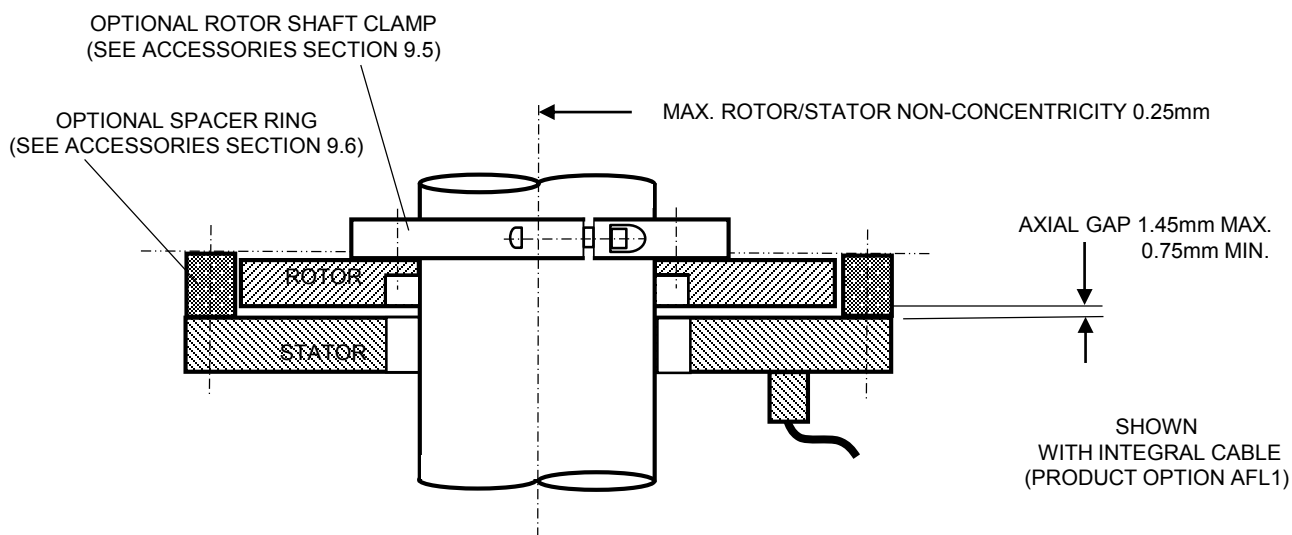
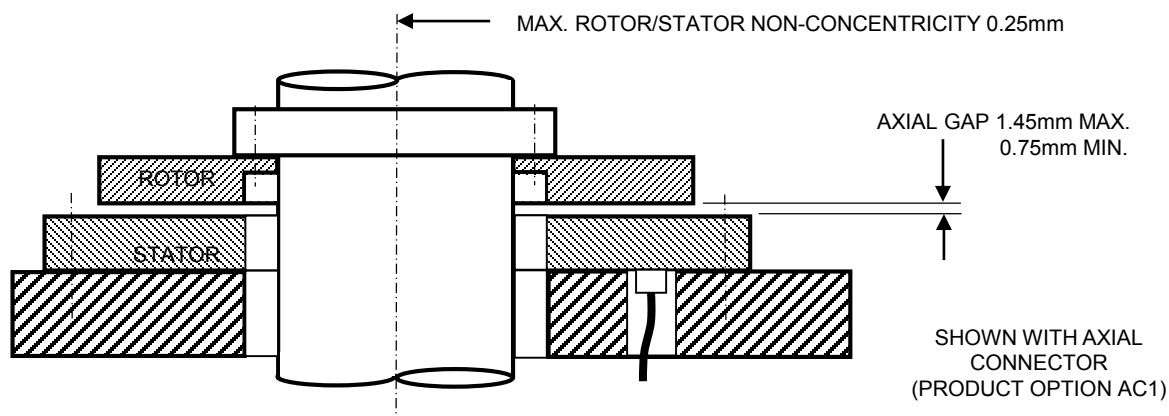


	INC-13-75	INC-13-100	INC-13-125	INC-13-150	INC-13-175	INC-13-200	INC-13-225	INC-13-250	INC-13-300	
Dim. A - Stator O.D.	100.00	125.00	150.00	175.00	200.00	225.00	250.00	275.00	325.00	mm
Dim. B - Stator I.D. & Rotor Shoulder	35.80	60.80	85.80	110.80	135.80	160.80	185.80	210.80	260.80	mm
Dim. F - Rotor O.D.	75.00	100.00	125.00	150.00	175.00	200.00	225.00	250.00	300.00	mm
Angle N - Stator Offset Angle	45.0	45.0	45.0	30.0	30.0	30.0	30.0	22.5	22.5	degrees
N - Hole (sets) on Stator	4	4	4	6	6	6	6	8	8	
Dim. N. - Stator P.C.D.	87.50	112.50	137.50	162.50	187.50	212.50	237.50	262.50	312.50	mm
Angle M - Rotor Offset Angle	30.00	30.00	30.00	30.00	30.00	30.00	30.00	20.00	20.00	degrees
M Repeats	4	4	4	6	6	6	6	8	8	
Dim. M - Rotor P.C.D.	30.5	55.5	80.5	105.5	130.5	155.5	180.5	205.5	255.5	mm



## 5.5 $\geq 75\text{mm}$ External Mount Stator & Screw Mount Rotor - Product Option INC-13

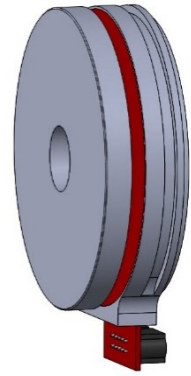
External Mount Format IncOders can be installed in various ways and the following sketches show a few examples. Provided the axial gap and concentricity tolerances are maintained, then the stated measurement performance will be met.



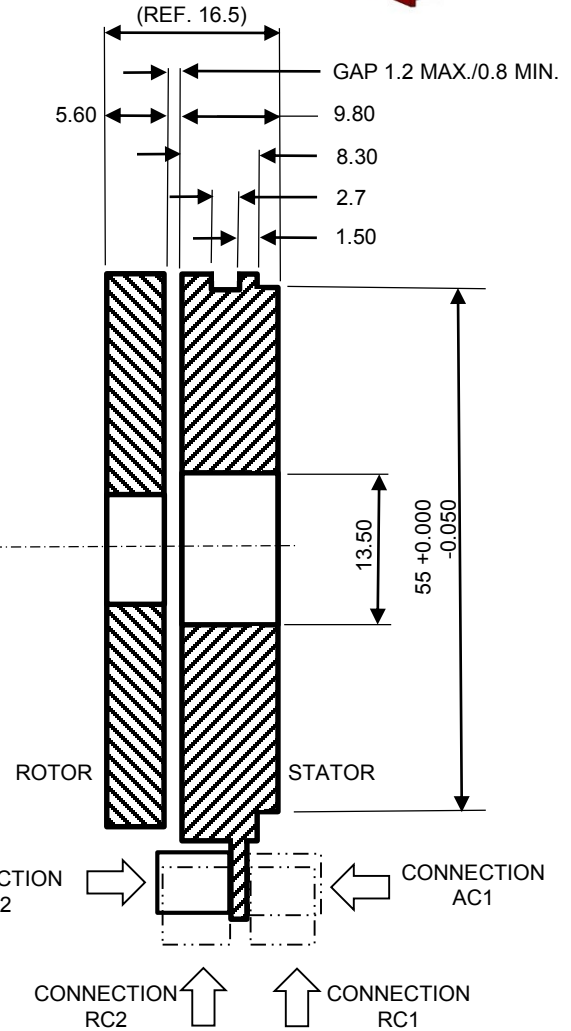
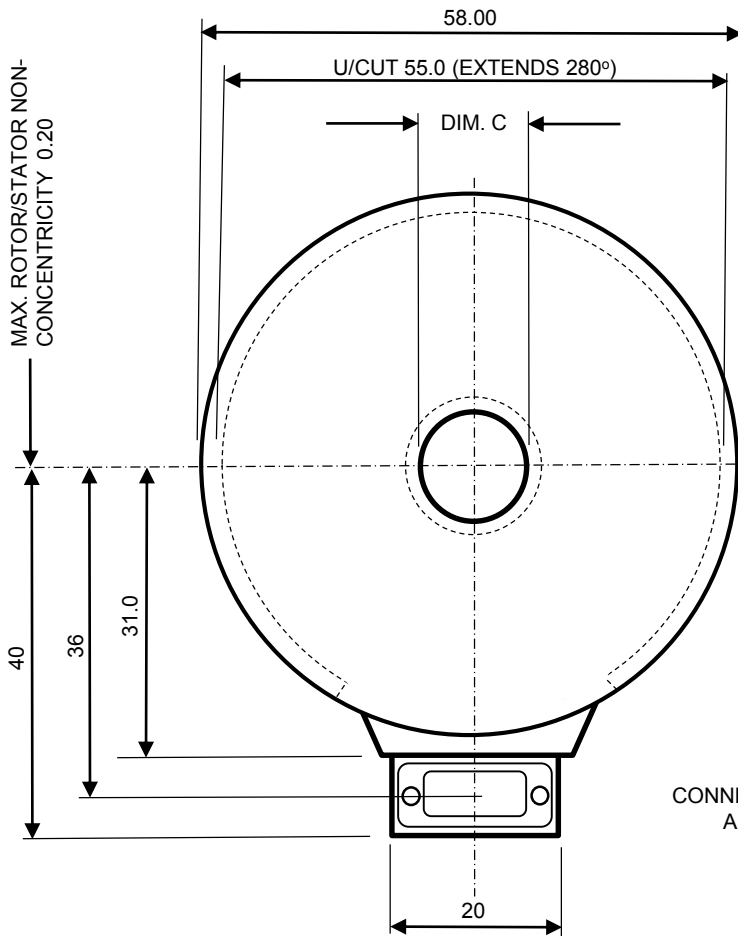
# 5.6 58mm Servo Clamp Stator & Plain Rotor - Product Option INC-6

## NOTES

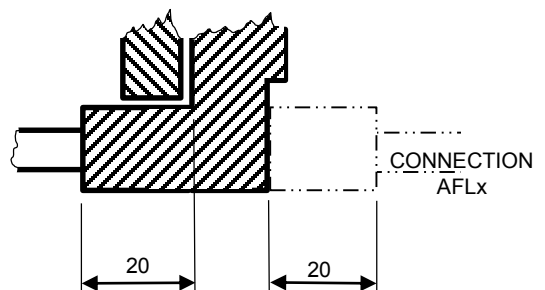
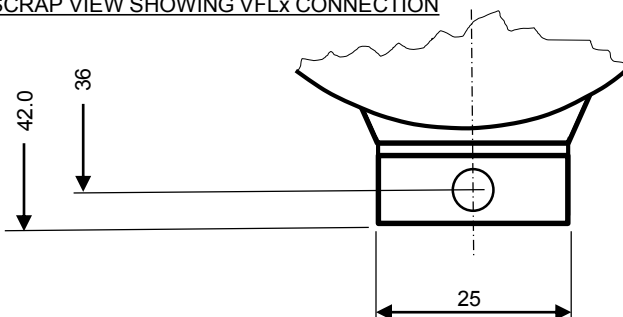
1. **3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)**
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. AL. ALLOY HOUSINGS SURTEC650 SURFACE PROTECTION 0.11-0.50g/m<sup>2</sup>
5. UNLESS STATED, TOLERANCES:-  
0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



PLAN VIEW SHOWING AC2 CONNECTION



SCRAP VIEW SHOWING VFLx CONNECTION



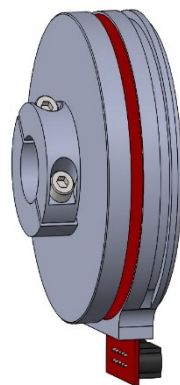
OPTIONS FOR DIM C = 6.00, 10.00, 12.00 & 12.70 ALL WITH H7 TOLERANCE.

OPTIONS FOR CONNECTOR = AC1, AC2, RC1, RC2, AFL1 TO 5, VFL1 TO 5 - SEE SECTION 8 ON HOW TO SELECT BY PART NUMBER.

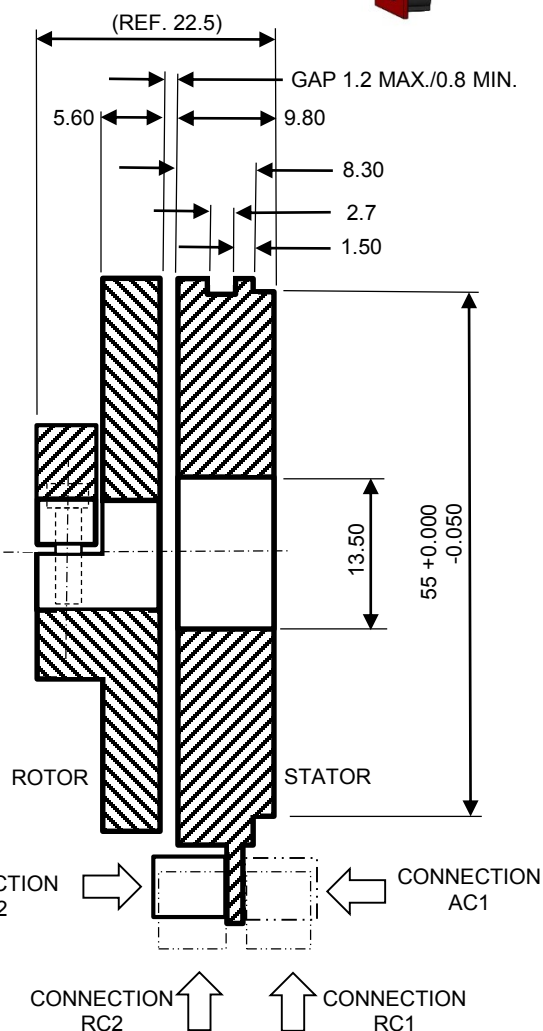
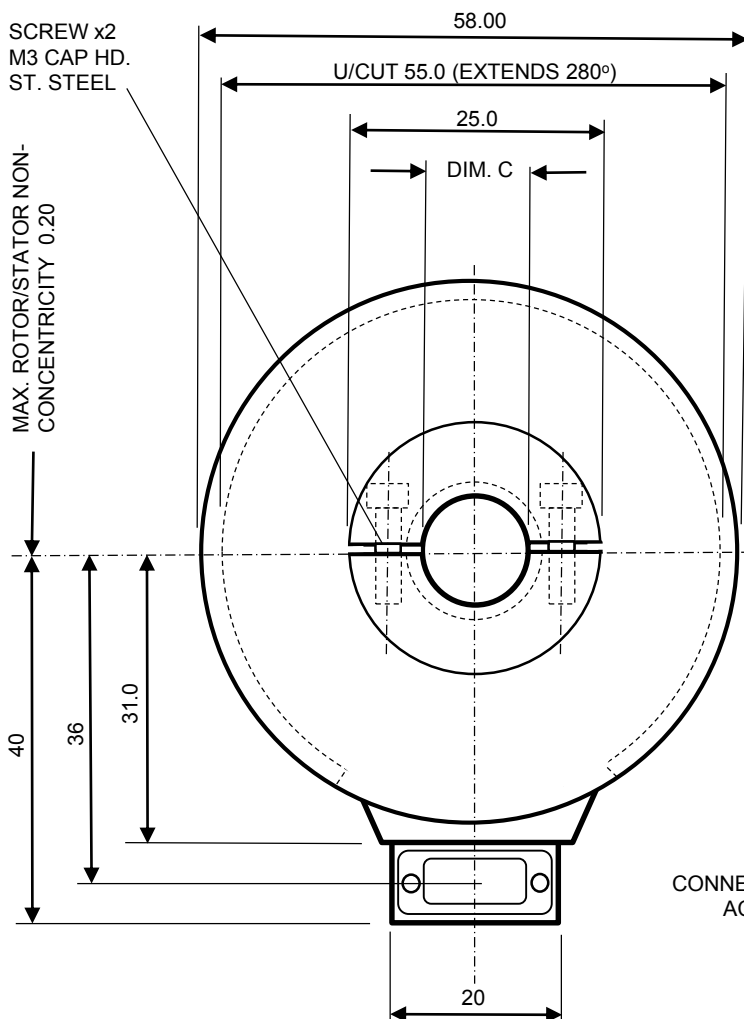
# 5.7 58mm Servo Clamp Stator & Shaft Clamp Rotor - Product Option INC-11

## NOTES

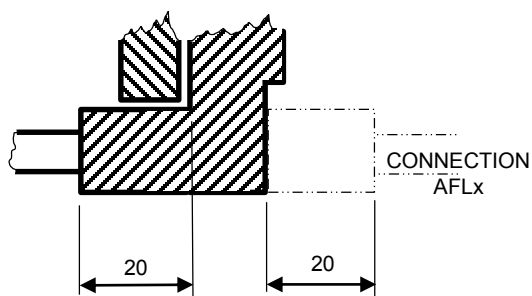
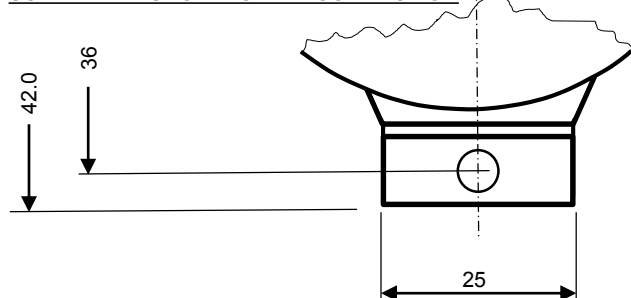
1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. AL. ALLOY HOUSINGS SURTEC650 SURFACE PROTECTION 0.11-0.50g/m<sup>2</sup>
5. UNLESS STATED, TOLERANCES:-  
0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



PLAN VIEW SHOWING AC2 CONNECTION



SCRAP VIEW SHOWING VFLx CONNECTION



OPTIONS FOR DIM C = 6.00, 10.00, 12.00 & 12.70 ALL WITH H7 TOLERANCE.

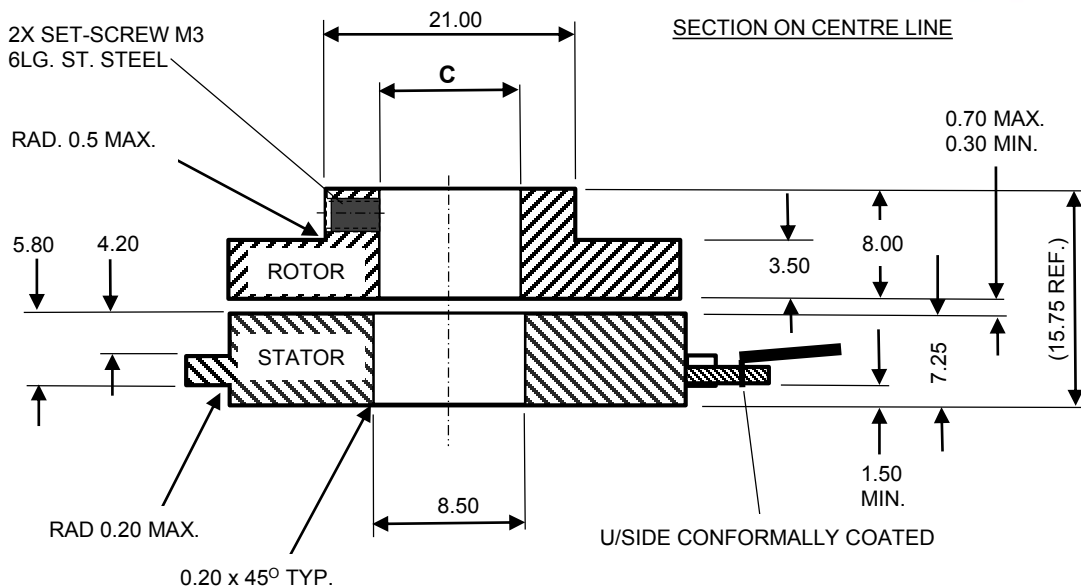
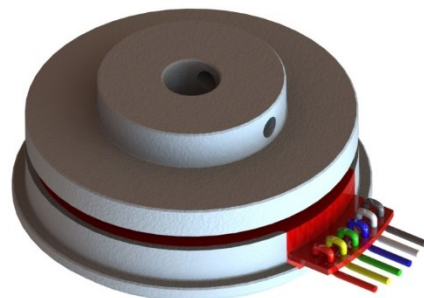
OPTIONS FOR CONNECTOR = AC1, AC2, RC1, RC2, AFL1 TO 5, VFL1 TO 5 - SEE SECTION 8 ON HOW TO SELECT BY PART NUMBER.



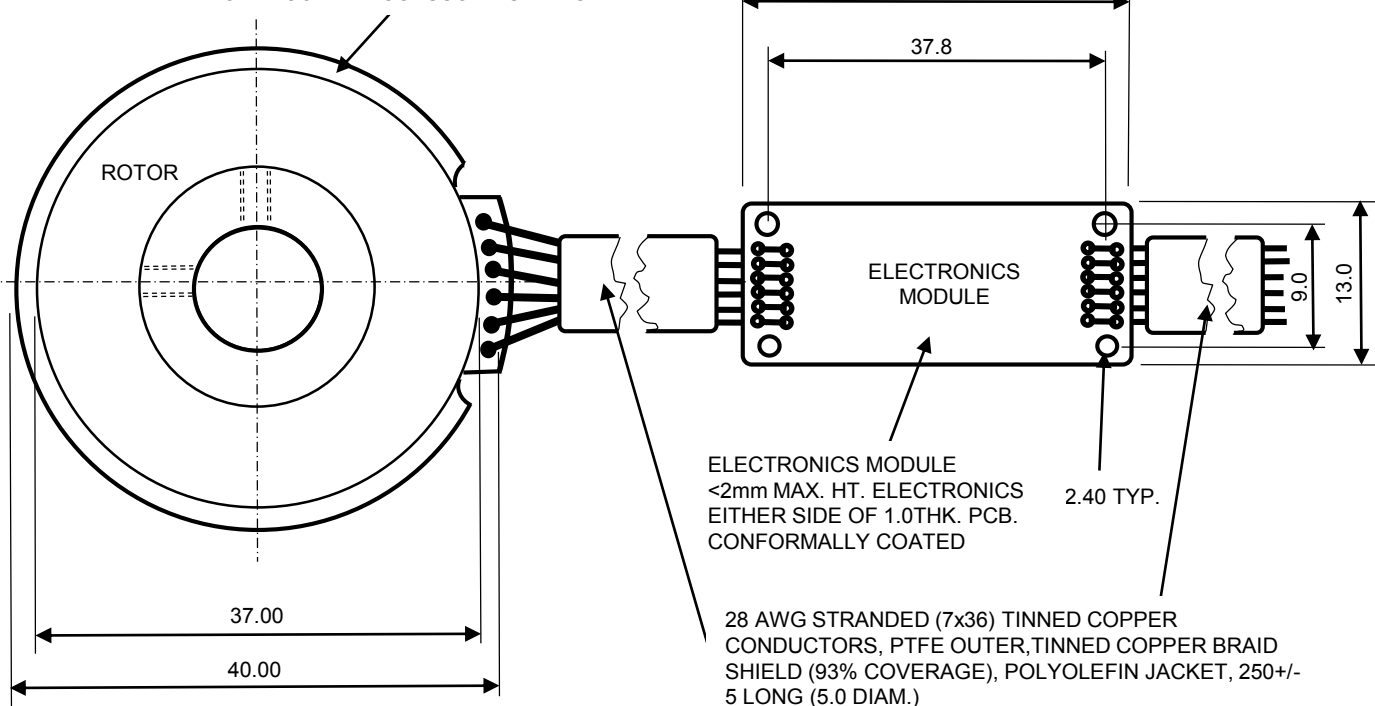
# 5.8 37mm Servo Clamp Stator & Set Screw Rotor - Product Option INC-4

## NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. AL. ALLOY HOUSINGS SURTEC650 SURFACE PROTECTION 0.11-0.50g/m<sup>2</sup>
5. UNLESS STATED, TOLERANCES:-  
0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



SUITABLE FOR SERVO CLAMP INC-CLAMP1  
FROM INCODER ACCESSORIES RANGE

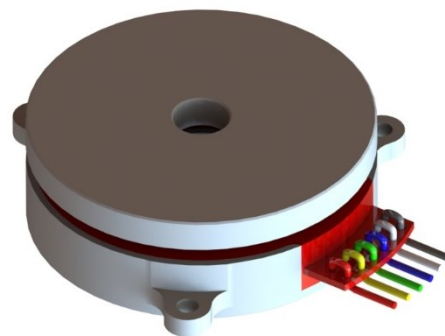


OPTIONS FOR DIM C = 5.00; 6.00; 6.35 AND 8.00 ALL WITH H7 TOLERANCE - SEE SECTION 8 ON HOW TO SELECT BY PART NUMBER.

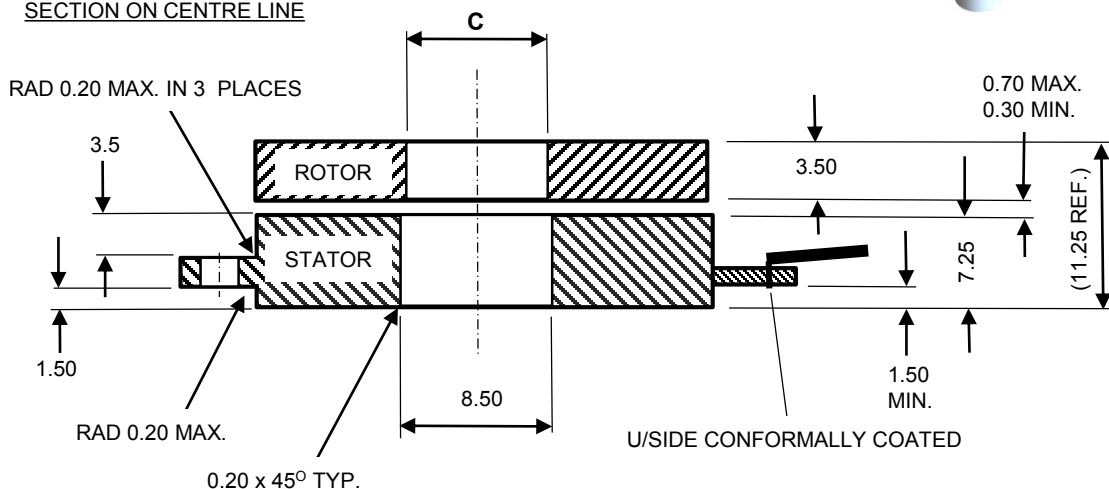
# 5.9 37mm Screw Mount Stator & Plain Rotor - Product Option INC-8

## NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLEx.COM](http://WWW.ZETTLEx.COM)
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. UNLESS STATED, TOLERANCES:-  
 0 DECIMAL PLACES =  $\pm 0.5$   
 1 DECIMAL PLACES =  $\pm 0.2$   
 2 DECIMAL PLACES =  $\pm 0.1$



## SECTION ON CENTRE LINE



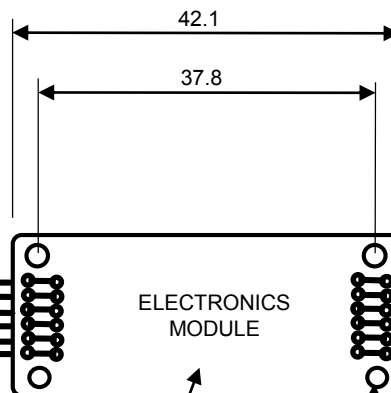
3 HOLES 2.40 THRO'  $\pm 0.10$   
ON 42.00 P.C.D.

RAD 3 TYP.

FULL RAD 2.5 TYP.

ROTOR

37.00



ELECTRONICS MODULE  
 <2mm MAX. HT. ELECTRONICS  
 EITHER SIDE OF 1.0THK. PCB.  
 CONFORMALLY COATED

2.40 TYP.

28 AWG STRANDED (7x36) TINNED COPPER  
 CONDUCTORS, PTFE OUTER, TINNED COPPER BRAID  
 SHIELD (93% COVERAGE), POLYOLEFIN JACKET, 250+/-  
 5 LONG (5.0 DIAM.)

## 5.10 Mechanical Format Combinations

Stators and Rotors (of the same size) from different mechanical formats can be combined. The full list of formats and combinations is shown below:-

- INC-3 Screw Mount Stator & Screw Mount Rotor
- INC-4 Servo Clamp Stator & Set Screw Rotor
- INC-6 Servo Clamp Stator & Plain Rotor
- INC-7 Screw Mount Stator & Set Screw Rotor
- INC-8 Screw Mount Stator & Plain Rotor
- INC-9 Servo Clamp Stator & Screw Mount Rotor
- INC-10 Duplex Stator & Duplex Rotor
- INC-11 Servo Clamp Stator & Shaft Clamp Rotor\*
- INC-12 Screw Mount Stator & Shaft Clamp Rotor\*
- INC-13 External Mount Stator & Screw Mount Rotor
- INC-14 External Mount Stator & Plain Rotor
- INC-15 External Mount Stator & Set Screw Rotor.



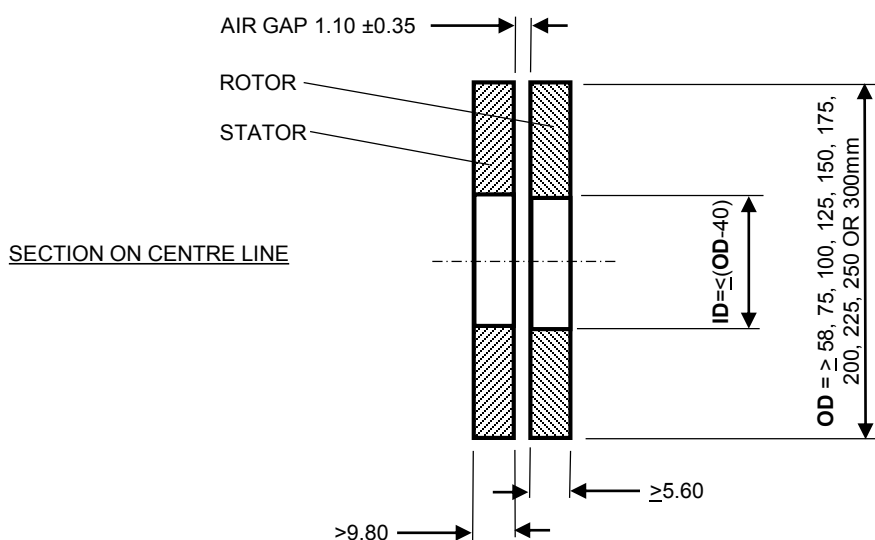
\* These formats only in 58mm. 58mm Screw Mount Stator & Shaft Clamp Rotor to be released 2016.

## 5.11 Custom Mechanical Formats

If a standard unit does not fit your design, a custom version may be needed. Zettlex make many custom housings and these are economical if unit volumes are >50 units/year. A few examples are shown below :-



To minimise any tooling charges, the OD of Stator & Rotor should preferably be a standard size:- 38, 58, 75, 100, 125, etc. together with a corresponding ID. For 58mm and upwards, the dimensions of the Stator and Rotor should not be less than the dimensions shown below:-



## 5.12 Radial Connections Product Options RFC1 to RFC10

For IncOder sizes 75 to 300mm there are 10 options for radial output connection. Types RFC1 to RFC6 employ a flexible radial output. Types RFC1 to RFC5 include a DATAMATE style connector.



**RFC1** – vertical connector, 100mm long radial.



**RFC2** – vertical connector, 12mm long radial.



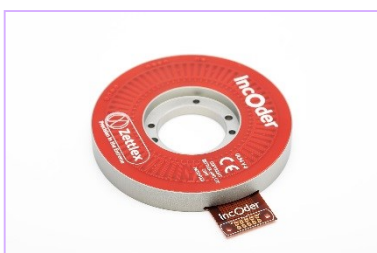
**RFC3** – 90 degree connector, 100mm long radial.



**RFC4** – 90 degree connector, 12mm long radial.



**RFC5** – connector not fitted, plated through holes, 100mm long radial. For customer fit of connector.

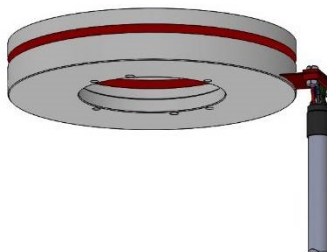


**RFC6** – connector not fitted, plated through holes, 12mm long radial. For customer fit of connector.

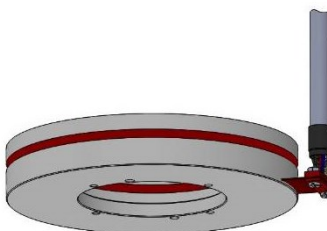
## 5.12 Radial Connections Product Options RFC1 to RFC10

Radial connection types RFC7 to RFC10 include a 2m cable which is directly soldered to the radial output. The 2m long cable is the same specification and colouring as INC-CAB3-2 or INC-CAB5-2 (see Section 9.1 & 9.2) depending on the electrical output (SSI etc. and A/B/Z outputs respectively). The cable has stripped and tinned ends.

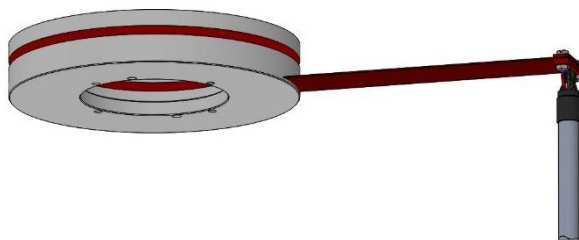
**RFC7** – 2m downward cable & 12mm long radial



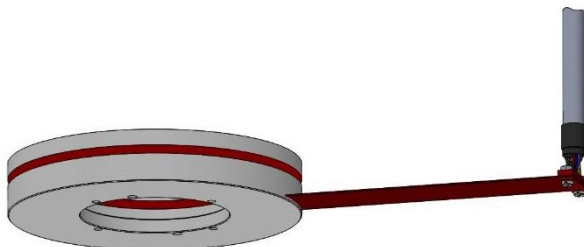
**RFC8** – 2m upward cable & 12mm long radial



**RFC9** – 2m downward cable & 100mm radial

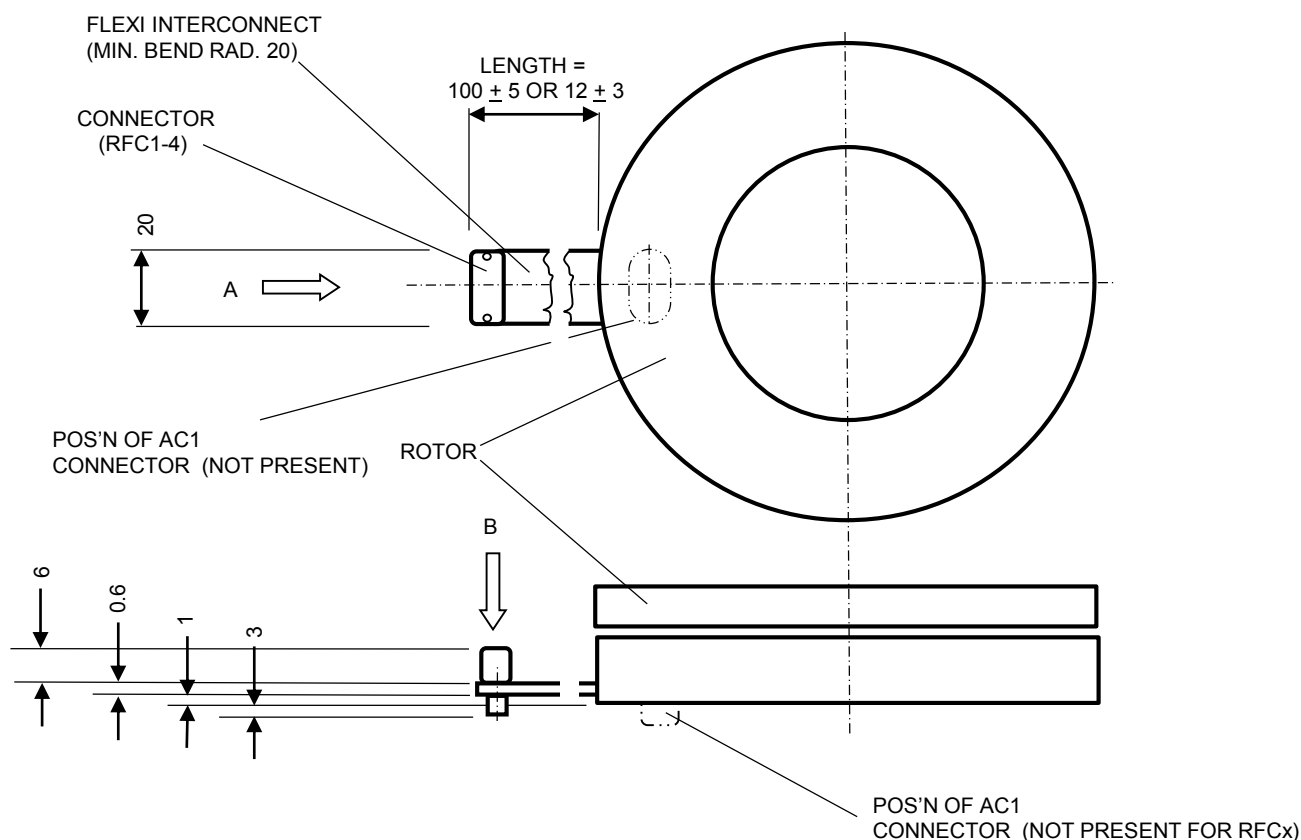


**RFC10** – 2m upward cable & 100mm radial

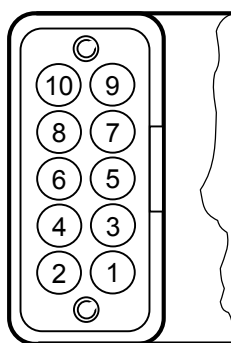




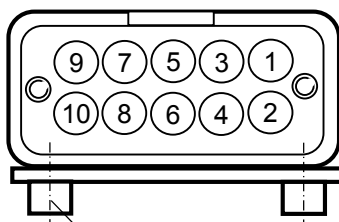
## 5.12 Radial Connections Product Options RFC1 to RFC10



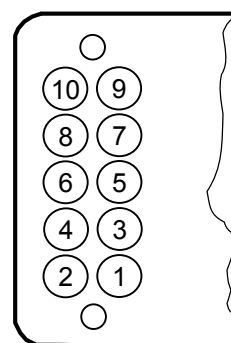
VIEW ON ARROW B  
RFC1 & 2  
VERTICAL CONNECTOR



VIEW ON ARROW A  
RFC3 & 4  
90 DEGREE CONNECTOR



VIEW ON ARROW B  
RFC5 & 6 - NO CONNECTOR FITTED  
PLATED THRO' HOLES DIAM 1.0



REMOVE THESE SCREWS ONLY IF ABSOLUTELY NECESSARY. IF REMOVED, ENSURE CONNECTIONS ON U/SIDE OF CONNECTOR ARE ALTERNATIVELY PROTECTED FROM CONTACTING CONDUCTIVE OR ABRADING SURFACES.

### Notes

- Connections for RFC7, 8, 9 & 10 are as per Section 9.1 and 9.2 regarding cable connections
- See Section 7 for pin allocations of connectors shown above.
- Drawing above is in 3rd angle projection. Do not scale from drawing. All dims in mm.
- General tolerance =  $\pm 1\text{mm}$  unless stated
- In all instances, ensure that the weight (or inertia under shock or vibration) of the mating cable is taken by local strain relief and not the RFC connection.

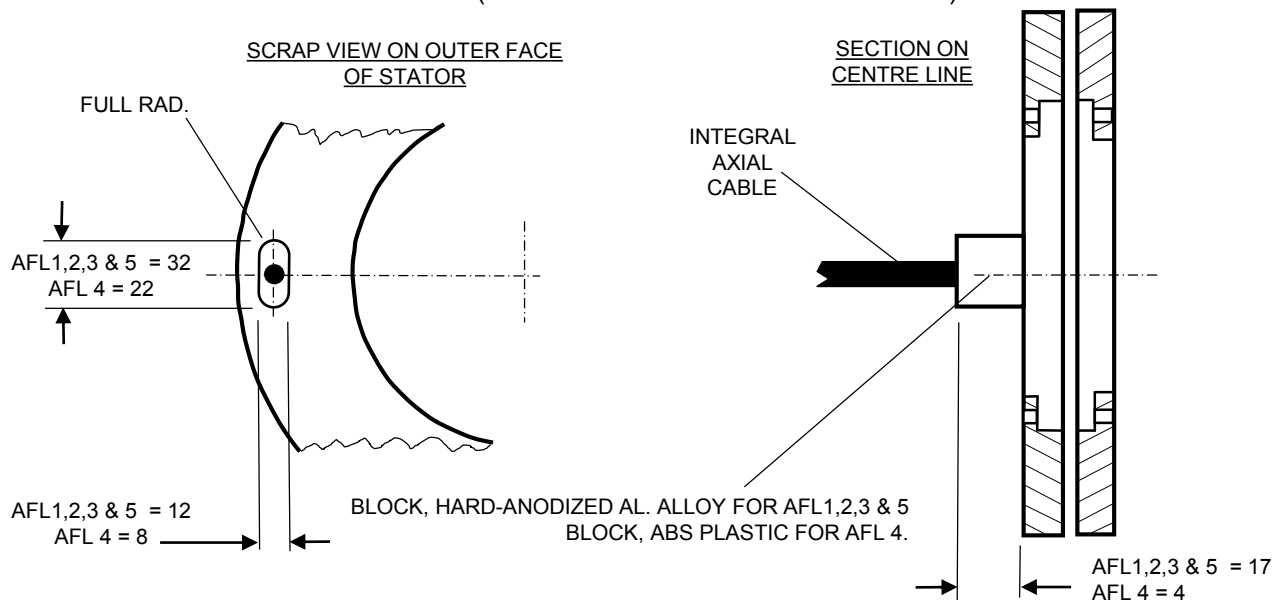
## 5.13 Integral Axial Cable Product Options AFL1-52 & VFL1-52

Integral Axial Cables are for wet and/or severe shock/vibration environments for all sizes other than 37mm. The connector is replaced by an integral cable and a block which covers the cable to IncOder joint.



- **AFL1 Integral Axial Cable.** IP67 for 1 hour & 1m depth. 2m long cable, 10-way, 24 AWG multi-strand copper wire, semi-rigid PVC insulation & outer jacket, twisted pairs, overall foil shield, tinned copper drain wire. Diam. 7.3mm. Min. flexing rad. = 76mm with a 1-off bend rad. (e.g. on installation) of 20mm. Operating temp.: -30 to 85°C.
- **AFL2 Integral Axial Cable, Sealed Rotor & Stator.** IP68 to 100m depth. Cable as per AFL1.
- **AFL3 Integral Axial, High Flex Cable.** IP67 for 1 hour & 1m depth and suitable for repeat bending (>5M cycles). IGUS CF11.02.05.02 cable, 2m long, TPE outer jacket, shielded, twisted pairs, 24AWG multi-strand, copper wire, PVC & halogen free. Hydrolysis, oil, UV & microbe resistant. Diam. 9.0mm. Min. radius 45mm (fixed) & 61mm (flexing). Operating temp.: -35 °C to +85°C (flexing) or -40°C to +85 °C (fixed). Operating temps. limited by IncOder, not cable.
- **AFL32 Integral Axial, High Flex Cable, Sealed Rotor & Stator.** IP68 to 100m depth. Cable as per AFL2.
- **AFL4 Integral Axial Cable, Low Profile.** IP67 for 1 hour & 1m depth. 0.6m long cable with individual Brandex SPC00443A00x PTFE coated 24AWG multi-strand, copper wire, in twisted pairs, to BS 3G 210. No shielding or outer sheath. Specify this option if space is tight. Axial length of the plastic cover block is shorter than other AFL options and min. bend radius of wires is 20mm with a 1 off min. bend radius. (e.g. on installation) of 10mm. Cables must not be substantially axially loaded (0.5kg max.) or strained during handling, installation or use. This option is not recommended for high shock or vibration unless cable is strain relieved locally. Operating temp.: -60 to +85°C (limited by IncOder, not cable).
- **AFL42 Integral Axial Cable, Low Profile, Sealed Rotor & Stator.** IP68 to 100m. Cable as per AFL4.
- **AFL5 Integral Axial, PTFE/MIL-Spec Cable.** IP67 for 1 hour & 1m depth. 1.1m cable with individual Brandex SPC00443A00x PTFE coated 24AWG multi-strand, copper wire, twisted pairs, to BS 3G 210, in overall Raychem RAY101-3.0 braided screen. Pro-Power STFE4-6.4-1.2MNAT PTFE outer sleeve. This non-flammable cable is resistant to oils, lubricants, fuels and is flexible. Min. flex rad.=76mm with 1 off bend rad. (e.g. on installation) of 8mm. Operating temp.= -60 to +85°C (limited by IncOder, not cable).
- **AFL52 Integral Axial, PTFE/MIL-Spec Cable, Sealed Rotor & Stator.** IP68 to 100m. Cable as per AFL5.
- **VFL1 to 52 Vertical Integral Cable (58mm only)** cable spec as above (excluding 4 or 42) but in opposite axial direction (cable egress in direction of Rotor).

**AFL Dimensions for 75 to 300mm Sizes** (see Section 5.5 & 5.6 for 58mm version):-



### Notes

- Drawing shown in 3rd angle projection. Do not scale from drawing.
- All dims in mm. Gen. tol. = ±1mm unless stated - all other dims as per relevant mechanical drawings.

## 5.13 Integral Axial Cable Product Options AFL1-52 & VFL1-52

### Wiring connections for AFL1, VFL1, AFL2, VFL2, AFL4, AFL42, AFL5, VFL5, AFL52, VFL52

Pair No.	Colour	Connector Pin (For Info. Only)	Signal (SSI1-8 & SPI)	Signal (AS11)	Signal (0-10V)	Signal (A/B pulses & Z Ref.)
1	Black	7	Data B	Data B	Ref. Voltage	A complement
1	Green	5	Data A	Data A	Signal	A
2	Black	6	Clk B	Not used - do not connect	Direction Set	B complement
2	Blue	8	Clk A	Not used - do not connect	Span Set	B
3	Black	9	0V	0V	0V	0V
3	Red	10	V <sub>supply</sub>	V <sub>supply</sub>	V <sub>supply</sub>	V <sub>supply</sub>
4	Black	1	Zero Set	Zero Set	Zero Set	Z Ref Set
4	Yellow	2	Zero Reset	Zero Reset	Zero Reset	Z Ref. Reset
5	Black	3	Not used - do not connect	Not used - do not connect	Not used - do not connect	Z
5	White	4	Not used - do not connect	Not used - do not connect	Not used - do not connect	Z complement

### Wiring connections for AFL3, AFL32, VFL3 & VFL32

Pair No.	Colour	Connector Pin (For Info. Only)	Signal (SSI1-8 & SPI)	Signal (AS11)	Signal (0-10V)	Signal (A/B pulses & Z Ref.)
1	Grey	7	Data B	Data B	Ref. Voltage	A complement
1	Pink	5	Data A	Data A	Signal	A
2	Yellow	6	Clk B	Not used - do not connect	Direction Set	B complement
2	Green	8	Clk A	Not used - do not connect	Span Set	B
3	Blue	9	0V	0V	0V	0V
3	Red	10	V <sub>supply</sub>	V <sub>supply</sub>	V <sub>supply</sub>	V <sub>supply</sub>
4	Violet	1	Zero Set	Zero Set	Zero Set	Z Ref Set
4	Black	2	Zero Reset	Zero Reset	Zero Reset	Z Ref. Reset
5	Brown	3	Not used - do not connect	Not used - do not connect	Not used - do not connect	Z
5	White	4	Not used - do not connect	Not used - do not connect	Not used - do not connect	Z complement

### Cable Lengths for AFL & VFL Product Options

Standard length AFL1, VFL1, AFL2 & VFL2, cables is 2m. Standard cable length for AFL4 & AFL42 is 0.6m. Standard length for AFL5, VFL5, AFL52 & VFL52 is 1.1m. If a different cable length is required, simply change the part number from, for example, AFL1 to AFL1.5.0 for a 5.0m cable or from AFL32 to a AFL32.0.9 for a 0.9m cable. For shorter cables there is no price difference. There may be a price variation for integral cables longer than standard – contact Zettlex or your local rep. General tolerance on cable lengths is  $\pm 50$ mm.

### Connectors for AFL & VFL Product Options

Fitting special connectors such as D-38999 military type or hermetically sealed connectors is something that Zettlex is frequently asked to do. Please contact Zettlex or your local representative if this is a requirement, stating cable length & connector type.



Extended Product Range Options are not necessary for most applications. However, in some applications – notably, very high-spec aerospace & military applications – additional steps/features may be required. Extended Product Range Options increase product costs & lead-times and should only be specified if necessary.

### **Electronics with Leaded Solder – Extended Product Option ‘P’**

Standard IncOders use RoHS compliant solder for electronic components. In some applications, the use of leaded solder is mandatory. Specify ‘P’ at the end of the standard Product Number.

### **Extended Thermal Stress Screen/Bake-Off – Extended Product Option ‘B’**

Standard IncOders undergo a rigorous final test after assembly. In some applications, extended thermal stress screening (or ‘burn-in’) is required. Similarly, some electro-optic applications require eradication of any volatile organic compounds. An extended thermal stress screen / bake-out for 24 hours at 70°C prior to final testing may be specified. Specify ‘B’ at the end of the standard Product Number.

### **Very High Shock & Vibration – Extended Product Option ‘G’**

Standard IncOders are designed for high shock & vibration environments, often found in airborne, marine & military vehicles. In applications with prolonged, very high shock (to 500g for 11ms) and/or very high vibration environments (to 100g for 10-2000Hz) the Very High Shock & Vibration Product Option should be specified. This is available in all IncOder sizes, formats and electrical interfaces but, preferably, should be used with integral cables (type AFL1, 2, 3 or 5). ‘G’ format IncOders have a reinforced internal structure. External mechanical & electrical interfaces are unchanged. Local strain relief of cables should be used in all applications with shock or vibration. Specify ‘G’ at the end of the standard Product Number.

### **Engraved Data – Extended Product Option ‘E’**

Standard IncOder Stators carry a serial number on a self-adhesive, metalized label. In some applications, a label is not acceptable and product data must be engraved. Engraved data includes part number & serial number on exterior faces of Stator and Rotor. Specify ‘E’ at the end of the standard Product Number.

### **Alocrom Surface Finish – Extended Product Option ‘A’**

Most standard IncOder aluminium-alloy housings have a clear, hard-anodized surface finish with low electrical conductivity. In some applications, housings must be electrically conductive to the host. Alocrom 1200 is an alternative, electrically-conductive surface finish, approved to DEF-STAN 03-18; MIL-C-5541C & MIL-C-81706. It has a golden colour and is often used in space applications. It contains hexavalent chromium and is not REACH compliant. Specify ‘A’ at the end of the standard Product Number.

### **SurTec 650 Surface Finish – Extended Product Option ‘S’**

Most standard IncOder aluminium alloy housings have a clear, hard-anodized surface finish with low electrical conductivity. In some applications, housings must be electrically conductive to the host. SurTec 650 ChromiAL<sup>®</sup> TCP is an alternative, electrically-conductive surface finish with a bluish-gold colour. It does not contain hexavalent chromium; is REACH compliant and has excellent corrosion protection. It meets or exceeds MIL-DTL-81706B & MIL-DTL-5541F (336h in NSS per ASTM B-117, respectively, DIN EN ISO 9227). It has a low electrical contact resistance (<5000µOhm per square inch as per MIL-DTL-81706B). Specify ‘S’ at the end of the standard Product Number.

### **Cold Temperature Option – Extended Product Option ‘12CT’ or ‘24CT’**

Standard IncOders have a lower operating temperature limit of -45°C. For prolonged or frequent operation at temperatures <-45°C, a cold temperature version (lower operating temperature of -60°C) should be specified using the 12CT or 24CT Product Option in the voltage supply section of the part number. For operating temperatures <-60°C consult Zettlex.

***Too much information? A bit confused?***

***We're here to help***

***Ask us on [info@zettlex.com](mailto:info@zettlex.com)  
or phone us on +44 (0) 1223 874444  
or contact your local rep (list on page 62)***





# 5.15 Measurement & Electrical Data (58-300mm)

## Measurement & Electrical Data for all Digital Comms Interfaces - Product Options SSI1-8, SPI, ASI1 & ASI2

	INC-x-58	INC-x-75	INC-x-100	INC-x-125	INC-x-150	INC-x-175	INC-x-200	INC-x-225	INC-x-250	INC-x-300	
Measurement	Absolute over 360°. Note this is true absolute - no motion required at start up										
Resolution (100101 Product Option)	10bits 1,024counts per rev 1265.6arc-secs 6144micro-rads										
Resolution (120101 Product Option)	12bits 4,096counts per rev 316.4arc-secs 1536micro-rads										
Resolution (140101 Product Option)	14bits 16,384counts per rev 79.1arc-secs 384micro-rads										
Resolution (160101 Product Option)	16bits 65,536counts per rev 19.77arc-secs 96micro-rads										
Resolution (180101 Product Option)	(17bits max.)	18bits 262,144counts per rev 4.94arc-secs 24micro-rads									
Resolution (190101 Product Option)	n/a	19bits 524,288counts per rev 2.47arc-secs 12micro-rads									
Resolution (200101 Product Option)	n/a	20bits 1,048,576counts per rev 1.24arc-secs 6micro-rads									
Resolution (210101 Product Option)	n/a	21bits 2,097,152counts per rev 0.62arc-secs 3micro-rads									
Resolution (220101 Product Option)	n/a	n/a	n/a	n/a	22bits 4,194,304counts per rev 0.31arc-secs 1.5micro-rads						
Repeatability	+/-1										count
Static Accuracy over 360°	≤150	≤125	≤80	≤65	≤50	≤50	≤50	≤45	≤40	≤38	arc-seconds
Static Accuracy over 360°	≤0.97	≤0.63	≤0.39	≤0.32	≤0.24	≤0.24	≤0.24	≤0.22	≤0.20	≤0.19	milliradians
Internal Position Update Period	<0.1										millisecond
Thermal Drift Coefficient	≤0.50										ppm/K Full-Scale
Max. Speed for Angle Measurement	10,000	9,000	7,200	5,760	4,965	4,500	4,500	4,500	4,500	4,500	r.p.m.
Max. Physical Speed	10,000										r.p.m.
Data Outputs	RS422 Compatible, supports SSI (Serial Synchronous Interface), asynchronous serial interface or SPI										
Power Supply	5VDC(4.5-32VDC) or 12VDC (4.5-32VDC) or 24VDC (4.5-32VDC)										VDC
Current Consumption	<100 (typically <75 and does not change significantly with voltage supply)										milliAmp
Reverse Polarity	PSU Reverse polarity protected to max. supply voltage										VDC
Connector (AC1 & RFCx Product Options)	Harwin Data Mate Vertical Plug 10 Way with 2 Jack Screws Type M80-500-10-42 or M80-510-10-42 or M80-540-10-42 For alternative connectors such as integral cable or military shell type contact Zettlex										
Mating Connector (AC1 & RFCx)	Harwin Data Mate Vertical Socket Type M80-461-10-42 (alternative M80-461-10-05)										
Zero Setting	Via Connector Pin (AC1 or RFCx) or integral cable (AFL1 or 2) - see details for set and reset in relevant Section										
Power Up Time To 1st Measurement	<100										millisecond

## Measurement & Electrical Data for A/B/Z Pulses Comms Interfaces - Product Option ABZ1-6

	INC-x-58	INC-x-75	INC-x-100	INC-x-125	INC-x-150	INC-x-175	INC-x-200	INC-x-225	INC-x-250	INC-x-300	
Measurement	Incremental with reference mark. Position of reference mark programmable by user.										
Resolution (100101 Product Option)	10bits 1,024counts per rev 1265.6arc-seconds 6144micro-radians 256pulses per rev										
Resolution (120101 Product Option)	12bits 4,096counts per rev 316.4arc-seconds 1536micro-radians 1024pulses per rev										
Resolution (140101 Product Option)	14bits 16,384counts per rev 79.1arc-seconds 384micro-radians 4,096pulses per rev										
Resolution (160101 Product Option)	16bits 65,536counts per rev 19.77arc-seconds 96micro-radians 16,384pulses per rev										
Resolution (180101 Product Option)	(17bits max.)	18bits 262,144counts per rev 4.94arc-seconds 24micro-radians 65,536pulses per rev									
Resolution (190101 Product Option)	n/a	19bits 524,288counts per rev 2.47arc-seconds 12micro-radians 131,072pulses per rev									
Repeatability	+/-1										count
Static Accuracy over 360°	≤150	≤120	≤80	≤65	≤50	≤50	≤50	≤45	≤40	≤38	arc-seconds
Static Accuracy over 360°	≤0.97	≤0.63	≤0.39	≤0.32	≤0.24	≤0.24	≤0.24	≤0.22	≤0.20	≤0.19	milliradians
Internal Position Update Period	<0.1										millisecond
Thermal Drift Coefficient	≤1										ppm/K Full-Scale
Max. Speed for Angle Measurement	10, 12 or 14bits = 6,000r.p.m. 16bits = 3,600r.p.m. 18bits = 900r.p.m. 19bits = 450r.p.m.										
Max. Physical Speed	10,000										r.p.m.
Data Outputs	A/B pulses with Z pulse ref. Z position settable from connector/cable. Z pulse width selectable by Product Option/ Part Number.										
Power Supply	5VDC±10% or 12VDC (8-32VDC) or 24VDC (8-32VDC)										VDC
Current Consumption	<150 (does not vary significantly with supply voltage)										milliAmp
Reverse Polarity	PSU Reverse polarity protected to max. supply voltage										VDC
Connector (AC1 & RFCx Product Options)	Harwin Data Mate Vertical Plug 10 Way, Jack Screw Sockets Type M80-500-10-42 or M80-510-10-42 or M80-540-10-42 For alternative connectors such as integral cable or military shell type contact Zettlex										
Mating Connector (AC1 & RFCx)	Harwin Data Mate Vertical Socket Type M80-461-10-42 (alternative M80-461-10-05)										
Z Position Setting	Via Connector Pin (AC1 or RFCx) or integral cable (AFL1 or 2) - see details for set and reset in Section 6.9										
Power Up Time To 1st Measurement	<120										millisecond

# 5.15 Measurement & Electrical Data (58 to 300mm)

## Measurement & Electrical Data for Analogue Voltage Comms Interfaces - Product Options V0360, W3601 etc.

	INC-x-58	INC-x-75	INC-x-100	INC-x-125	INC-x-150	INC-x-175	INC-x-200	INC-x-225	INC-x-250	INC-x-300
Span (Product Option -0360)	n/a	360° measured clockwise								n/a
Default setting unless specified		If required range is other than a factory ranges - use this code and set requirements at installation using set/reset								
Span (Product Option -3601)	n/a	360° measured counter-clockwise								n/a
Span (Product Option -0270)	n/a	270° measured clockwise.								n/a
Span (Product Option -2701)	n/a	270° measured counter-clockwise								n/a
Span (Product Option -0180)	n/a	180° measured clockwise								n/a
Span (Product Option -1801)	n/a	180° measured counter-clockwise								n/a
Span (Product Option -0090)	n/a	90° measured clockwise								n/a
Span (Product Option -0901)	n/a	90° measured counter-clockwise								n/a
Resolution (Product Option 140101)	n/a	≤0.0061% of Span (in Spans of 45 to 360°) ≥16384steps over Span (in Spans of 45 to 360°)								n/a
Repeatability	n/a	≤0.0061% of Span (in Spans of 45 to 360°) ±1step over Span (in Spans of 45 to 360°)								n/a
Linearity over Full-Scale	n/a	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	≤0.05	n/a % of 10V
Position Update Period	n/a	≤1.0								n/a millisecond
Thermal Drift Coefficient	n/a	≤70								n/a ppm/K full-scale
Max. Physical Speed	n/a	10,000								n/a r.p.m.
Output Signal	n/a	0.5 to 4.5VDC; 0.5 to 5.0VDC; 0.5 to 9.5VDV; 0.5 to 10.0VDC								n/a
Output Load	n/a	5kOhm min.								n/a
Power Supply	n/a	11.5 to 32								n/a VDC
Current Consumption	n/a	<100 (typically 75 and does not change significantly with voltage supply)								n/a milliAmp
Reverse Polarity	n/a	PSU Reverse polarity protected to max. supply voltage								n/a VDC
Connector (AC1 & RFCx Product Options)	n/a	Harwin Data Mate Vertical Plug 10 Way, Jack Screw Sockets Type M80-500-10-42; M80-510-10-42 or M80-540-10-42. For alternative connectors such as integral cable or military shell type contact Zettlex								n/a
Mating Connector	n/a	Harwin Data Mate Vertical Socket Type M80-461-10-42 (alternative M80-461-10-05)								n/a
Zero, Direction & Span Setting	n/a	Via Connector Pin (AC1 or RFCx) or integral cable (AFL1 or 2) - see details for set and reset in relevant Section								n/a
Power Up Time To 1st Measurement	n/a	<100								n/a millisecond

## Measurement & Electrical Data for Digital + 1Vpk to pk. Sin/Cos - Product Options SSI1V-SSI8V, SPIV & ASI1V

	INC-x-58	INC-x-75	INC-x-100	INC-x-125	INC-x-150	INC-x-175	INC-x-200	INC-x-225	INC-x-250	INC-x-300
Measurement	True absolute over 360° for digital (no motion required). Incremental over 25 cycles for analogue.									
Digital Resolution (140101 Product Option)			14bits	16,384counts per rev	79.1arc-seconds	384micro-radians				
Digital Resolution (160101 Product Option)			16bits	65,536counts per rev	19.77arc-seconds	96micro-radians				
Digital Resolution (180101 Product Option)			18bits	262,144counts per rev	4.94arc-seconds	24micro-radians				
Digital Repeatability					+/-1					count
Digital Static Accuracy over 360°	n/a	n/a	n/a	≤165	n/a	n/a	n/a	n/a	n/a	n/a arc-seconds
Digital Static Accuracy over 360°	n/a	n/a	n/a	≤0.80	n/a	n/a	n/a	n/a	n/a	n/a milliradians
Analogue Accuracy over Full-Scale	n/a	n/a	n/a	≤1.00	n/a	n/a	n/a	n/a	n/a	n/a degrees
Digital Internal Position Update Period					≤1.0					millisecond
Analogue Internal Position Update Period					≤10					microseconds
Digital Thermal Drift Coefficient					≤0.50					ppm/K full-scale
Max. Physical Speed for Digital Output					650					r.p.m.
Max. Physical Speed for Analogue Output					10,000					r.p.m.
Max. Physical Speed					10,000					r.p.m.
Digital Data Outputs					RS422 Compatible, supports SSI (Serial Synchronous Interface), asynchronous serial interface or SPI					
Analogue Signal Outputs					25 cycles of 1V nominal peak to peak sin and cos output with 2.5+0.2VDC reference					
Tolerance on Analogue Signal Outputs					1.2 V peak to peak max. and 0.8V peak to peak min.					
Power Supply					12VDC (8-15VDC)					VDC
Current Consumption					<100 (typically <75)					milliAmp
Output Load					<300					MOhm
Reverse Polarity					PSU Reverse polarity protected to max. supply voltage					VDC
Connector (AC1 Product Option)					Harwin Data Mate Vertical Plug 20 Way with 2 Jack Screw Sockets Type M80-500-20-42					
Mating Connector					Harwin Data Mate Vertical Socket Type M80-461-20-42 (alternative M80-461-20-05)					
Digital Zero Setting					Via Connector Pin (AC1) - see details for set and reset in Section 8.3					
Digital Zero Position Variation					≤1					LSBit
Power Up Time To 1st Measurement					<75					millisecond

# 5.16 Environmental & Further Data (58 to 300mm)

## Environmental Data - Product Options (58 to 300mm)

	INC-x-58	INC-x-75	INC-x-100	INC-x-125	INC-x-150	INC-x-175	INC-x-200	INC-x-225	INC-x-250	INC-x-300	
Operating Temp.	Minus 45 to +85 Minus 60 to +85Celsius for 12VCT & 24VCT Product Option. +65Celsius max. for 58mm device at >28VDC power supply Operation outside limits to be qualified by user. At temperatures >85Celsius, duration should be minimized Options available below minus 60 Celsius operation: contact Zettlex or local representative										Celsius
Storage Temp.	Minus 55 to +125 (Minus60 to +125 for 24CT Product Option)										Celsius
Temperature Shock:	MIL-STD-810G, Method 503.5, Procedure I-B (T1=-40 °C, T2=55 °C.)										
IP Rating - Rotor & Stator	IP67 for <60 minutes & 1m depth (Installed with mechanically protected connector or AFL1, 3, 4, 5 & VFL Product Options) IP68 100m depth (Installed with mechanically protected connector or AFL2 Product Option) For immersion at depths of >100m contact Zettlex or your local representative										
IP Rating - Connector	IP50 (AC1 or RFC1-5 Product Option). IP68 for RFC6-10 . see above for AFL1 & AFL2 Product Option										
Humidity	RH 0-99% non-condensing - <i>but unaffected by occasional condensation</i>										
Salt Fog	(Installed with protected cable/connector or any AFL or VFL) Complies with DEF STAN 00-35 Pt 3 Iss. 4, Test CN2 Salt Mist Test										
Bio Hazards	(Installed with protected cable/connector or any AFL or VFL) Complies with DEF-STAN 00-35 Pt 4 Iss. 4 Section 11 (Hazards)										
Induced Dust & Sand	Complies with DEF STAN 00-35 Part 3 Issue 4, Test CL25 (Turbulent Dust) Cat 1										
Mechanical Impact Resistance	IK07 - <i>suitable for mechanical impacts from objects of &gt;200grams from 1m height</i>										
Shock	IEC 60068-2-6 100g for 11ms - axial & radial - <i>suitable for most airborne, marine &amp; armoured vehicles</i> MIL-STD-810G, Method 516.6, Procedure I-Functional Shock - axial and radial - 40 g 11 ms, sawtooth waveform For more extreme or prolonged conditions specify Extended Product Option G and preferably AFL or VFL Product Options										
Vibration	IEC 60068-2-6 20g for 10-2000Hz - axial and radial - <i>suitable for most high vibration &amp; airborne environments</i> MIL-STD-810G, Method 514.6, Procedure I - axial and radial - Category 20, for tracked vehicles For more extreme or prolonged conditions specify Extended Product Option G and preferably AFL1 or AFL2 Product Options										
Environmental pressure range	0 to 4 ( <i>in other words vacuum to 4</i> )										Bar
Max. permissible press. change rate	1										Bar/second
EMC Susceptibility	(Installed) Complies with IEC 61000-6-2 - <i>suitable for fitment in harsh EMC environments</i>										
EMC Emissions	(Installed) Complies with IEC 61000-6-4 - <i>suitable for fitment adjacent to EMI sensitive devices</i>										
Materials - all Product Options											
Rotor & Stator Housings	Standard range:- Hard, clear anodized al. alloy (6061-T6 or 6084-T6). Sensor surfaces: FR4 grade epoxy Product Option A or S:- Alclom or SurTec650 finish al. alloy (6061-T6 or 6084-T6). Sensor surfaces: FR4 grade epoxy										
Connector (Axial - AC1 Product Option)	PPS with Stainless Steel Screw Fixings and Gold & Tin Electrical Connections										
nnector (Radial - RFCx Product Option)	PPS with St. Steel Screw Fixings and Gold & Tin Electrical Connections and Polyimide Flexi with Polyimide Coverlay										
onnector (Axial - AFL1 Product Option)	Exposed surfaces :- Hard, clear anodized aluminium & PVC sheathed cable										
onnector (Axial - AFL2 Product Option)	As AFL1 plus acrylic conformal coat over FR4 sensor surfaces to MIL-46058C & DEFSTAN 59/47 issue 4										
Miscellaneous - all Product Options											
Mass Screw Mount Rotor (max.)	N/A	50	70	90	110	130	150	170	192	235	grams
Mass Set-Screw Rotor (max.)	43	75	105	135	165	195	225	255	287	350	grams
Mass Plain Rotor (max.)	32	45	63	81	99	117	135	153	172	215	grams
Mass Screw Mount Stator (AC1)	N/A	83	117	150	184	217	250	284	319	390	grams
Mass Servo Clamp Stator (AC1)	43	79	111	143	174	206	238	270	303	360	grams
om. of Inertia Screw Mount Rotor (max.)	N/A	4.8E-05	1.3E-04	2.5E-04	4.4E-04	7.5E-04	1.2E-03	1.8E-03	2.5E-03	4.5E-03	Kgm <sup>2</sup>
Mom. of Inertia Set-Screw Rotor (max.)	2.0E-05	7.2E-05	1.9E-04	3.7E-04	6.6E-04	1.1E-03	1.8E-03	2.7E-03	3.8E-03	6.7E-03	Kgm <sup>2</sup>
Mom. of Inertia Plain Rotor (max.)	1.8E-05	4.3E-05	1.2E-04	2.2E-04	3.9E-04	6.8E-04	1.1E-03	1.6E-03	2.3E-03	4.4E-03	Kgm <sup>2</sup>
MTBF	0.22 failures per 1M hours based on MIL-HBK-217+ method for ground military vehicles at 20Celsius average										
MTBF	0.35 failures per 1M hours based on MIL-HBK-217+ method for naval sheltered at 35Celsius average										
Hazardous materials	Standard range - Hazardous materials not used. RoHS compliant. RoHS certificate available. REACH statement available.										
Outgassing materials	Complies with NASA classification as low outgassing material with TML <1% & CVCM <0.1% at 125C & 24hrs in vacuum to ASTM E-595-90										
ITAR classification	Not ITAR controlled. No ITAR components										
Approvals	Flammability Rating UL94V-0. Standard range - RoHS compliant - RoHS certificate available. REACH statement available.										
Marking	Zettlex, logo, CE & UL94V-0 printed on Rotor & Stator faces; Serial No. labelled on exterior diameter of Stator housing Extended Product Range Option E - engraved serial number and part number on exterior faces of Stator & Rotor										
Country of Manufacture	UK										
Export Licence Requirements	Not required for products of <1000mm diameter										

# 5.17 Measurement, Electrical & Environmental Data (37mm)

## Measurement, Electrical, Environmental & Material Data for 37mm IncOrder

Measurement				
Measurement	Absolute over 360°. Note this is true absolute - no motion required at start up			
Resolution (100101 Product Option)	10bits	1,024counts per rev	1265.6arc-secs	6144micro-rads
Resolution (120101 Product Option)	12bits	4,096counts per rev	316.4arc-secs	1536micro-rads
Resolution (140101 Product Option)	14bits	16,384counts per rev	79.1arc-secs	384micro-rads
Resolution (160101 Product Option)	16bits	65,536counts per rev	19.77arc-secs	96micro-rads
Resolution (170101 Product Option)	17bits	131,072counts per rev	2.47arc-secs	12micro-rads
Repeatability	+/-1			count
Static Accuracy over 360°	≤0.098 degrees or ≤1.71milliradians			
Internal Position Update Period	<0.1			millisecond
Thermal Drift Coefficient	≤1.0			ppm/K Full-Scale
Max. Speed for Angle Measurement	6,000			r.p.m.
Max. Physical Speed	10,000			r.p.m.
Electrical				
Data Outputs	RS422 Compatible, supports SSI (Serial Synchronous Interface), asynchronous serial interface (ASI) or SPI.			
Power Supply	5VDC (4.5-8VDC) or 12VDC (4.5-14VDC)			VDC
Current Consumption	<100 (typically <75 and does not change significantly with voltage supply)			milliAmp
Reverse Polarity	PSU Reverse polarity protected to max. supply voltage			VDC
Zero Setting	Zero Set or Reset to factory value via Electronics Module - Section 7.1			
Power Up Time To 1st Measurement	<75			millisecond
Environment				
Operating Temp.	Minus 45 to +85 (+65 at >8VDC power supply)  Operation outside limits to be qualified by user. At temperatures >85Celsius, duration should be minimized.  Options available below minus 60 Celsius operation: contact Zettlex or local representative for details			Celsius
Storage Temp.	Minus 55 to +125			Celsius
Temperature Shock:	MIL-STD-810G, Method 503.5, Procedure I-B (T1=-40 °C, T2=55 °C.)			
IP Rating - Rotor & Stator	IP67 for <60 minutes & 1m depth			
Humidity	RH 0-99% non-condensing - <i>but unaffected by occasional condensation</i>			
Salt Fog	Complies with DEF STAN 00-35 Pt. 3 Iss. 4, Test CN2 Salt Mist Test			
Bio Hazards	Complies with DEF-STAN 00-35 Pt. 4 Iss. 4 Section 11 (Hazards)			
Induced Dust & Sand	Complies with DEF STAN 00-35 Part 3 Issue 4, Test CL25 (Turbulent Dust) Cat 1			
Shock	IEC 60068-2-6 100g for 11ms - axial & radial - <i>suitable for most airborne, marine &amp; armoured vehicles</i> MIL-STD-810G, Method 516.6, Procedure I-Functional Shock - axial and radial - 40 g 11 ms, sawtooth waveform			
Vibration	IEC 60068-2-6 20g for 10-2000Hz - axial and radial - <i>suitable for most high vibration &amp; airborne environments</i> MIL-STD-810G, Method 514.6, Procedure I - axial and radial - Category 20, for tracked vehicles			
Environmental pressure range	0 to 4 ( <i>in other words vacuum to 4</i> )			Bar
Max. permissible press. change rate	1			Bar/second
EMC Susceptibility	(Installed) Complies with IEC 61000-6-2 - <i>suitable for fitment in harsh EMC environments</i>			
EMC Emissions	(Installed) Complies with IEC 61000-6-4 - <i>suitable for fitment adjacent to EMI sensitive devices</i>			
Miscellaneous				
Mass Set-Screw Rotor (max.)	10 (for 8mm bore)			grams
Mass Plain Rotor (max.)	7 (for 8mm bore)			grams
Mass Screw Mount Stator (max.)	20 (for 8mm bore)			grams
MTBF	0.22 failures per 1M hours based on MIL-HBK-217+ method for ground military vehicles at 20Celsius average			
MTBF	0.35 failures per 1M hours based on MIL-HBK-217+ method for naval sheltered at 35Celsius average			
Hazardous materials	Standard range - Hazardous materials not used. RoHS compliant. RoHS certificate available. REACH statement available.			
Outgassing materials	Complies with NASA classification as low outgassing material with TML <1% & CVCM <0.1% at 125C & 24hrs in vacuum to ASTM E-595-90			
ITAR classification	Not ITAR controlled. No ITAR components.			
Approvals	Flammability Rating UL94V-0. Standard range - RoHS compliant - RoHS certificate available. REACH statement available.			
Marking	Zettlex, logo, CE & UL94V-0 printed on Rotor & Stator faces; Serial Number label.  Extended Product Range Option E - engraved serial number and part number on exterior faces of Stator & Rotor			
Country of Manufacture	UK			
Export Licence Requirements	Not required for products of <1000mm diameter			

The IncOder range offers 6 different Communication Interfaces:-

- Synchronous Serial Interface – see Section 6.4 (Product Options SSI1-9)
- Asynchronous Serial Interface – see Section 6.5 (Product Option ASI1)
- Serial Peripheral Interface – see Section 6.6 (Product Option SPI1)
- Digital + 1V sin/cos – see Section 6.7 (Product Options SSI1-8V, ASI1V, SPI1V)
- Analogue Voltage – see Section 6.8 (Product Options V0360, W3601, X0270 etc.)
- A/B/Z pulses – see Section 6.9 (Product Option ABZ1 etc.)

All the digital Communications Interfaces conform to the RS422 Standard. Note that for all Communications Interfaces DATA & CLOCK inputs are not terminated with load resistors.

### 6.1 Output Resolution

The IncOder range offers various Options for the resolution of the output data. The required digital resolution is simply specified using the relevant Product Option – see Section 8.

**INC - X - XXX - XXXXXX - XXXX - XXXX - X - XXX**

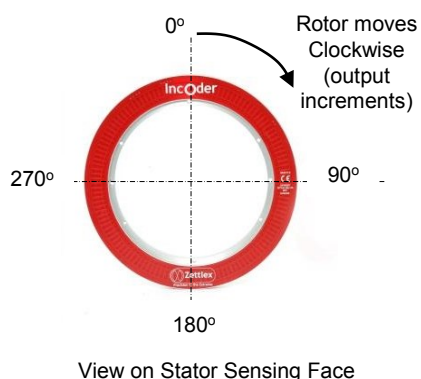
Resolution measured in bits.	
10 Bits	<b>101001</b>
11 Bits	<b>111001</b>
12 Bits	<b>121001</b>
13 Bits	<b>131001</b>
14 Bits (all 0-5 or 10V options)	<b>141001</b>
15 Bits	<b>151001</b>
16 Bits	<b>161001</b>
17 Bits	<b>171001</b>
18 Bits	<b>181001</b>
19 Bits	<b>191001</b>
20 Bits	<b>201001</b>
21 Bits	<b>211001</b>
22 Bits (only sizes $\geq 150\text{mm}$ )	<b>221001</b>
Alternatively, for ABZ pulse output only, specify number of pulses per rev up to a max of 131,072 e.g. <b>P123,456</b>	

### 6.2 Multi-Turn or Single Turn

The default electrical output from an IncOder is over 1 rev. For multi-turn devices please contact Zettlex or your local rep. IncOder offers the possibility to count how many turns have been made by modifying the IncOder's software. To maintain turn count, an uninterruptable power supply is necessary.

### 6.3 Zero Point Set & Reset for Digital Outputs (58 to 300mm)

**Product Options - SSI1-9, SPI1, ASI1-2, SSI1V-8V, SPI1V, ASI1V**



The Zero Point is the datum from which angle is measured. As supplied, the IncOder carries a factory Zero Point setting. For Screw Mount & Duplex products the Zero Point is in a range of  $\pm 5^\circ$  of the Rotor and Stator dowel positions at 12 o'clock (near the 'O' of the printed 'IncOder'). The Zero Point can be changed using the Zero Set and Zero Reset lines on the IncOder's electrical interface. The Zero Set signal will set the current IncOder position as the Zero Point (held in memory when power removed). Zero Reset signal will reset the Zero Point to the factory setting (held in memory when power removed). To use, the relevant connection should be connected to 0V for  $\geq 1$  second at power up but left unconnected (i.e. open circuit) during operation. (For 37mm see Section 7.1)

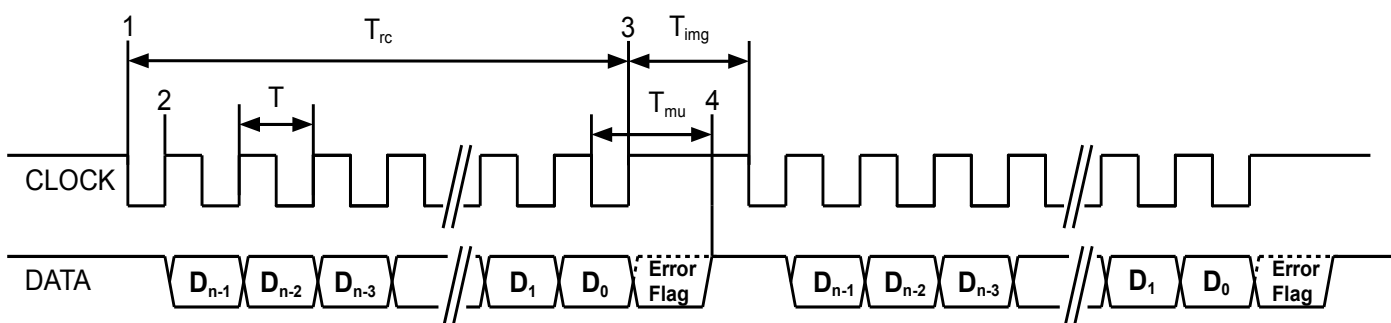


## 6.4 Synchronous Serial Interface (SSI) – Product Options SSI1-SSI9

### 6.4.1 Generic Protocol Definition– Product Options SSI1-SSI9

SSI is a widely used serial interface between position sensors and controllers. It implements a differential output for the DATA and a differential input for the CLOCK. (Note that DATA outputs and CLOCK inputs are not terminated with load resistors.)

Synchronous SSI uses a clock sequence from a controller to initiate the transmission of position data from the sensor (a Read Cycle), with the latest position data (see Section 5 for internal position update rate) available for transmission after each SSI Read Cycle is completed. See timing information below:-



T: Clock Period ( $1/T = 100 \text{ kHz to } 2 \text{ MHz}$ )

Trc: Read Cycle time: This is defined as  $(n \times T) + (0.5 \times T)$

Tmu: Message Update time. The time from last falling edge of clock to when new data is ready for transmission.

$T_{mu} = 20\mu\text{s} \pm 1 \mu\text{s}$ . The DATA line will be HIGH after this time indicating a new Read Cycle can be started.

Timg: Intermassage Gap time. Must be  $> T_{mu}$  otherwise position data will be indeterminate.

n: The number of bits in the message (not including the Error Flag).

In idle state CLOCK and DATA are both HIGH

#### Notes:

1. The first falling edge after  $T_{mu}$  starts the Read Cycle and the transfer of data.
2. Each rising edge of the CLOCK transmits the next data bit of the message, starting with  $D_{n-1}$ .
3. After the last rising edge of the clock sequence, the data line is set by the Error Flag (if supported) for the period  $T_{mu} - 0.5 \times T$
4. After  $T_{mu}$ , the latest position data is now available for transmission in the next Read Cycle – see Section 5 for position update rate.

SSI can support a variety of protocols in which data is transmitted depending on the requirements of the SSI controller. **IncOder can be supplied with any of the following protocols – just choose what you need by using the relevant Product Option when ordering (see Section 9).** If the protocol you require is not listed here then please consult Zettlex or your local representative.

#### SSI1 (n = 24)

*Most popular  
choice*

<b>D23</b>	PV	Position Valid Flag. Set to 1 when data is valid, otherwise 0 (the inverse of the ERROR FLAG).
<b>D22</b>	ZPD	Zero Point Default. Set to 1 when the Zero Point is at Factory Default, otherwise 0
<b>D21-D0</b>	PD[21:0]	Binary position data. If resolution of device is less than 22 bits, then the MSBs of this field are set to 0. The LSB of this field is in D0. When PV is 0, PD[21:0] value is not defined.

#### SSI2 (n = 24)

<b>D23-D2</b>	PD[21:0]	Binary position data. If resolution of device is less than 22 bits, then the MSBs of this field are set to 0. The LSB of this field is in D2. When Alarm bit is 1, PD[21:0] value is not defined.
<b>D1</b>	P	Parity Bit 0 indicates an even number of 1's in data (D23-D2), 1 indicates an odd number of 1's in data.
<b>D0</b>	A	Alarm Bit – 0 indicates normal operation, 1 indicates error condition.

#### SSI3 (n = 16)

<b>D15-D0</b>	PD[15:0]	Binary position data. When ERROR FLAG is 1, PD[15:0] value is not defined.
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Note: the use of SSI3 effectively limits the measurement resolution to a maximum of 16bits. If a higher resolution is specified in the part number, the least significant bits will not be accessible by the user.

#### SSI4 (n = 32)

<b>D31</b>	PV	Position Valid Flag. Set to 1 when position data valid, otherwise 0 (inverse of ERROR FLAG).
<b>D30</b>	ZPD	Zero Point Default. Set to 1 when the Zero Point is at Factory Default, otherwise 0
<b>D29-D11</b>	PD[18:0]	Binary position data. If resolution of device is less than 19 bits, then the MSBs of this field are set to 0. The LSB of this field is in D11. When PV is 0, PD[18:0] value is not defined.
<b>D10-D0</b>	TS[10:0]	Time stamp data. The value of the Time Stamp counter when the position was measured. This data is always valid. The Time Stamp counter is a continuously incrementing counter in the range: 0.00ms to 20.47ms (at which point it restarts at 0.00ms). It has a resolution of 10us, with an accuracy better than 1% (based on the system oscillator).

Note: the use of SSI4 effectively limits the measurement resolution to a maximum of 19bits. If a higher resolution is specified in the part number, the least significant bits will not be accessible by the user.

#### SSI5 (n = 16)

<b>D15-D0</b>	PD[15:0]	Gray code, position data. When ERROR FLAG is 1, PD[15:0] value is not defined.
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Note: the use of SSI5 effectively limits the measurement resolution to a maximum of 16bits. If a higher resolution is specified in the part number, the least significant bits will not be accessible by the user.

#### SSI6 (n = 32)

<b>D31-D24</b>	CRC[7:0]	CRC-8: To verify transmission, calculate the CRC of the bottom 24 bits of the message. The resulting CRC should be the same as the received CRC field. The following parameters define CRC-8: Polynomial 0x97 Initial data 0x00 MSB First (not reversed) No final XOR calculation
<b>D23</b>	PV	Position Valid Flag. Set to 1 when position data is valid, otherwise 0 (the inverse of the ERROR FLAG).
<b>D22</b>	ZPD	Zero Point Default. Set to 1 when the Zero Point is at Factory Default, otherwise 0
<b>D21-D0</b>	PD[21:0]	Binary position data. If resolution of device is less than 22 bits, then the MSBs of this field are set to 0. The LSB of this field is in D0. When PV is 0, PD[21:0] value is not defined.

#### SSI7 (n = 30)

<b>D29-D24</b>	-	Data always 0.
<b>D23-D2</b>	PD[21:0]	Binary position data. If resolution of device is less than 22 bits, then the MSBs of this field are set to 0. The LSB of this field is in D2. When Alarm bit is 1, PD[21:0] value is not defined.
<b>D1</b>	P	Parity Bit 0 indicates an even number of 1's in data (D23-D2) 1 indicates an odd number of 1's in data.
<b>D0</b>	A	Alarm Bit – 0 indicates normal operation, 1 indicates error condition.

#### SSI8 (n = 18)

<b>D17-D0</b>	PD[17:0]	Gray code, position data. When ERROR FLAG is 1, PD[17:0] value is not defined.
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Note: the use of SSI8 effectively limits the measurement resolution to a maximum of 18bits. If a higher resolution is specified in the part number, LSBs will not be accessible by the user.

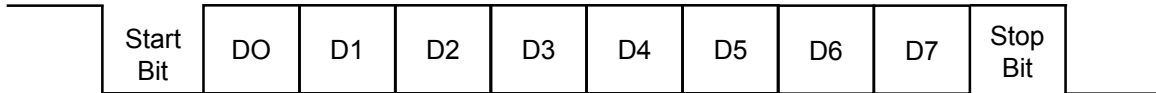
#### SSI9 (n = 32)

<b>D31</b>	PV	Position Valid Flag. Set to 1 when position data valid, otherwise 0 (inverse of ERROR FLAG).
<b>D30</b>	ZPD	Zero Point Default. Set to 1 when the Zero Point is at Factory Default, otherwise 0
<b>D29-D11</b>	PD[18:0]	Binary position data. If resolution of device is <19bits, then the MSBs of this field are set to 0. The LSB of this field is in D11. When PV is 0, PD[18:0] value is not defined.
<b>D10-D0</b>	TS[10:0]	Time stamp data. The value of the Time Stamp counter when the position was measured. This data is always valid. The Time Stamp counter is a continuously incrementing counter in the range: 0.00ms to 2.047ms (at which point it restarts at 0.00ms). It has a resolution of 1us, with an accuracy better than 1% (based on the system oscillator).

Note: the use of SSI9 effectively limits the measurement resolution to a maximum of 19bits. If a higher resolution is specified in the part number, the LSBs will not be accessible by the user.

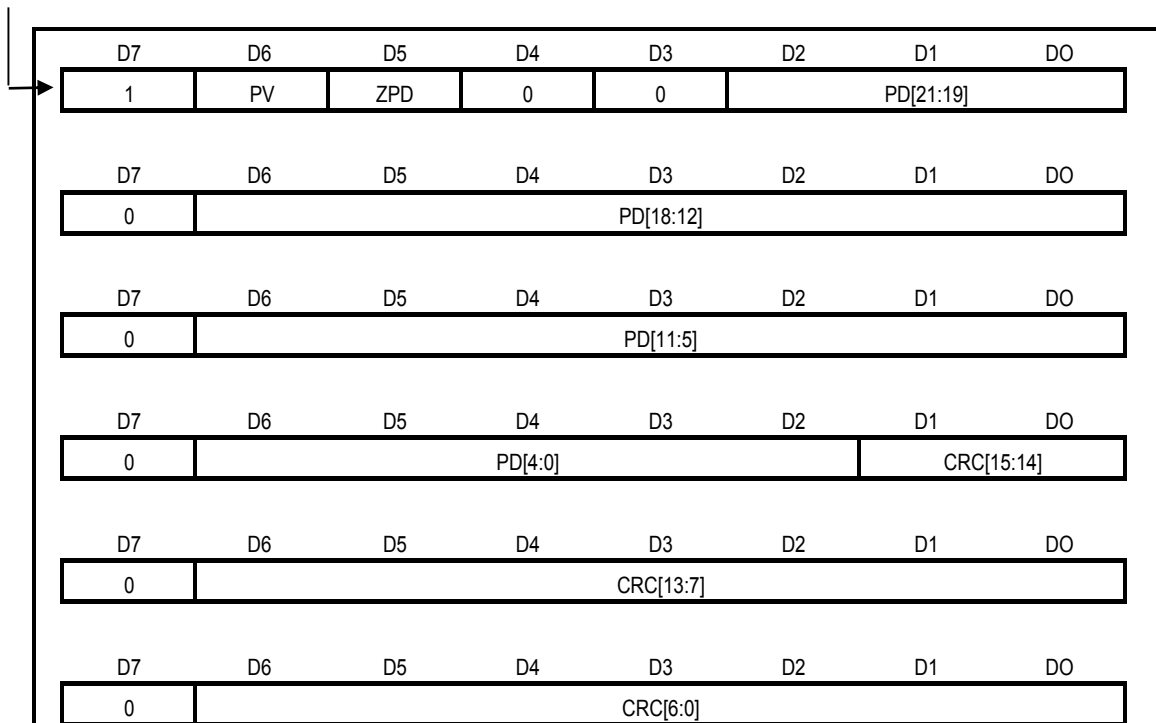
## 6.5 Asynchronous Serial Interface Protocol – Product Options ASI1 & ASI2

This section describes the communications interface for IncOders with ASI1 or ASI2 serial protocols. Data is transmitted by the IncOder continuously formatted into Frames. Each Frame consists of a number of 8 bit data words. Each 8 Bit data word (or byte) is transmitted from a standard UART using N-8-1 (no parity, 8 data bits, 1 stop bit). ASI1 has a Baud rate of 230400 and ASI2 has a Baud rate of 921600. See below for the data format of each transmitted data word. The Frames are transmitted at a rate of 10kHz nominal (same rate as Internal Position Update Period).



The following is the Asynchronous Serial Data protocol specified with the ASI1 or ASI2 Product Option. Each frame is defined as 6 bytes and the data format is defined as follows:

First byte (transmitted first):



### Data Definition for Asynchronous Serial Interface

- PV      Position Valid flag. Set to 1 when data is valid, otherwise set to 0
- ZPD      Zero Point Default. Set to 1 when the Zero Point is at Factory Default, otherwise set to 0.
- PD[21:0]      IncOder Position Data. If resolution of device is less than 22 bits then the MSBs of this field are set to 0.  
When PV is 0, PD[21:0] value is not defined.
- CRC[15:0]      CRC-16: To verify transmission, calculate the CRC of all 48 bits of the message but with CRC[15:0] set to 0.  
The resulting 16 bit CRC result should be the same as the received CRC[15:0].  
Use the following CRC-16 parameters:  
  - Polynomial      0x8005
  - Initial data      0x0000
  - MSB first (not reversed)
  - No final XOR calculation.

## 6.6 Serial Peripheral Interface Protocol Definition – Product Option SPI1

This section describes the communications interface for IncOders with SPI1 (Serial Peripheral Interface) serial protocol. SPI is a widely used serial interface between micro processors/controllers and peripherals. SPI uses a clock sequence from a master to control the transmission of data from the IncOder. IncOders with SPI data interface conform to the RS422 hardware specification.

Note that the DATA outputs and the CLOCK inputs are not terminated with load resistors.

The following section defines the communication protocol.

The IncOder protocol specifies that each data frame consists of 6 bytes of data (each of 8 bits, 48 bits in total) containing the position, status flags and CRC (see timing diagram on the following page).

SPI Clock Polarity is defined so that the CLOCK idle state is HIGH and the Clock Phase is defined so that the data is captured on the falling edge of CLOCK, and the data is propagated on the rising edge of CLOCK. This is commonly depicted as CPOL=1, CPHA=0 (also depicted as UCCKPL=1, UCCKPH=1).

Clock rate is 100kHz to 5MHz.

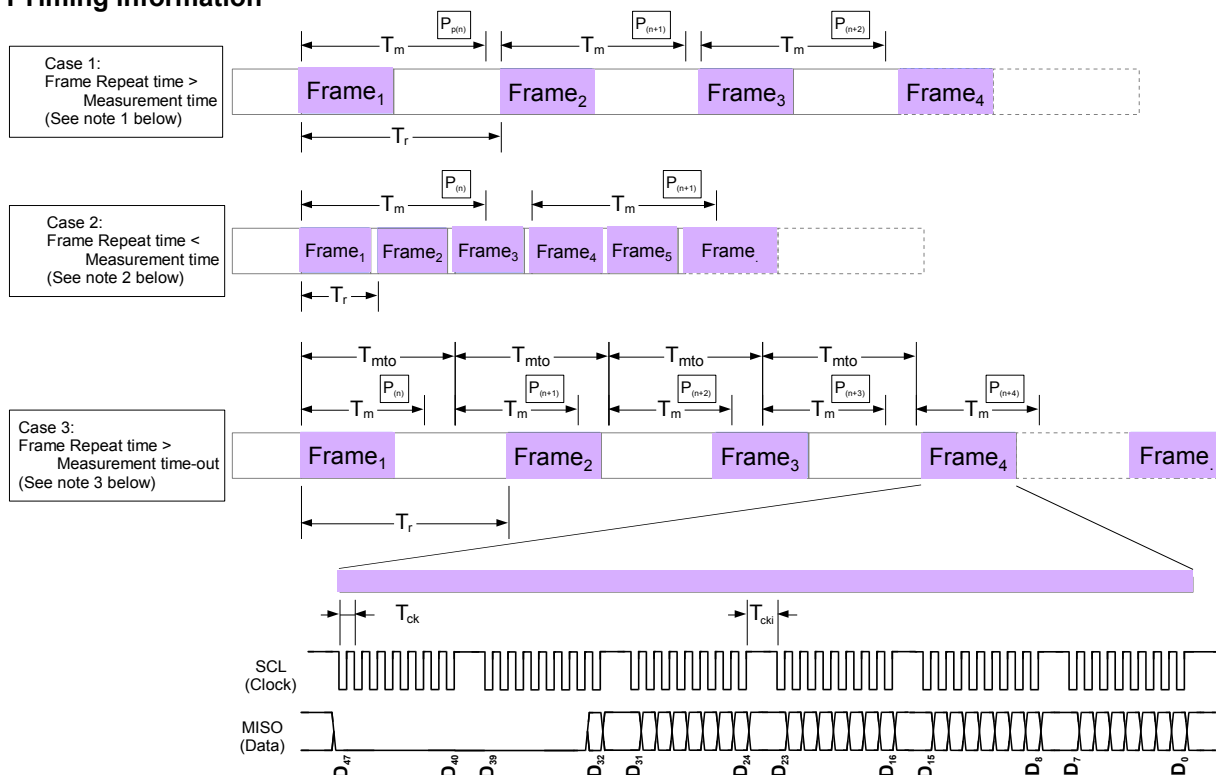
### Data Definition for IncOder SPI Protocol

<b>D47-D33</b>	SBZ	These bits will always be Zero.
<b>D32</b>	ZPD	Zero Point Default flag. Set to 1 when the Zero Point is at Factory Default, otherwise 0
<b>D31</b>	PV	Position Valid Flag. Set to 1 when position data is valid, otherwise 0.
<b>D30</b>	PS	Position Synchronised flag. Set to 1 when the position measurement was triggered by a previous SPI Frame. Set to 0 when the position measurement was triggered by a Measurement Time-out (see note 3 overleaf). Use this flag to ensure that the IncOder has synchronised position measurements to the SPI Frames (Case 1, overleaf).
<b>D29-D8</b>	PD[21:0]	Binary position data. If resolution of device is less than 22 bits, then the most significant bits of this field are set to 0. The LSB of this field is in D0. When PV is 0, PD[21:0] value is not defined.
<b>D7</b>	SD	Stale Data flag. Set to 1 when the position data has been transmitted at least once before. Set to 0 when the position data has not been transmitted before. Use this flag to detect when a new measurement has been completed (Case 2, overleaf).
<b>D6-D0</b>	CRC[6:0]	Cyclic Redundancy Checksum. 7 Bit CRC: Polynomial 0x5B, Initial data 0x0000, MSB first (not reversed), No Final XOR.

Note – the CRC is generated from bits D7 through D32. It is calculated using a 32 bit word (or 4 bytes) with D7 shifted in to the Least Significant Bit and the 6 Most Significant Bits set to '0' as required.



## SPI Timing information



### Timings determined by the Controller (SPI Master):

- $T_{ck}$  Clock period ( $1/T = 100\text{kHz}$  to  $5\text{MHz}$ ).
- $T_{cki}$  Clock Idle Period. Time between bytes during which CLOCK is idle.  $T_{cki}$  should be  $< T_{ckimax} = 10\mu\text{s}$
- $T_r$  Frame Repetition period.

### Timings defined by the IncOder (SPI Slave):

- $T_m$  Position Measurement time. The time from the start of a position measurement to when the position and status is ready for transmission.  $90\mu\text{s} \leq T_m \leq 95\mu\text{s}$
- $T_{mto}$  Position Measurement Time-out. The time after a position measurement has been triggered that the IncOder will automatically trigger a new measurement.  $135\mu\text{s} \leq T_{mto} \leq 145\mu\text{s}$ .

### Notes:

1. The IncOder will always attempt to trigger a new position measurement when a new SPI frame is started by the host. This will always be the case when  $T_r$  is greater than  $T_m$  and less than  $T_{mto}$ .
2. If a position measurement has already been triggered when a new SPI frame is started by the host, then a new position measurement will not be re-triggered. This may be the case when  $T_r$  is less than  $T_m$ .
3. If the Host does not start a new SPI frame within time  $T_{mto}$  from the previous frame (the case when  $T_r$  is greater than  $T_{mto}$ ), then the IncOder will automatically trigger a new position measurement.
4. In all cases, the IncOder will transmit the most recently completed measured position and status (see table below).
5. When CLOCK is idle for at least  $T_{ckimax}$ , then the IncOder SPI interface will reset. The first falling edge on CLOCK after  $T_{ckimax}$  will start the transmission of a new frame. This can be useful if the SPI host and slave (IncOder) lose Frame/Byte synchronisation (detected by invalid CRC).

Frame Number	Position transmitted (case 1)	Position transmitted (case 2)	Position transmitted (case 3)
Frame 1	$P_{(n-1)}$	$P_{(n-1)}$	$P_{(n-1)}$
Frame 2	$P_{(n)}$	$P_{(n-1)}$	$P_{(n)}$
Frame 3	$P_{(n+1)}$	$P_{(n-1)}$	$P_{(n+1)}$
Frame 4		$P_{(n)}$	$P_{(n+3)}$
Frame 5		$P_{(n)}$	

## 6.7 Digital + 1V peak to peak sin/cos I/face Product Options SSIV-8V, ASI1V & SPI1V

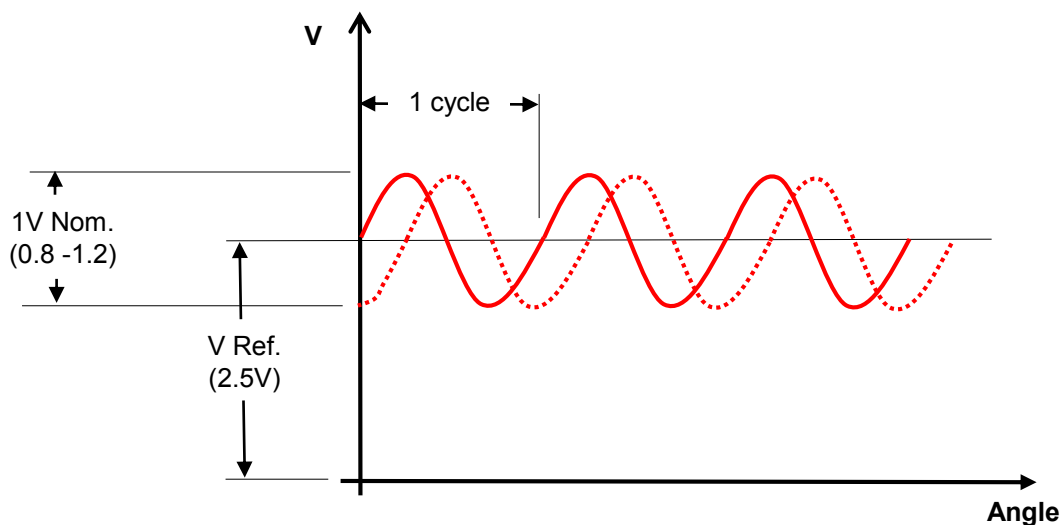
The IncOder range offers 10 Options of digital + 1V peak to peak sin/cos Interfaces.

Digital + 1V peak to peak sin/cos IncOders are designed to offer the combined advantages of precision, absolute digital data with rapid, incremental analogue outputs. Most applications do not require this and (lower cost) digital only options are most appropriate.

The internal update rate the 1V peak to peak analogue outputs is <10microseconds. The digital output is typically >20 times more accurate than the analogue output.

All formats of digital output are available: SSI1-8, ASI1 & SPI1 in combination with the 1V peak to peak sin/cos outputs and may be specified using Product Option SSI1V, SSI2V etc. in the part number. Note max. resolution of the digital output is limited to  $\leq 18$  Bits in this format. Only the axial connector option (Product Option AC1) is available for digital + 1V sin/cos outputs.

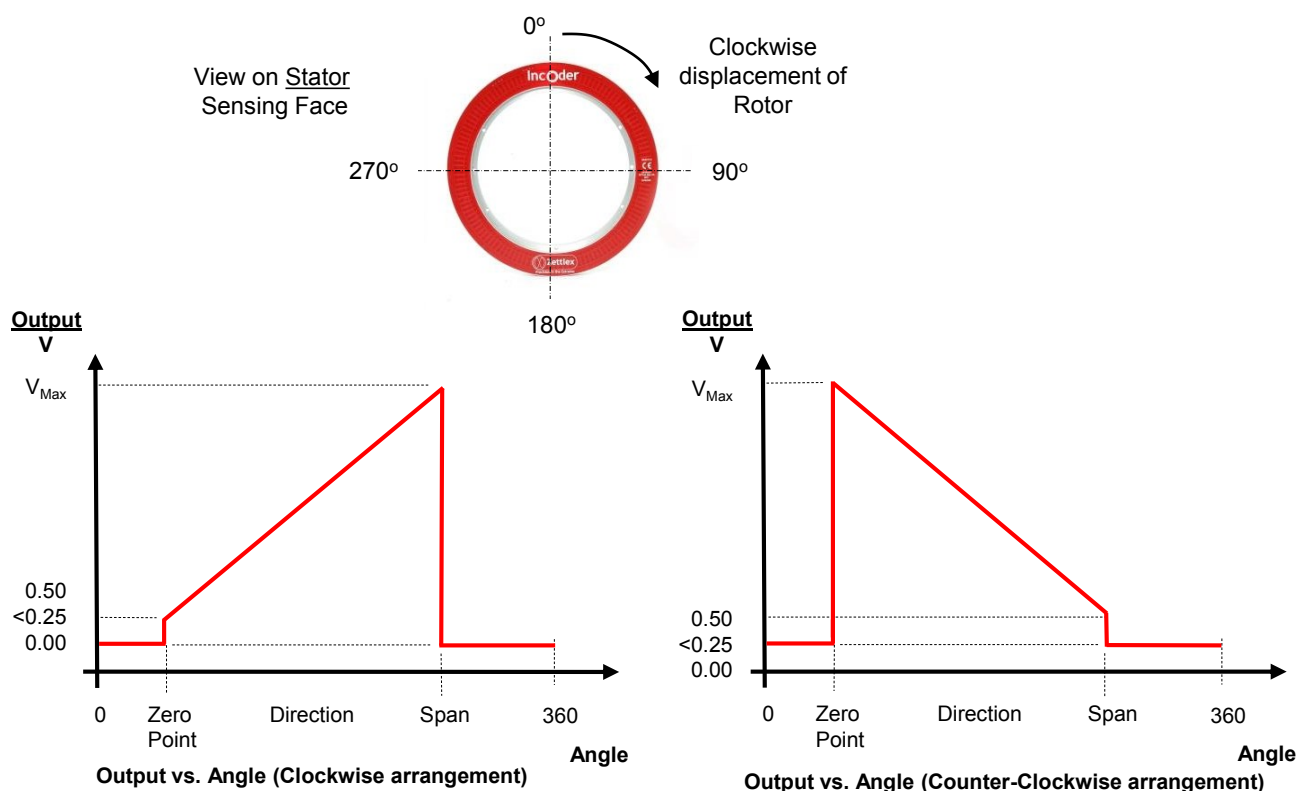
The analogue output is in the form of sin and cos 1V (nominal) peak to peak voltage as shown below:-



Analogue Voltage Interface versions of IncOder are available for all sizes of IncOder (other than 37, 58 & 300mm) with max. voltage outputs of 4.5, 5.0, 9.5 and 10.0V in 90°, 180°, 270° & 360° spans with either clockwise or counter-clockwise directions. Zero, direction & span are field programmable without a PC. The following sections 6.8.1 - 7 describe the various Product Options and field programming:-

### 6.8.1 Zero Point & Zero Set for Analogue Voltage Interface

The Zero Point is the datum from which angle is measured. IncOders carry a factory Zero Point setting. For Screw Mount products, the Zero Point lies within a range of  $\pm 5^\circ$  of the Rotor and Stator dowel positions at 12 o'clock (near the 'O' of the printed 'IncOder'). The Zero Point factory setting can be changed using the Zero Set line on the IncOder's connector or cable – see Section 7.2 or 9.1. The Zero Set signal will set the current IncOder position as the Zero Point (held in memory when power is removed). If only a new Zero Point is set, then Direction & Span factory settings are shifted automatically to suit the new Zero Point. To use the Zero Set function, the relevant connection should be connected to 0V for at least 1 second at power up – see Section 7.2 or 9.1. This line should be left unconnected (i.e. open circuit) during normal operation.



### 6.8.2 Selecting Max. Voltage Output for Analogue Voltage Interface

IncOders are available with 4 different Max. Voltage Outputs: 4.5, 5.0, 9.5 or 10.0V. These are set at the factory and so need to be specified, using the relevant Product Option, when ordering. For example:-

Part number INC-X-XXX-XX1001-**V**XXXX-XXX-XX-XX

For $V_{max}$ = 10.0V, <b>V = V</b>
For $V_{max}$ = 4.5V, <b>V = W</b>
For $V_{max}$ = 5.0V, <b>V = X</b>
For $V_{max}$ = 9.5V, <b>V = Y</b>

#### 6.8.3 Direction & Direction Set for Analogue Voltage Interface

IncOders measure angle from a datum or Zero Point, so if factory settings are to be over-written, a point other than Zero & Span is needed to indicate sense of direction. This differentiates between measurement over 300° versus 60°, for example. IncOders are supplied with a factory direction setting as per their Product Option. The Direction Set signal will set the current IncOder position as the Direction Set point between Zero and Span - thus giving the IncOder with its direction sense (held in memory when power is removed). This position need not be exact but must be between Zero Position and 50% of Span. To use this function, the relevant connection should be connected to 0V for at least 1 second at power up – see Section 7.2 or 9.1. This line should be left unconnected (i.e. open circuit) during normal operation. Until a new Span is set, after Direction setting, the Zero & Span remain as the most recent settings. **If any of the Zero, Direction & Span factory settings are to be changed by field programming, this must be carried out in sequence:- Zero - Direction - Span.**

#### 6.8.4 Span & Span Set for Analogue Voltage Interface

The Span is the angular range (measured from Zero) over which angle is measured. IncOders carry a factory setting in accordance with the Product Option e.g. V0360 is 0.5-10V over 360° clockwise and W2701 is 0.5-4.5V over 270° counter-clockwise. See Section 8 for the full list of options. Unless specified by the relevant Product Option, the default is 360° measured in a clockwise direction from the Zero Point.

The Span Set signal will set the current IncOder position as the Span (this is held in memory when power is removed). To use this function, the relevant connection (see Section 7.2 or 9.1) should be connected to 0V for at least 1 second at power up. This line should be left unconnected (i.e. open circuit) during normal operation. If only Span is set then Zero & Direction remain as the factory settings.

If a Span of 360° is required, then the Reset signal should be used (see Section 6.8.4) followed by Zero setting and then Direction setting (but not Span). If a small Span is required, take care to ensure the Direction setting is between Zero Position and 50% of Span

Resolution and repeatability is equivalent to 16,384 steps (14bits) over the Span, so the smaller the Span, the finer the resolution and repeatability in real terms. The specified measurement performance is valid to a minimum Span of 45°.

#### 6.8.5 Reset for Analogue Voltage Interface

The Reset signal will reset all settings to the 0 to 360° clockwise default (in other words, the 0360 Product Option). To use this signal, the relevant connection (see Section 7.2 or 9.1) should be connected to 0V for at least 1 second at power up. This line should be left unconnected (i.e. open circuit) during normal operation.

#### 6.8.6 Error Values for Analogue Voltage Interface

IncOders output 0.5V at the Zero point and  $V_{max}$  at Span. If there is an internal error or malfunction within the IncOder then the output drops to <0.25V. Similarly, if Span is not 360° and IncOder travels past either Zero or Span positions, the output drops to <0.25V. In other words, an error signal shows out of range. For 360° IncOders, the changeover is from  $V_{max}$  to 0.5V at the 360° position.

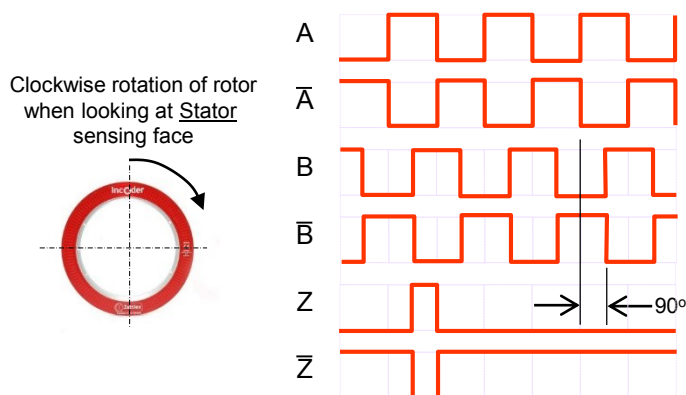
#### 6.8.7 Power Supply for Analogue Voltage Interface

Analogue Voltage Interface output IncOders can accept power from any DC voltage from 11.5 to 32VDC. Accordingly, Product Options for either 12, 24 or 24CT Power Supply may be specified (but not 5).

IncOders with A/B/Z pulses are often used as velocity or brushless motor encoders. A/B/Z pulse IncOders provide cyclical outputs as the encoder rotates. Streams of pulses are arranged in phase quadrature for direction sensing. The Z-reference or 'index' pulse is triggered once per turn. There are 6 Product Options:-

**Product Option ABZ1 - RS422 with 90° width Z reference**

**Product Option ABZ2 - RS422 with 180° width Z reference**



A leads B for clockwise rotation of rotor  
Phasing: 90° electrical  
Symmetry: 180° electrical  
Max. pulse frequency: 1MHz  
High signal: >2.5V  
Low signal: <0.5V  
Max. output load: 30mA  
Diagram shows 90° width Z reference (ABZ1)

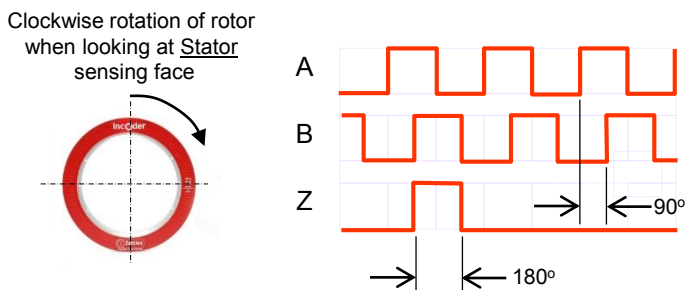
**Product Option ABZ3 - Push-Pull (TTL) with 90° width Z reference**

**Product Option ABZ4 - Push-Pull (TTL) with 180° width Z reference**

**Product Option ABZ5 - Push-Pull (HTL) with 90° width Z reference**

**Product Option ABZ6 - Push-Pull (HTL) with 180° width Z reference**

Push-Pull devices may be run in antivalent mode (shown above) or single ended mode (shown below).



A leads B for clockwise rotation of rotor  
Phasing: 90° electrical  
Symmetry: 180° electrical  
Max. pulse frequency: 1MHz  
High signal: >Vsupply – 2V (HTL) or >4.5V (TTL)  
Low signal: <0.2V  
Max. current: 30mA  
Diagram shows 180° width Z reference (ABZ4 or 6)

Note: 1 edge = 1 count or 1 bit. 4 counts per pulse. Readers should be set to 4x resolution for full resolution.

**Z Reference Position :** The factory set Z Reference Position is at +/-5° of the Rotor and Stator dowel positions at 12 o'clock (near the 'O' of the printed 'IncOder'). Z Reference Position may be changed using the Z Set or Z Reset lines on the IncOder's electrical interface (see Section 7.4 or 9.2).

**Setting Z Reference Position:** Z Set signal sets the current position as Z Reference Position. This is held in memory when power removed. Z Reset signal will reset the Z Reference Position to factory setting (held in memory when power removed). To use, the relevant connection should be connected to 0V for at least 1 second at power up but left unconnected (i.e. open circuit) during normal operation (see Section 7.4 or 9.2).

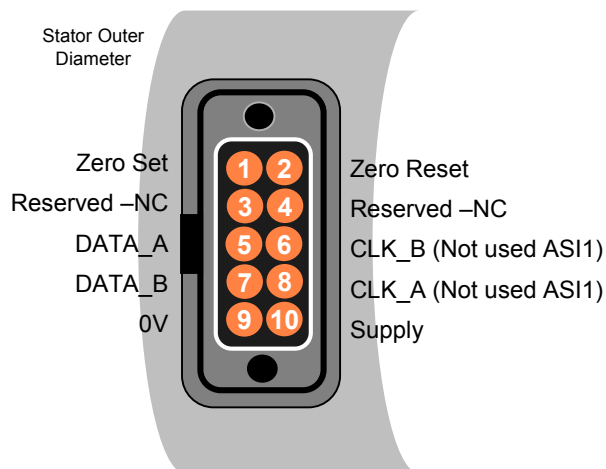
**Error Signalling:** IncOders carry out various self checks. If an error is detected then an error signal is generated. This is shown by all outputs going to low signal (including differential outputs).

**Counts per rev (CPR) & Pulses per rev(PPR):** CPR may be chosen as any integer number of bits up to 19 e.g.12 (4096CPR). PPR may be chosen up to 131,072. See Section 8 on how to select CPR or PPR from the part number. In part number, letter P in front of chosen pulses per rev indicates selection.

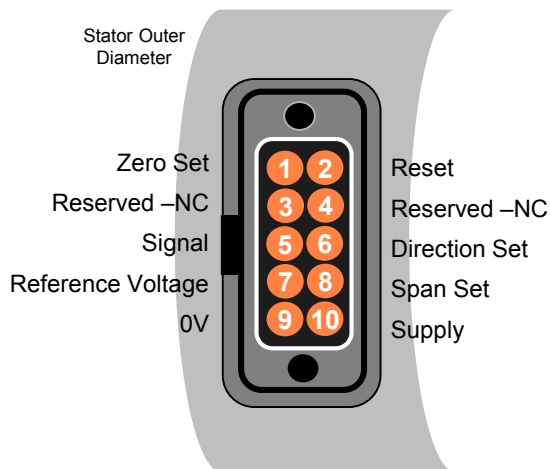


## 7. Connector Diagrams

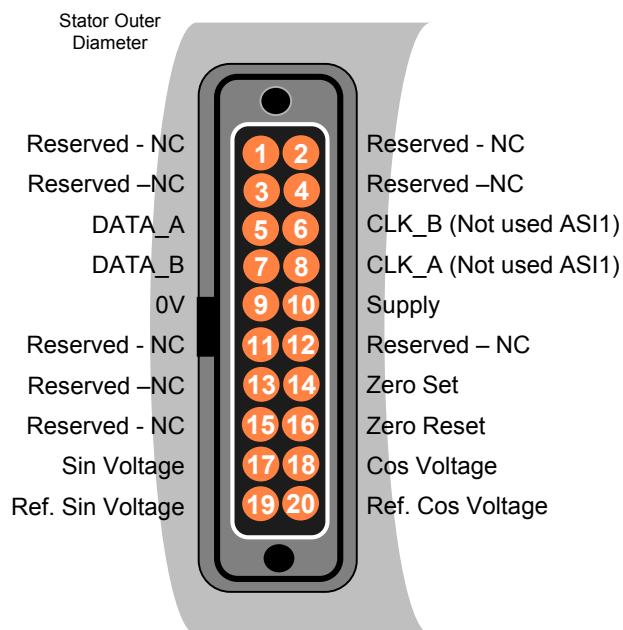
### 7.1 Product Option AC1\* + Digital Outputs SSI1-8, ASI1, SPI1



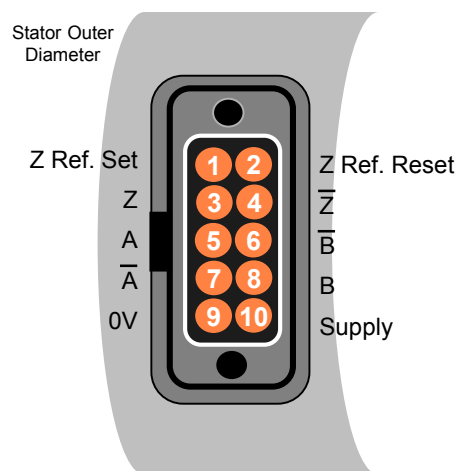
### 7.2 Product Option AC1\* + Analogue Voltage Outputs V0360, X3601 etc.



### 7.3 Product Option AC1 with + 1V Sin/Cos Outputs SSI1V-8V, ASI1V, SPI1V



### 7.4 Product Option AC1\* + A/B/Z Pulse Outputs ABZ1 - 6

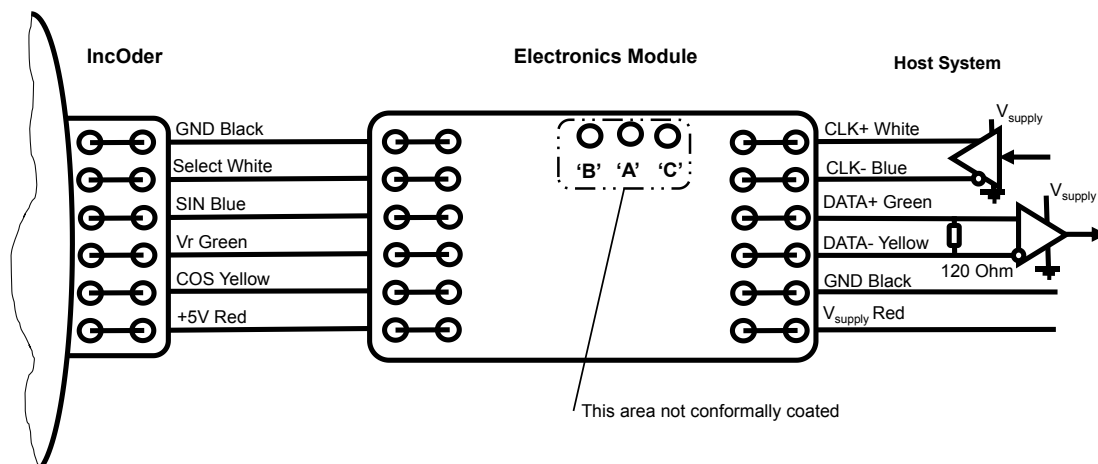


#### Notes:-

- \* Data also applies to AC2, RC1 & RC2 for 58mm products. Data also applies to connectors at end of radial connections on RFC1-4 on 75-300mm products.
- 27kOhm pull up resistors fitted to Zero Set, Span Set, Direction Set, Zero Reset & Reset inputs
- Reserved pins are for factory use only and should be left open circuit
- SSI1V-8V, ASI1V and SPI1V Product Options are only available with AC1 connection.

## 7.1 Connector Diagram & Zero Setting for 37mm

For compactness, the 37mm IncOder has a separate Electronics Module with integral cable, rather than a connector. The electrical connections are shown below:-



The Zero Point is the datum from which angle is measured. As supplied, the IncOder carries a factory Zero Point setting. The Zero Point can be changed using a Zero Set or Zero Reset function.

The Zero Set function will set the current IncOder position as the Zero Point (held in memory when power removed). This Zero Set function is carried out as an input to the Electronics Module. Inputs 'A' and 'B' (1mm diameter plated through holes identified on Electronics Module) should be electrically connected together for more than 1 second at power up (carried out manually using a wire jumper provided with each IncOder)

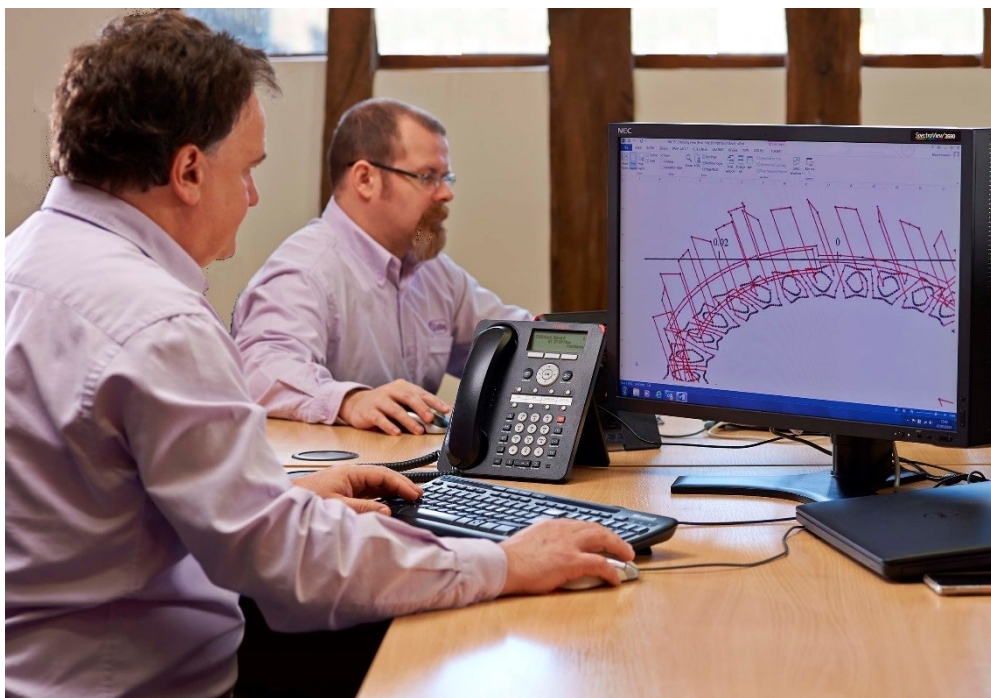
The Zero Reset signal will reset the Zero Point to the factory setting (held in memory when power removed). The Zero Reset function is carried out as an input to the Electronics Module. Inputs 'A' and 'C' (1mm diameter plated through holes identified on Electronics Module) should be electrically connected for more than 1 second at power up (carried out manually using a wire jumper provided with each IncOder).



***Too much information? A bit confused?***

***We're here to help***

***Ask us on [info@zettlex.com](mailto:info@zettlex.com)  
or phone us on +44 (0) 1223 874444  
or contact your local rep (list on page 62)***



# 8.1 Product Ordering (75 to 300mm)

**INC - X - XXX - XXXXXX - XXXX - XXXX - X - XX**

## Mechanical Format

Screw Mount Stator  
& Screw Mount Rotor – **3**

Servo Clamp Stator  
& Set Screw Rotor – **4**

Servo Clamp Stator  
& Plain Rotor – **6**

Screw Mount Stator  
& Set Screw Rotor – **7**

Screw Mount Stator  
& Plain Rotor – **8**

Servo Clamp Stator  
& Screw Mount Rotor – **9**

Duplex Stator  
& Duplex Rotor – **10**

External Mount Stator &  
Screw Mount Rotor – **13**

External Mount Stator &  
Plain Rotor – **14**

External Mount Stator &  
Set-Screw Rotor – **15**

## Outer Diameter

<b>075</b>	<b>150</b>	<b>225</b>
<b>100</b>	<b>175</b>	<b>250</b>
<b>125</b>	<b>200</b>	<b>300</b>

## Resolution

10 Bits <b>101001</b>	17 Bits <b>171001</b>
11 Bits <b>111001</b>	18Bits <b>181001</b>
12 Bits <b>121001</b>	19Bits <b>191001</b>
13 Bits <b>131001</b>	20Bits <b>201001</b>
14Bits (Note 3) <b>141001</b>	21Bits <b>211001</b>
15 Bits <b>151001</b>	22Bits (Note 11) <b>221001</b>
16 Bits <b>161001</b>	PPR (Note 12) <b>PXXXXXX</b>

## Finish

**AN** clear, hard-anodized

## Supply Voltage

<b>5</b>	<b>12CT</b> cold temp.
<b>12</b>	<b>24CT</b> cold temp.
<b>24</b>	

## Connector

**AC1** for axial connector  
**RFC1** vertical connector, 100mm radial  
**RFC2** vertical connector, 12mm radial  
**RFC3** 90 degree connector, 100mm radial  
**RFC4** 90 degree connector, 12mm radial  
**RFC5** no connector, 100mm radial  
**RFC6** no connector, 12mm radial  
**RFC7** downward cable, 12mm radial  
**RFC8** upward cable, 12mm radial  
**RFC9** downward cable, 100mm radial  
**RFC10** upward cable, 100mm radial  
**AFL1** integral axial cable  
**AFL2** integral axial cable, sealed Rotor & Stator  
**AFL3** integral axial, high flex cable  
**AFL32** integral axial, high flex cable, sealed Rotor & Stator  
**AFL4** integral axial cable, low profile  
**AFL42** integral axial cable, low profile, sealed Rotor & Stator  
**AFL5** integral axial, PTFE / MIL spec,  
**AFL52** integral axial, PTFE / MIL spec, sealed Rotor & Stator

## Communication Interfaces

<b>ASI1</b> Asynch. Serial I/face 1	<b>SSI6V</b> SSI Type 6+1V sin/cos
<b>ASI2</b> Asynch. Serial I/face 2	<b>SSI7V</b> SSI Type 7+1V sin/cos
<b>SSI1</b> SSI Type 1	<b>SSI8V</b> SSI Type 8+1V sin/cos
<b>SSI2</b> SSI Type 2	<b>SPI1V</b> SPI + 1V sin/cos
<b>SSI3</b> SSI Type 3 (Note 8)	<b>V0360</b> 0-10V Clockwise 360° (Note 2)
<b>SSI4</b> SSI Type 4 (Note 8)	<b>V3601</b> 0-10V C-clockwise 360°
<b>SSI5</b> SSI Type 5 (Note 8)	<b>V0270</b> 0-10V Clockwise 270°
<b>SSI6</b> SSI Type 6	<b>V2701</b> 0-10V C-clockwise 270°
<b>SSI7</b> SSI Type 7	<b>V0180</b> 0-10V Clockwise 180°
<b>SSI8</b> SSI Type 8 (Note 8)	<b>V1801</b> 0-10V C-clockwise 180°
<b>SSI9</b> SSI Type 9 (Note 8)	<b>V0090</b> 0-10V Clockwise 90°
<b>SPI1</b> Serial Peripheral I/face	<b>V0901</b> 0-10V C-clockwise 90°
<b>ASI1V</b> ASI + 1V sin/cos	<b>ABZ1</b> RS422 90° width Z (Note 5)
<b>SSI1V</b> SSI Type1+1V sin/cos	<b>ABZ2</b> RS422 180° width Z
<b>SSI2V</b> SSI Type2+1V sin/cos	<b>ABZ3</b> Push-Pull TTL 90° width Z
<b>SSI3V</b> SSI Type3+1V sin/cos	<b>ABZ4</b> Push-Pull TTL 180° width Z
<b>SSI4V</b> SSI Type4+1V sin/cos	<b>ABZ5</b> Push-Pull HTL 90° width Z
<b>SSI5V</b> SSI Type5+1V sin/cos	<b>ABZ6</b> Push-Pull HTL 180° width Z

## Notes:

- 1 IncOder includes 1 Stator & 1 Rotor but excludes Accessories (e.g. Servo Clamps)
- 2 Zero, Span & Direction for analogue output may be over-written by user.  $V_{max}$  is specified by Product Option. For  $V_{max}$  of 10Volts then  $V=V$ ; for  $V_{max}$  of 4.5Volts then  $V=W$ ; for  $V_{max}$  of 5Volts then  $V=X$ ; for  $V_{max}$  of 9.5Volts then  $V=Y$
- 3 Analogue Voltage Interfaces are all 14Bit resolution & 12, 24, 12CT or 24CT Supply Voltage
- 4 Digital + 1V sin/cos output only available in AC1 Connection, 12 Supply Voltage & 125mm size
- 5 Highest resolution for ABZ output is 19Bits
- 6 INC-10 only available in 125mm and higher sizes with AC1 or AFL connector options.
- 7 INC-10 default is for inner and outer devices to be identical – see Section 5.4.1 for alternative
- 8 Maximum effective resolution limited by communications protocol – see Section 6.4.2
- 9 0-10V Communication Interface not available in 300mm (yet)
- 10 See Section 8.3 for Extended Product Range options
- 11 22Bit resolution only available in sizes of 150mm and above
- 12 For ABZ pulse output only - if required resolution is not an integer bit value, specify pulses per rev up to a max of 131,072.

**If you have difficulty in specifying what you need, please contact Zettlex or your local representative.**

Here are some examples of part numbers:-

**INC - 3 - 075 - 181001 - SSI1 - AC1 - 12 - AN**

Screw mount format, 75mm diameter, 18 bit resolution, SSI1, axial connector, 12V, hard-anodized.

**INC - 4 - 150 - 191001 - ASI1 - RFC1 - 24 - AN**

Servo clamp format, 150mm diam., 19 bit resolution, asynchronous serial data, radial flex connector 100mm long, 24V, hard-anodized.

In the event that a custom or non-standard product is required, we will generate a part number accordingly – like the following example:-

**INC - ACME - 508 - 141002 - X3601 - AB - 12CT - A**

ACME design mechanical format, 508mm diam., 14 bit resolution, data output over 2 revs, 0.5 to 5.0V over 360° clockwise, custom connector, 12V supply, cold temperature option, Alocrom finish.

## 8.3 Product Ordering – Extended Range

**For most applications Extended Product Range Options are not necessary.** However, in those instances where these additional / alternative steps are mandatory or deemed necessary, please add the following Product Options to the end of the standard part number. One or more of Extended Product Range Codes may be added. Note that selection of any Extended Product Range Codes increase costs and lead-times and should only be specified if necessary.

- A** Alocrom 1200 conductive surface finish
- B** Extended thermal stress-screening (burn-in test) / bake-off
- E** Engraved serial number and part number on Stator & Rotor (rather than serial label)
- G** Very high shock & vibration mechanical arrangement
- P** Use of leaded solder (rather than RoHS compliant solder)
- S** Surtec-650 conductive surface finish (rather than clear, hard-anodized surface finish) – note this is standard finish on 37 and 58mm devices

For cold temperature option (down to -60°C operating temperature) select **12CT** or **24CT** in Supply Voltage Product Option.

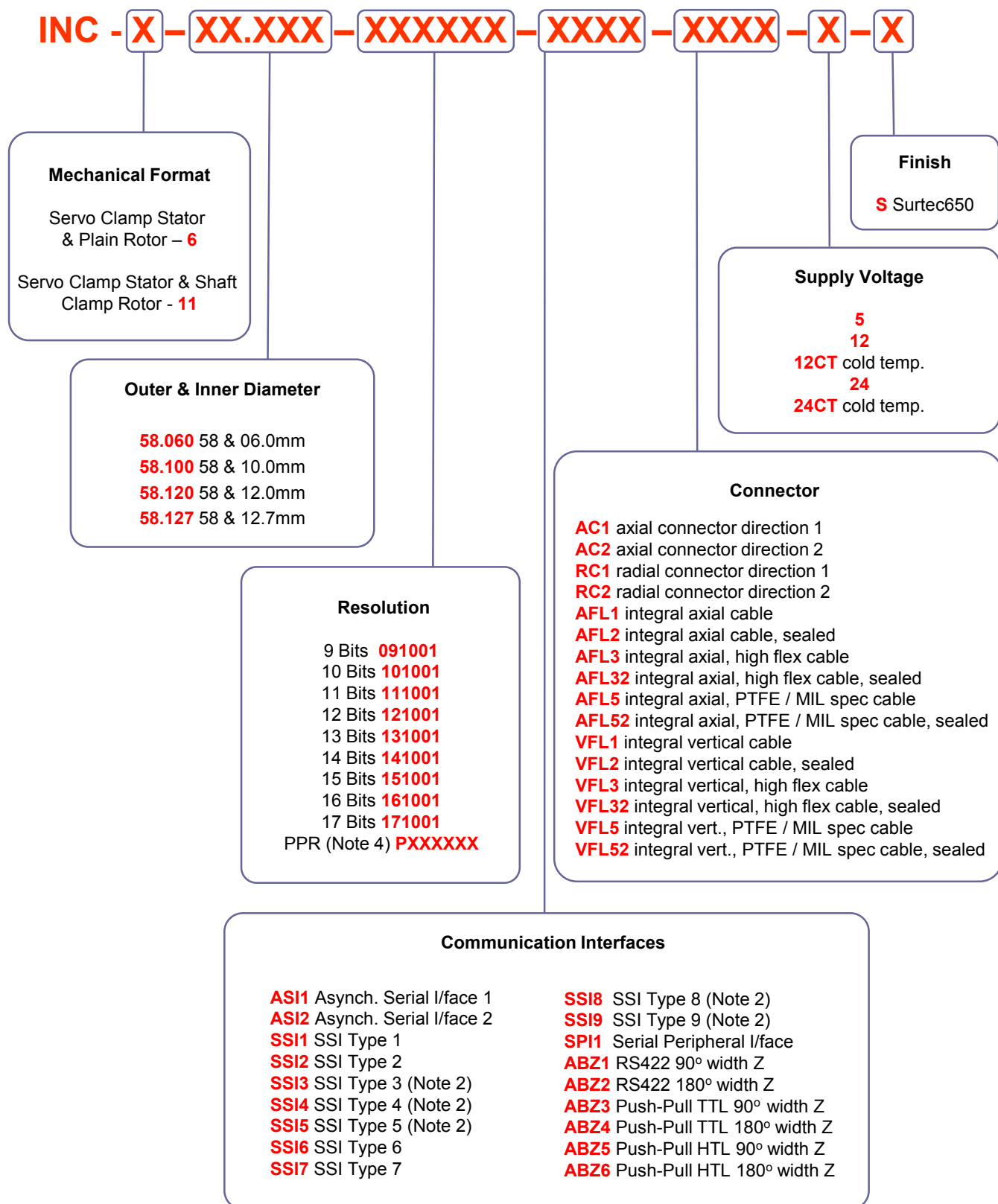
Example of an extended part number:

**INC - 4 - 150 - 191001 - ASI1 - RFC1 - 12CT - ABG**

Servo clamp format, 150mm diam., 19 bit resolution, asynchronous serial data, radial connection 100mm long with vertical connector, 12V (cold temperature), Alocrom surface finish, extended thermal stress-screening, very high shock & vibration arrangement.



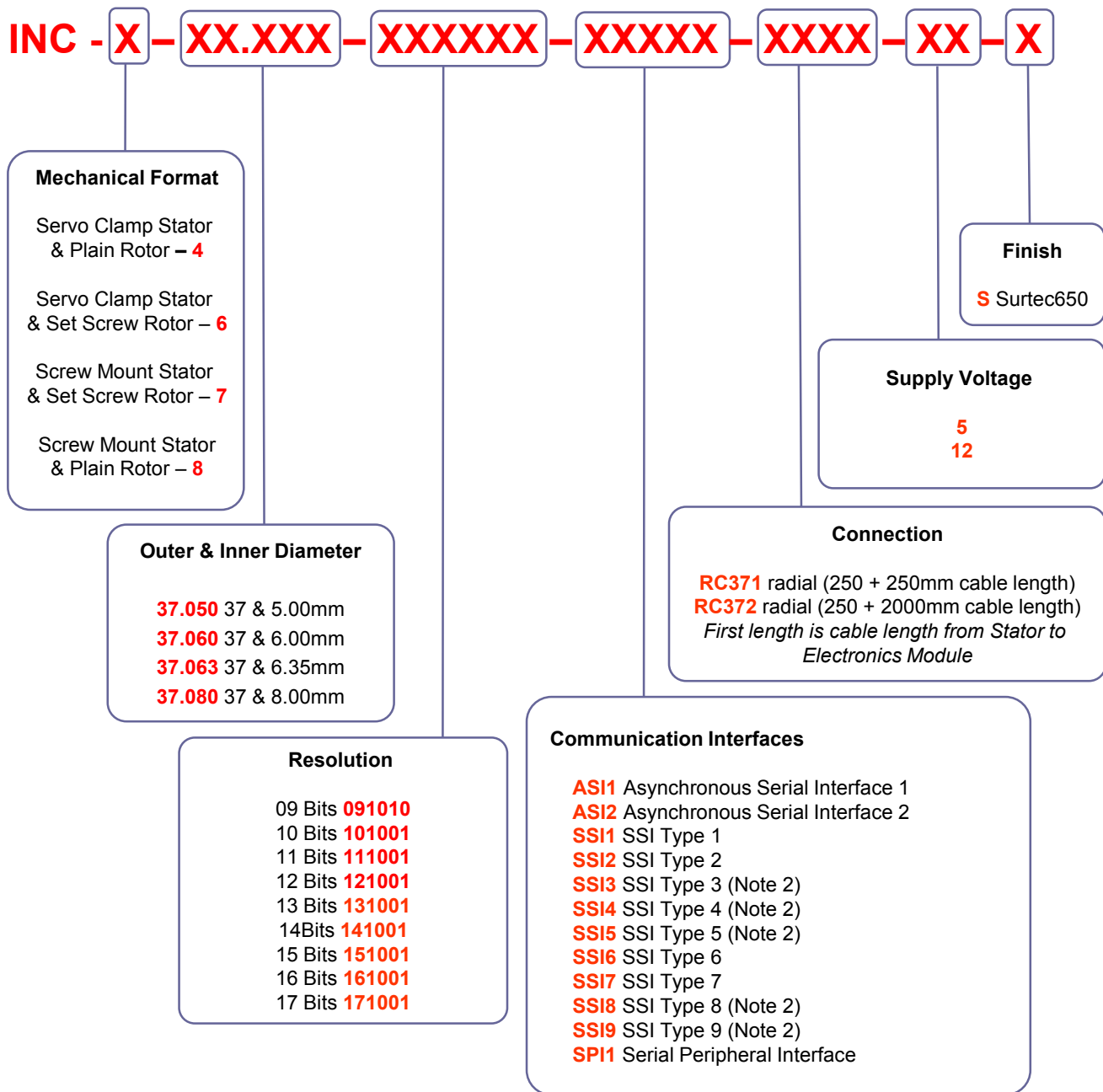
## 8.4 Product Ordering (58mm)



### Notes:

1. 1 IncOder includes 1 Stator & 1 Rotor but excludes Accessories (e.g. Servo Clamps)
2. Maximum effective resolution limited by communications protocol – see Section 6.4.2
3. See Section 8.3 for Extended Product Range options
4. For ABZ pulse output only - if required resolution is not an integer bit value, specify pulses per rev up to a max of 32,768.

## 8.5 Product Ordering (37mm)



### Notes:

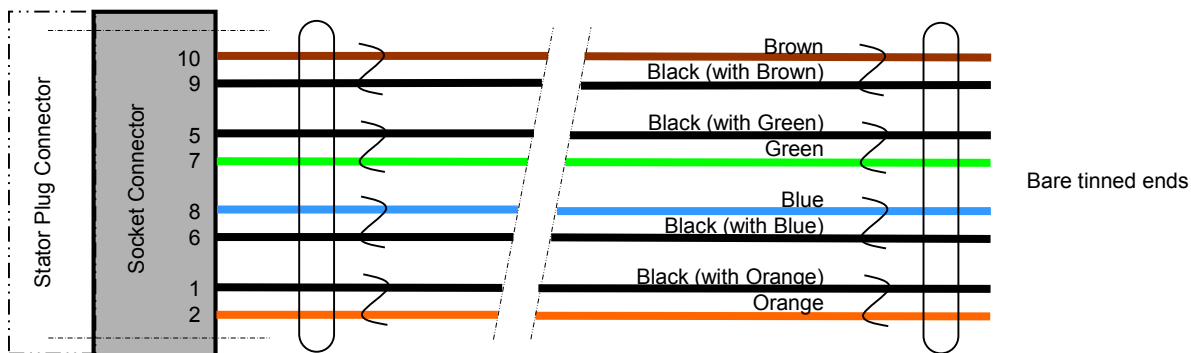
- Each 37mm IncOder includes 1 Stator & 1 Rotor & 1 Electronics Module and interconnecting cables but excludes Servo Clamps – which are sold separately – please see Section 10.
- Maximum effective resolution limited by communications protocol – see Section 6.4.2
- Only a sub-group of Extended Product Range options apply to 37mm
  - A** Alocrom 1200 conductive surface finish
  - B** Extended thermal stress-screening (burn-in test) / bake-off
  - E** Engraved serial number and part number on Stator & Rotor (rather than serial label)
  - P** Use of leaded solder (rather than RoHS compliant solder)

## 9.1 Standard Cable (8-way)

Mating connector and tinned wires on other end.  
 Use this for all SSI1-8, SPI1, ASI1, 0-10V comms.  
 Use the 10-way cable – shown overleaf – for A/B Pulse comms.



**Product Option** INC – CAB3 – 2 (2m long)  
**Product Option** INC – CAB3 – 5 (5m long)  
**Product Option** INC – CAB3 – 10 (10m long)



Pair No.	Colour	Connector Pin (For Info. Only)	Signal (SSI1-8 & SPI)	Signal (ASI1)	Signal (0-10V)
1	Brown	10	V <sub>supply</sub>	V <sub>supply</sub>	V <sub>supply</sub>
1	Black	9	0V	0V	0V
2	Black	5	Data A	Data A	Signal
2	Green	7	Data B	Data B	Signal Ref.
3	Blue	8	Clock A	Not Used	Span Set
3	Black	6	Clock B	Not Used	Direction Set
4	Black	1	Zero Set	Zero Set	Zero Set
4	Orange	2	Zero Reset	Zero Reset	Reset

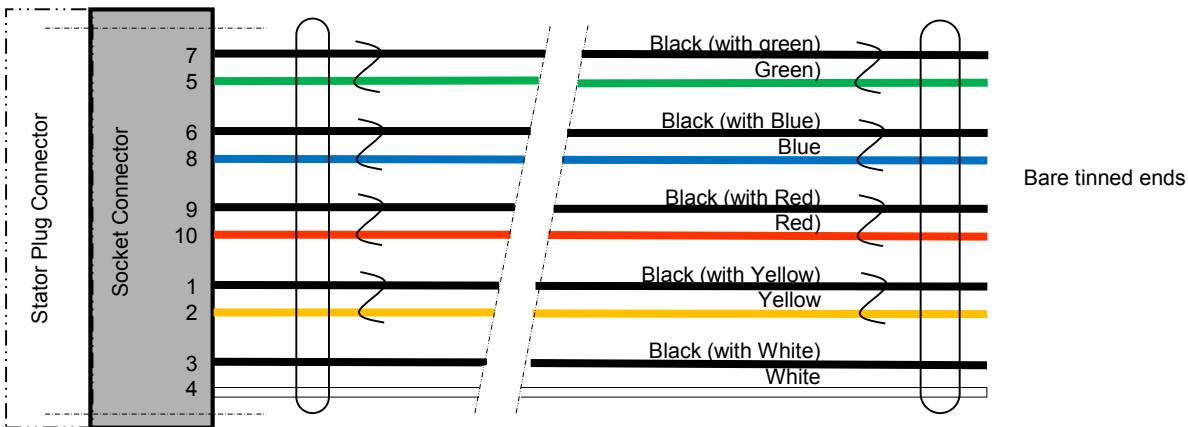
- Socket Connector: Harwin DataMate J-Tek 10-way with 2 jack screws, part number M80-461-10-42
- Temperature Rating = -30 to +80Celsius. UL Temperature Rating 80Celsius (UL AWM Style 2464)
- Diameter 6mm
- Cable length = 2000 +/- 100mm as standard
- Cable sheath = PVC
- Conductor insulation = polyethylene
- For integral axial cable (Product Option AFL1-6 & VFL1-6) connection table see Section 5.13.**

9.2 Standard Cable (10-way)

Mating connector and tinned wires on other end.  
Use this cable for A/B pulse comms.



- Product Option INC – CAB5 – 2 (2m long)
- Product Option INC – CAB5 – 5 (5m long)
- Product Option INC – CAB5 – 10 (10m long)



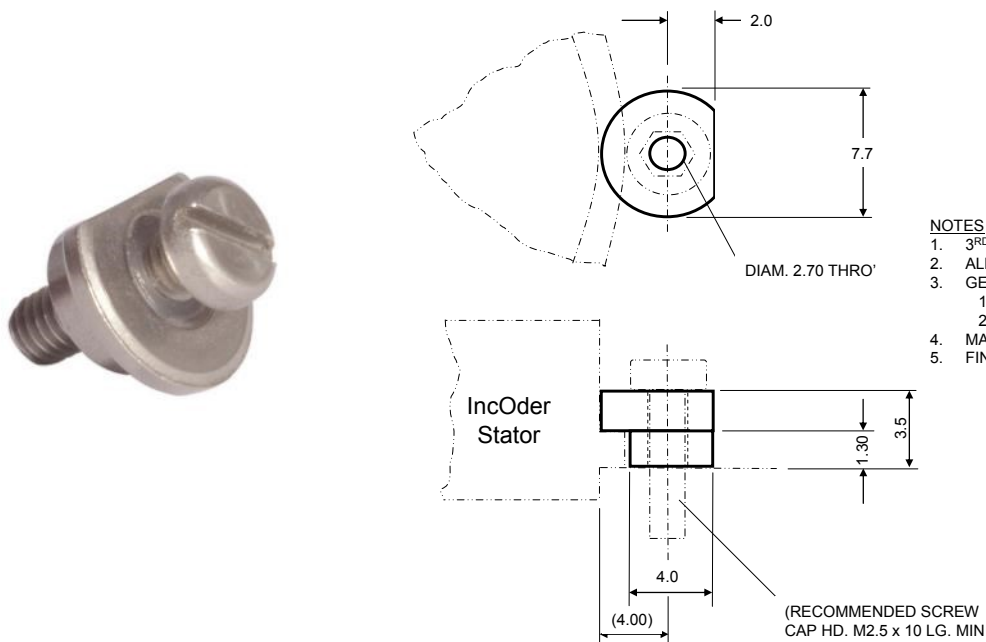
Notes

- Cable is 10-way, 24 AWG stranded (7x32) conductors, semi-rigid PVC external insulation & jacket, 5x twisted pairs, overall foil shield (100% cover), 24AWG stranded drain tinned copper drain wire.
- All other specification points as per Belden 9505
- Socket Connector: Harwin DataMate J-Tek 10-way with 2 jack screws, part number M80-461-10-42
- Temperature Rating = -30 to +80Celsius. UL Temperature Rating 80Celsius (UL AWM Style 2464)
- Diameter 7.3mm
- Cable length = 2000 +/- 100mm as standard
- **For integral axial cable (Product Option AFL1-6 & VFL1-6) connection table see Section 5.13.**

Pair No.	Colour	Connector Pin (For Info. Only)	Signal (A/B pulses & Z Ref.)
1	Black	7	A complement
1	Green	5	A
2	Black	6	B complement
2	Blue	8	B
3	Black	9	0V
3	Red	10	V <sub>supply</sub>
4	Black	1	Z Ref Set
4	Yellow	2	Z Ref. Reset
5	Black	3	Z
5	White	4	Z complement

### 9.3 Servo Clamp – Part Number INC-CLAMP1

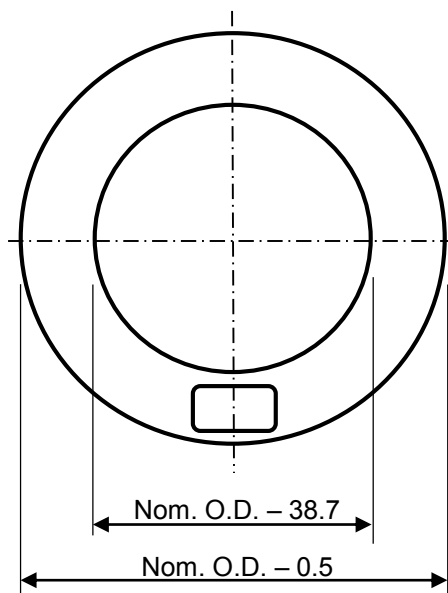
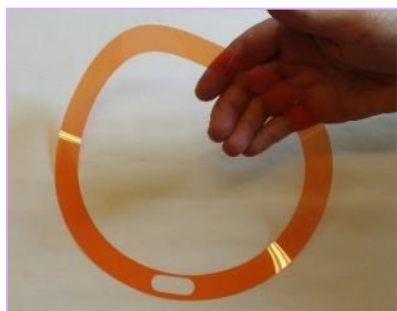
For use with Servo Clamp format IncOder Stators. These clamps are sometimes referred to as 'Clamp Cleat' or 'Screw Clamp'. Zettlex recommends the use of at least 3 Clamps to be used on each Stator in M2.5 locations equispaced on a P.C.D. of IncOder dimension ( $A + 8.00$ ). Supplied in a pack of 3 clamps.



### 9.4 Shim – Part Number INC-SH-XX

For use with all mechanical format IncOder Stators and/or Rotors where the host system is arranged such that axial gap IncOder limits cannot otherwise be met. The shims are nominally 0.1mm thick Polymex™ Polyester. A variety of sizes is available from 75 to 250mm sizes in 25mm steps. Specify by the nominal O.D. e.g. INC-SH-75. An aperture allows axial cable/connector egress. Supplied in packs of 5.

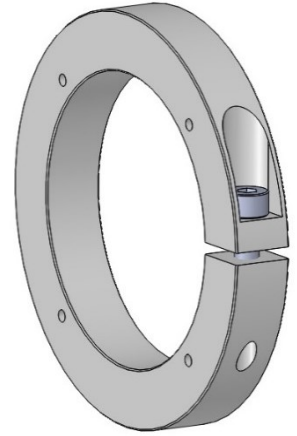
Part Number INC – SH -75 Nominal O.D. 75.0mm  
 Part Number INC – SH -100 Nominal O.D. 100.0mm  
 Part Number INC – SH -125 Nominal O.D. 125.0mm  
 Part Number INC – SH -150 Nominal O.D. 150.0mm  
 Part Number INC – SH -175 Nominal O.D. 175.0mm  
 Part Number INC – SH -200 Nominal O.D. 200.0mm  
 Part Number INC – SH -225 Nominal O.D. 225.0mm  
 Part Number INC – SH -250 Nominal O.D. 250.0mm





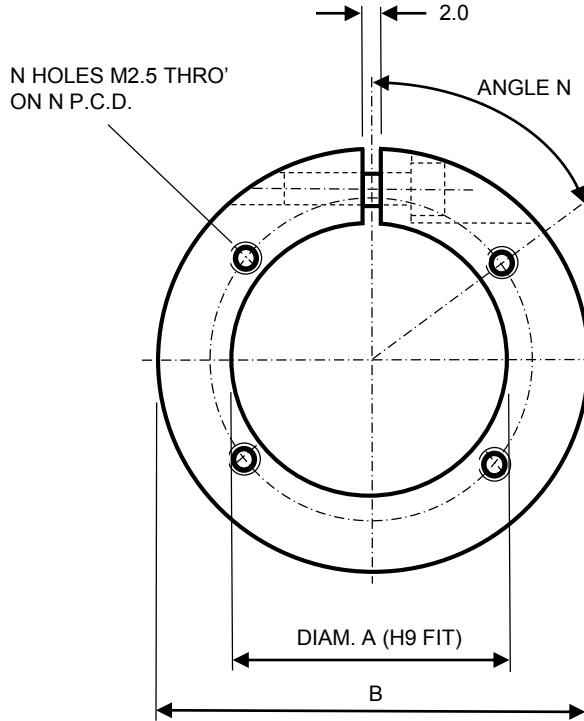
### 9.5 Rotor Shaft Clamp – Part Number INC-RSC-X

Rotor Shaft Clamps are for use with Screw Mount Rotors and allow the Rotors to be clamped, rather than screwed, to a through shaft. Rotor Shaft Clamps screw to the Rotors using the holes on the inner part of the Rotor. Once attached, the assembly is then tightened on to the through shaft using the Clamp's own screw. Rotor Shaft Clamps come in various sizes suitable for 75 to 300mm IncOrders.

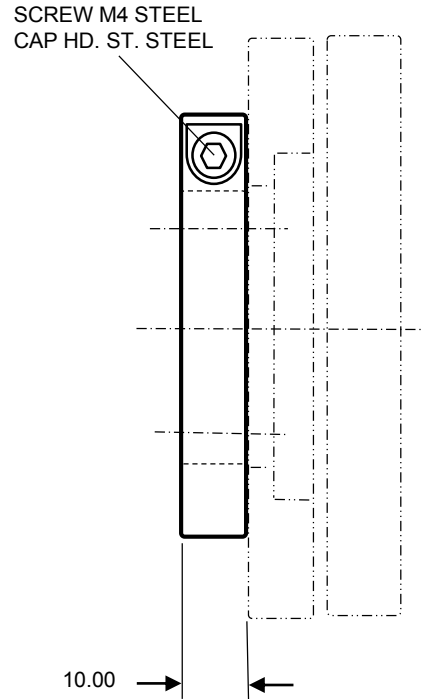


#### NOTES

1. 3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLER.COM](http://WWW.ZETTLER.COM)
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. MATERIAL = ALUMINIUM ALLOY, HARD ANODIZED
5. TOLERANCES (UNLES STATED OTHERWISE):-  
0 DECIMAL PLACES =  $\pm 0.5$   
1 DECIMAL PLACES =  $\pm 0.2$   
2 DECIMAL PLACES =  $\pm 0.1$



SIDE ELEVATION SHOWING POSITION OF A SCREW MOUNT ROTOR & A STATOR

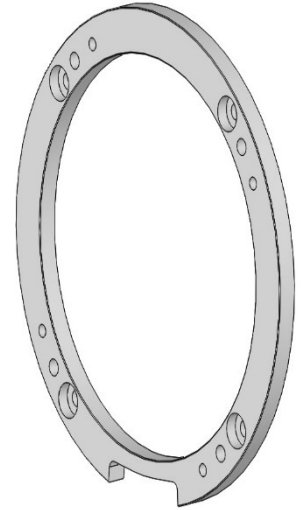


NOTE REGARDING ATTACHMENT METHOD. FIRSTLY, ATTACH CLAMP TO ROTOR USING 'N' SCREWS. TIGHTEN M4 SHAFT CLAMP SCREW TO SECURE TO SHAFT AND ONLY THEN TIGHTEN THE 2 SCREWS ADJACENT TO SHAFT CLAMP SPLIT LINE.

Description	Part Number	Dim. A mm	Dim. B mm	N P.C.D. mm	N Angle Degrees	N Holes
Rotor Shaft Clamp for 75mm IncOder	INC-RSC-75	24.000	44.00	30.50	45	4
Rotor Shaft Clamp for 100mm IncOder	INC-RSC-100	49.000	69.00	55.50	45	4
Rotor Shaft Clamp for 125mm IncOder	INC-RSC-125	74.000	94.00	80.50	45	4
Rotor Shaft Clamp for 150mm IncOder	INC-RSC-150	99.000	119.00	105.50	30	6
Rotor Shaft Clamp for 175mm IncOder	INC-RSC-175	124.000	144.00	130.50	30	6
Rotor Shaft Clamp for 200mm IncOder	INC-RSC-200	149.000	169.00	155.50	30	6
Rotor Shaft Clamp for 225mm IncOder	INC-RSC-225	174.000	194.00	180.50	30	6
Rotor Shaft Clamp for 250mm IncOder	INC-RSC-250	199.000	219.00	205.50	22.5	8
Rotor Shaft Clamp for 300mm IncOder	INC-RSC-300	249.000	269.00	255.50	22.5	8

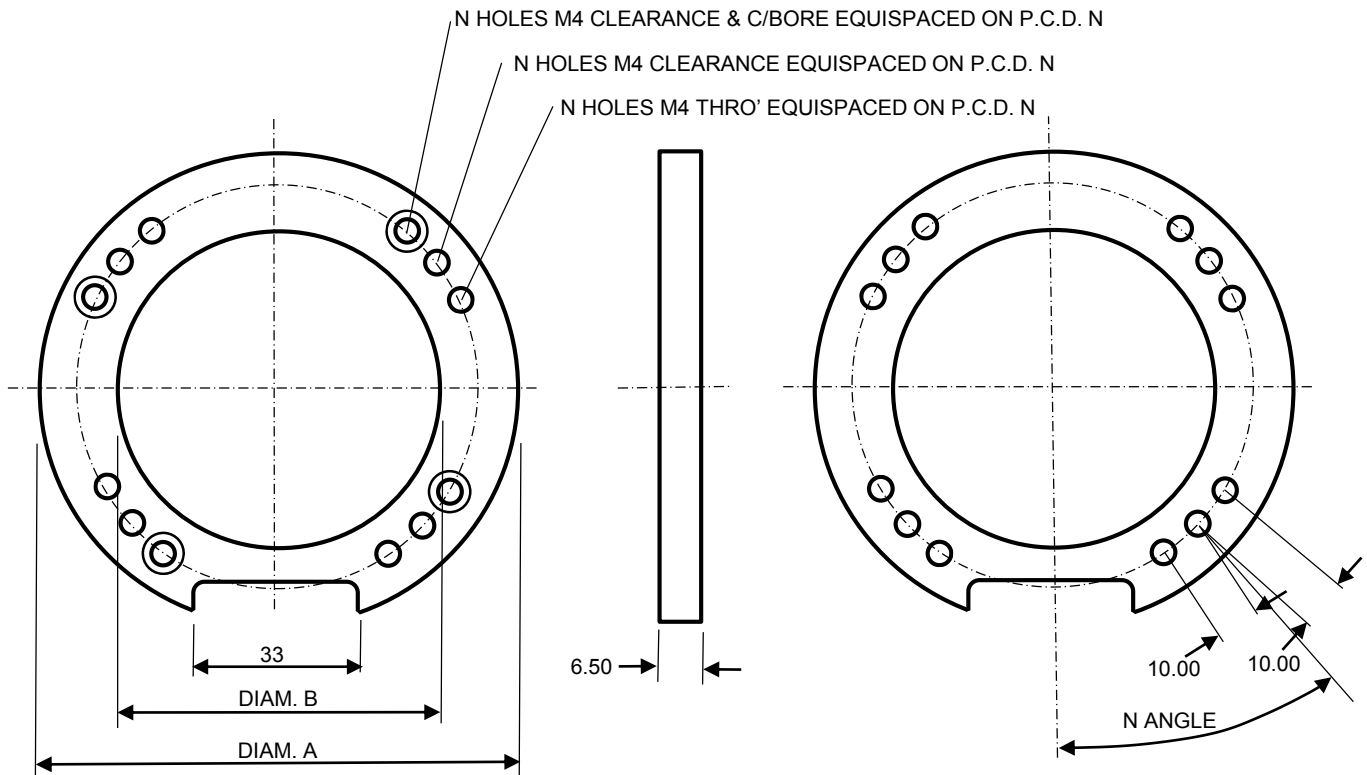
### 9.6 Spacer Ring – Part Number INC-RG-X

Spacer Rings are for use with External Clamp Stators and may be used to space the Stator from host equipment and provide an enclosed space for the Rotor. Such arrangements are suited to environments where harsh mechanical impact might damage the sensing faces of Rotor or Stator.



#### NOTES

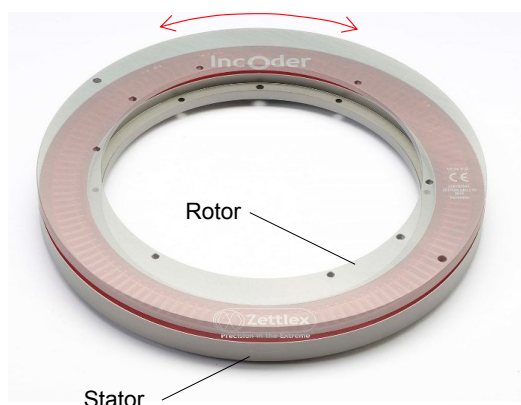
1. **3D CAD IGES FILES AVAILABLE ON [WWW.ZETTLIX.COM](http://WWW.ZETTLIX.COM)**
2. ALL DIMS IN mm – DO NOT SCALE
3. 3<sup>RD</sup> ANGLE PROJECTION
4. MATERIAL = ALUMINIUM ALLOY, HARD ANODIZED
5. TOLERANCES (UNLES STATED OTHERWISE):-  
 0 DECIMAL PLACES =  $\pm 0.5$   
 1 DECIMAL PLACES =  $\pm 0.2$   
 2 DECIMAL PLACES =  $\pm 0.1$



Part Description	Part Number	Dim. A mm	Dim. B mm	N P.C.D. mm	N Angle Degrees	N Holes
Spacer Ring for 75mm IncOder	INC-RG-75	100.00	77.00	87.50	38.4	4
Spacer Ring for 100mm IncOder	INC-RG-100	125.00	102.00	112.50	38.4	4
Spacer Ring for 125mm IncOder	INC-RG-125	150.00	127.00	137.50	38.4	4
Spacer Ring for 150mm IncOder	INC-RG-150	175.00	152.00	162.50	23.4	6
Spacer Ring for 175mm IncOder	INC-RG-175	200.00	177.00	187.50	23.4	6
Spacer Ring for 200mm IncOder	INC-RG-200	225.00	202.00	212.50	23.4	6
Spacer Ring for 225mm IncOder	INC-RG-225	250.00	227.00	237.50	23.4	6
Spacer Ring for 250mm IncOder	INC-RG-250	275.00	252.00	262.50	15.9	8
Spacer Ring for 300mm IncOder	INC-RG-300	325.00	302.00	312.50	15.9	8

## 10.1. How do IncOders work?

IncOders work in a similar way to rotary variable transformers, brushless resolvers or synchros. The Stator receives DC power and produces a low power AC electromagnetic field between the Stator & Rotor. This field is modified by the Rotor depending on its angle. The Stator senses the resulting field and outputs the rotation angle as an analogue or digital signal. Unlike resolvers, IncOders use laminar circuits rather than wound wire spools. This technology enables IncOder's compact form, low mass, low inertia and high accuracy without high precision installation.



## 10.2. Is IncOder measurement truly absolute for absolute output devices?

Yes. Measurement will be the same before and after power interruption. No motion is needed at start up.

## 10.3. Does measurement performance vary with Rotor concentricity?

Resolution, repeatability & accuracy (linearity) will be as specified, provided Rotor concentricity is within specified limits. One might expect accuracy to degrade significantly with concentricity, but IncOders use the full faces of Rotor & Stator, so errors are nulled by diametrically opposing factors. This is different to other encoder technologies – notably optical or capacitive devices - where performance depends on tightly controlled concentricity.

## 10.4. Can IncOders be used outside the stated operating temperature limits?

Operating temperature limits are set by some of IncOder's electronic parts rather than the basic technique. Standard IncOders are rated -40 or 85°C operation and with a cold option (Product Options 12VCT & 24VCT) for -60°C operation. IncOders can be used outside these limits following qualification by the user. At temperatures >85°C the duration of any elevated temperature should be minimized. At temperatures at or below the stated lower limit, it is recommended to leave the unit powered or allow an extended powered period (>1 minute) before operation.

## 10.5. What happens if the Rotor or Stator get wet or dirty?

Measurement performance is unaffected by humidity, condensation, dirt, dust, oil, mud or sand. All IncOders will survive temporary immersion to depths of 1m in salt or fresh water. Where frequent exposure to liquids, or immersion, is part of the operating environment, units with connections type AFL or VFL should be used.

## 10.6. How can an IncOder be calibrated?

Calibration is only relevant for some ultra high accuracy applications such as astronomical telescopes. Readings from an IncOder are stored and compared to a reference in a look-up table in the host system. Such an arrangement will negate any inaccuracy due to inherent non-linearity or installation tolerances. Resolution & repeatability are unaffected by calibration.

## 10.7. At what Baud rate can the data interface operate at and does this effect cable length?

The longer the transmission distance (Cable Length), the slower the recommended Baud Rate. This table shows recommended Baud Rates vs. Cable Length.

Baud Rates For Data Transmission				
Cable Length (m)	<30	<60	<120	<250
Baud Rate	<400 kHz	<300 kHz	<200kHz	<100 kHz

## 10.8. Are IncOders affected by magnets?

No. Magnets produce DC fields. IncOders use AC electro-magnetic fields at a highly specific frequency.

### 10.9. Are IncOders suitable for use in harsh electromagnetic fields?

Yes. Many IncOders are used near powerful sources of electromagnetic noise such as motors or transformers. IncOder's aluminium housing produces a Faraday cage effect around the internal electronics and the technology is designed so that incoming, far-field radiation is self cancelling or filtered out.

### 10.10. Do IncOders produce electromagnetic emissions?

Radiated emissions are tiny and limited to the IncOder's internal sensor faces. The IncOder housing has a Faraday cage effect. IncOders are often used in proximity to sensitive devices such as navigation aids.

### 10.11. What if we need to earth the IncOder casing?

Some applications such as fighting vehicles and aircraft require the IncOder casework to be electrically earthed. Some IncOder housing finishes are hard-anodized which is non-conductive. A connection can be made using an earth strap with a crinkle washer which penetrates the anodized surface. Alternatively, remove the anodized surface in the immediate vicinity of the strap (usually located using one of the attaching screws) using a file or abrasive. Alternatively, conductive finishes such as Alocrom or Surtec650 may be specified from the Extended Product Range (standard for 37 and 58mm products).

### 10.12. Does the Rotor need electrical earthing?

No. Some capacitive devices require the rotating shaft to be electrically connected to earth so as to avoid electrostatic interference. There is no such requirement with IncOder.

### 10.13. Does measurement performance vary with Rotor to Stator gap?

Resolution, repeatability & linearity will be as specified, provided gap is to specified tolerances. Within limits, the IncOder's measurement resolution & repeatability are independent of gap. If gap tolerance is increased from  $\pm 0.35\text{mm}$  to  $\pm 0.50\text{mm}$  the *guaranteed* measurement non-linearity will double. For example, if a 250mm IncOder has a gap tolerance of  $\pm 0.50\text{mm}$  (rather than the specified  $\pm 0.35\text{mm}$ ) the *guaranteed* linearity will increase from  $\pm 40$  arc-secs to  $\pm 80$  arc-secs. Gap tolerances are most easily achieved using Set Screw or Shaft Clamp Rotors. Alternatively the required gap may be maintained by the use of a shim – see IncOder Accessories – Section 9.4.

### 10.14. Do IncOders carry out self checks or Built-In-Test (BIT)?

Yes. If BIT shows an internal error then an error signal is generated. The BITs include continuity/damage, presence of Rotor, in-range Rotor, gross electromagnetic malfunction, window watchdog timer, power on reset, power brownout reset, timeouts for clock input, read/write and internal flash data memory value checks.

### 10.15. Do IncOders outgas?

IncOder housings are hard-anodized, Surtec or Alocrom finished aluminium which produce no outgassing. The epoxies and other materials used inside the devices comply with NASA's classification of low outgassing materials for spacecraft with TML of  $<1\%$  and CVM of  $<0.1\%$  measured at  $125^\circ\text{C}$  over 24 hours in vacuum according to ASTM E-595-90. IncOders are successfully used with sensitive optical devices without residues from the IncOder affecting the lenses.

### 10.16. How can we specify a custom IncOder variant?

Use this document as a basis and specify any differences. Preferably, a standard outer diameter 'A' dimension (i.e. 37, 58, 75, 100, 125mm etc.) and a proportionate inner diameter should be used – see Section 5.11. This enables us to use regular sensor components with an alternative mechanical format.

### 10.17. What's the largest IncOder you can build?

573mm outer diameter. Contact Zettlex or your local representative (see Section 12) for larger sizes.

### 10.18. Do IncOders require an Export License?

Not usually. IncOders are exempt from Annex I to Council Regulation (EC) No. 428/2009, as amended [EU Dual-Use List] and only require an export license if the diameter is greater than or equal to 1000mm or accuracy is  $<1$ arc-second. No standard products are in this class.

## 10.19. How does Zettlex manage the obsolescence of electronic components?

Zettlex has detailed obsolescence policies and procedures as part of our Quality Management System. Generally, our policy is only to use electronic components which are widely used; available from a variety of sources and have low likelihood of obsolescence. In the event of an electronic component becoming obsolete we typically select, specify and, if necessary, qualify a suitable form, fit & functional alternative.

## 10.20. Can IncOders be used submerged in oil or water?

Yes. Use AFL or VFL cable connections or provide a mechanical seal around the connector. Some AFL or VFL connections are rated for submersion at  $\leq 100\text{m}$ , however, some applications are successfully using such devices for prolonged submersion in water or mineral oil at  $>100\text{m}$  depth, without modification. If application requirements are for prolonged and  $>100\text{m}$  submersion, this should be qualified by the user. Contact Zettlex for further information.

## 10.21. Does the accuracy of IncOders improve if the range is reduced?

Yes. Repeatability is unaffected but accuracy – in other words, linearity - improves as the range reduces. This can be advantageous in some applications where the range of motion is restricted, such as elevation controls in pointing devices which are often  $<90^\circ$ . The following table shows the effect on quoted accuracy as scale reduces for all devices with a digital output:-

IncOder Size mm	Static accuracy. Ranges up to $360^\circ$ arc-seconds	Static accuracy. Ranges up to $90^\circ$ arc-seconds	Static accuracy. Ranges up to $60^\circ$ arc-seconds	Static accuracy. Ranges up to $30^\circ$ arc-seconds
75	125	95	65	50
100	80	70	50	50
125	65	65	50	30
150	50	40	40	30
175	50	40	40	30
200	50	40	30	20
225	45	40	30	20
250	40	40	30	20

The rate of improvement of static accuracy vs. range is not a simple linear function. This means that if your application's range is say  $120^\circ$  the quoted accuracy should be taken from the column 'up to  $360^\circ$ '. Similarly if your range is  $45^\circ$  the quoted accuracy should be taken from the column 'up to  $60^\circ$ '. For clarity, the above applies to all IncOders not just customised products with reduced scale.

## 10.22. Can we accurately calculate speed using an IncOder?

Yes. There are various approaches and the optimal approach depends on the nature of your application and how accurately speed is to be measured. Generally, 0-10V output IncOders are not suitable for speed calculation because they are typically only suitable for  $<1$  revolution operation rather than continuous rotation. The first option is to use an IncOder with A/B pulses. The second option is to use a Duplex IncOder (INC-10) with an A/B pulse inner and an absolute angle outer. The third option is to use a device with an absolute angle output such as SPI or SSI, and where SPI1 or SSI4 product options are particularly advantageous. The approach for this third option is detailed in a separate document - please refer to Zettlex IncOder App Note – Calculating Speed. You can find this in the IncOder section of our web-site ([www.zettlex.com](http://www.zettlex.com)) or ask your local Zettlex representative for a copy.

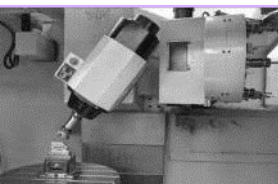
## 10.23. Does current consumption depend on supply voltage?

No - because we use linear voltage regulators in the IncOder stator.

# 11. Conversion Table

Degrees	Radians	Milli-Radians	Micro-Radians	Arc-Minutes	Arc-Seconds	% of a rev
<b>1</b>	0.0174556	17.4555712	17,455.57	60	3,600	0.2777778
57.2883514	<b>1</b>	1,000	1,000,000	3,437.3	206,238.1	15.9134309
0.0572884	0.0010000	<b>1</b>	1,000	3.4373011	206.24	0.0159134
0.0000573	0.0000010	0.0010000	<b>1</b>	0.0034373	0.2062381	0.0000159
0.0166666	0.0002909	0.2908656	290.8656195	<b>1</b>	60	0.0046296
0.0002778	0.0000048	0.0048478	4.8477797	0.0166667	<b>1</b>	0.0000772
3.6	0.0628571	62.8571	62,857.143	216	12,960	<b>1</b>
360	6.2857143	6,286	6,285,714	21,600	1,296,000	<b>100</b>

Binary Digits	Counts per rev	Degrees per Bit	Radians per Bit	Milli-Radians per Bit	Micro-Radians per Bit	Arc-Minutes per Bit	Arc-Seconds per Bit
<b>10</b>	1,024	0.3515625	0.0061355	6.135471	6135.4712	21.094	1265.625
<b>11</b>	2,048	0.1757813	0.0030677	3.067736	3067.7356	10.547	632.813
<b>12</b>	4,096	0.0878906	0.0015339	1.533868	1533.8678	5.273	316.406
<b>13</b>	8,192	0.0439453	0.0007669	0.766934	766.9339	2.637	158.203
<b>14</b>	16,384	0.0219727	0.0003835	0.383467	383.4670	1.318	79.102
<b>15</b>	32,768	0.0109863	0.0001917	0.191733	191.7335	0.659	39.551
<b>16</b>	65,536	0.0054932	0.0000959	0.095867	95.8667	0.330	19.775
<b>17</b>	131,072	0.0027466	0.0000479	0.047933	47.9334	0.165	9.888
<b>18</b>	262,144	0.0013733	0.0000240	0.023967	23.9667	0.082	4.944
<b>19</b>	524,288	0.0006866	0.0000120	0.011983	11.9833	0.041	2.472
<b>20</b>	1,048,576	0.0003433	0.0000060	0.005992	5.9917	0.021	1.236
<b>21</b>	2,097,152	0.0001717	0.0000030	0.002996	2.9958	0.010	0.618
<b>22</b>	4,194,304	0.0000858	0.0000015	0.001498	1.4979	0.005	0.309
<b>23</b>	8,388,608	0.0000429	0.0000007	0.000749	0.7490	0.003	0.154
<b>24</b>	16,777,216	0.0000215	0.0000004	0.000374	0.3745	0.001	0.077





<b>Australia</b>	Motion Technologies Pty., Australia <a href="http://www.motiontech.com.au">www.motiontech.com.au</a> +61 (0) 2 9524 4782
<b>Austria</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Belarus</b>	Aviton, Russia <a href="http://www.aviton.spb.ru">www.aviton.spb.ru</a> +7 812 702 1001
<b>Belgium</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Canada</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>China (NE &amp; E)</b>	Shanghai Mingcheng Control Technology Ltd. <a href="http://www.shmcct.com">www.shmcct.com</a>
<b>China (SW)</b>	Chongqing Fuleji <a href="http://www.fuleji.net">www.fuleji.net</a> +86 (0) 23 8890 6991
<b>Czech Republic</b>	Z.M.Systems, Slovakia, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 1223 852452
<b>Eire</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Finland</b>	Aseko Oy Automation, Finland <a href="http://www.aseko.fi">www.aseko.fi</a> +358 (0) 10 400 1012
<b>France</b>	Vicatronic, France <a href="http://www.vicatronic.com">www.vicatronic.com</a> +33 2 4856 6335
<b>Germany</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Holland</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Romania</b>	Z.M.Systems, Slovakia, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 1223 852452
<b>India</b>	Sika Interplant Systems Ltd., India <a href="http://www.sikaglobal.com">www.sikaglobal.com</a> +91 80 25599144
<b>Indonesia</b>	OptoCom, Malaysia, <a href="http://www.optocom.com.my">www.optocom.com.my</a> +603 (0) 8706 6806
<b>Israel</b>	Relcom Systems, Israel <a href="http://www.relsys.co.il">www.relsys.co.il</a> +972 9 9565070
<b>Italy</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Japan</b>	Midori Precision Ltd., Japan <a href="http://www.midori.co.jp">www.midori.co.jp</a> +81 42 554 5650
<b>Malaysia</b>	OptoCom, Malaysia, <a href="http://www.optocom.com.my">www.optocom.com.my</a> +603 (0) 8706 6806
<b>New Zealand</b>	Motion Technologies Pty., Australia <a href="http://www.motiontech.com.au">www.motiontech.com.au</a> +61 (0) 2 9524 4782
<b>Norway</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Poland</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Portugal</b>	Giza Technologies SAU, Spain, <a href="http://www.gizatech.com">www.gizatech.com</a> , +34 (0) 917 216 630
<b>Romania</b>	Z.M.Systems, Slovakia, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 1223 852452
<b>Russia</b>	Aviton, Russia <a href="http://www.aviton.spb.ru">www.aviton.spb.ru</a> +7 812 702 1001
<b>Singapore</b>	OptoCom, Malaysia, <a href="http://www.optocom.com.my">www.optocom.com.my</a> +603 (0) 8706 6806
<b>Slovakia</b>	Z.M.Systems, Slovakia, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 1223 852452
<b>South Africa</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>South Korea</b>	SamJeong Automation <a href="http://www.sjautomation.com">www.sjautomation.com</a> +82 (0) 31 469 3090
<b>Spain</b>	Giza Technologies SAU, Spain, <a href="http://www.gizatech.com">www.gizatech.com</a> , +34 (0) 917 216 630
<b>Sweden</b>	Hemomatik, Sweden <a href="http://www.hematik.com">www.hematik.com</a> +46 8 771 0220
<b>Switzerland</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444
<b>Taiwan</b>	Daybreak International Corp., Taiwan, <a href="http://www.daybreak.com.tw">www.daybreak.com.tw</a> +886 (2) 8866 1234
<b>Thailand</b>	OptoCom, Malaysia, <a href="http://www.optocom.com.my">www.optocom.com.my</a> +603 (0) 8706 6806
<b>USA (East)</b>	Everight Position Technologies, USA, <a href="http://www.evrtp.com">www.evrtp.com</a> +1 (0) 856 727 9514
<b>USA (Central)</b>	Precision Measurement, USA, <a href="http://www.precisionmeasurement.com">www.precisionmeasurement.com</a> +1 (0) 847 426 8446
<b>USA (West)</b>	Zettlex Ltd., UK, <a href="http://www.zettlex.com">www.zettlex.com</a> +44 (0) 1223 874444

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Zettlex UK Ltd.  
 Newton Court  
 Newton  
 Cambridge  
 CB22 7ZE  
 United Kingdom  
 Tel [+44] 01223 874444  
 Fax [+44] 01223 874111  
 Email [info@zettlex.com](mailto:info@zettlex.com)  
[www.zettlex.com](http://www.zettlex.com)

## Revision History

### Revision 4.10 to 4.11

- ✓ General - changes to logo and page layout
- ✓ Front page - revision and date updated
- ✓ Page 2 - number of options increased
- ✓ Contents - updated
- ✓ Section 1 through 12 - application images updated
- ✓ Section 1 - rewritten with new product images, application images and text
- ✓ Section 2 - rewritten with new options – notably all integer bit values of resolutions and new integer values of pulses per rev
- ✓ Section 3 – minor changes to text of custom products updated
- ✓ Section 4 - facility images and text updated
- ✓ Section 5 - 37mm product range added (note absolute digital data outputs only – not 0-10V or A/B/Z yet)
- ✓ Section 5 - 58mm product range added (note digital data outputs only – not 0-10V)
- ✓ Section 5 - 300mm product range (note digital data outputs only – not 0-10V)
- ✓ Section 5 - tolerancing of screw and dowel holes and positions amended on Screw Mount Stators & Rotors (no backward compatibility issues)
- ✓ Section 5 - dimensioning of ring on Servo Clamp Stators amended (no backward compatibility issues)
- ✓ Section 5 - new mechanical ('External Mount') format with mounting holes around the OD – may be used with new Spacer Ring Accessory
- ✓ Section 5 – newly added options RFC7, 8, 9 & 10 with soldered cable & radial connections
- ✓ Section 5 - advisory note on screws re RFC cables added
- ✓ Section 5 - AFL3, 4 & 5 now offered as standard items and VFL1-5 added for 58mm only. Also Sealed Rotor & Stator Versions
- ✓ Section 5 – IP rating of AFL & VFL Product Options with sealed Rotors and Stators improved
- ✓ Section 5 – standard & non-standard cable lengths notes added for AFL & VFL Product Options
- ✓ Section 5 - options for connectors such as D-38999 military shell etc. noted as an additional offering with AFL or VFL Product Options
- ✓ Section 5 – 12CT added as an option for Extended Range
- ✓ Section 5 - internal update rate for digital comms interfaces increased from 1kHz to 10kHz update rate. This is now standard for all digital (only) output devices and, unless Zettlex is specifically requested, will be supplied as the standard product. A/B/Z output is unchanged at 10kHz; 0-10V remains as 1kHz update rate and the internal update rate of the digital aspects of digital + 1V sin/cos remains and Voltage Output at 1kHz.
- ✓ Section 5 - max. speed for angle measurement increased for absolute digital outputs
- ✓ Section 5 – voltage supply tolerances expanded for absolute digital outputs and ABZ pulse outputs
- ✓ Section 5 - improved 75mm linearity for digital output options
- ✓ Section 5 - temp. coefficient corrected for absolute digital output options
- ✓ Section 5 – typo on IEC number standard for EMC corrected
- ✓ Section 6 – notes on Zero Set & Zero Reset added in various sub-sections to clarify that 'unconnected' means open circuit
- ✓ Section 6.1 - further options on resolution added
- ✓ Section 6.7 - advisory note on max. resolution added
- ✓ Section 6.8 - further options on 0.5-9.5V; 0.5-5.0V and 0.5-4.5V versions of analogue voltage output added. Instructions clarified
- ✓ Section 6.9 – counts per rev based on non-integer bit values now included
- ✓ Section 7.1 – added. Notes on connections and zero set and reset for 37mm device added
- ✓ Section 8 – 37 & 58mm tables added. Product part numbering table largely rewritten
- ✓ Section 9.1 - Accessories - cable with standard 5m & 10m length added – custom length option removed
- ✓ Section 9.2 - Accessories - cable with standard 5m & 10m length added – custom length option removed
- ✓ Section 9.2 – erratum on diagram corrected. Pins 3 & 4 swapped round (table was and is correct)
- ✓ Section 9.5 - Accessories – Rotor Shaft Clamp added
- ✓ Section 9.6 - Accessories - Spacer Ring added
- ✓ Section 10 – FAQs rationalised to delete obvious ones and clarify some text
- ✓ Section 10 - various minor amendments so answers match Rev 4.11 of this document plus minor grammatical amendments
- ✓ FAQ. 10.21 – clarification added that this applies to all IncOrders not just custom versions with restricted angles
- ✓ FAQ. 10.23 - added on current consumption and any relevant notes updated in main body of the document
- ✓ Section 12 - Contact data updated for USA, Italy, Malaysia, Singapore, Thailand, Indonesia & China
- ✓ Revision History – updated.

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