nanoSeries® Encoders

“A Revolutionary True Absolute Encoder”
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## CAPABILITY STATEMENT

### CORE COMPETENCIES

BEI Precision Systems & Space Company, Inc. is the leading developer and manufacturer of advanced sensing solutions for space and military applications where critical accuracy and resolution are needed for pointing, aiming, and control of weapon systems, satellite payload instruments, robotic arms, radar systems, optical tracking, and astronomical telescopes.

BEI PSSC has provided Products and Engineering Services to many Military and Space customers, enabling them to meet or exceed their mission pointing or tracking requirements. BEI PSSC has more experience than any other encoder company at meeting demanding program requirements.

- New Sensor Product Development
- Design of Electro-Optical Mechanical Sensors
- System Engineering and Program Management
- Life Cycle Product Realization
- Test Equipment Design and Development
- Manufacturing to Space and Military Standards
- Quality and Test to ISO standards

### DEPLOYMENTS

**PAYLOAD POINTING**
- Sighting Systems
- Laser Designators
- Battlefield Radars
- Satellite Communications
- Turret/gun Position
- Shipboard Radar
- Airborne Radar Missiles
- Launchers Acceleration Measurement

**RADAR**
- Optical Tracking
- Astronomical Telescope
- Lab Instruments

**OPTICAL TRACKING**
- Payload Pointing
- Payload Instrumentation
- Robotics
- Solar Array Pointing
- Antenna Pointing
- Dual Spin Attitude Control
- Scan Mechanisms
- Optical Crosslinks
- Image Motion
- Compensation
- Line of Sight Stabilization

### PAST PERFORMANCE

As a subcontractor, BEI PSSC has provided the Design, Development Support, Integration Support, and Hardware for the encoders on many programs. Many military systems depend on BEI PSSC encoders for aiming ordnance, while space systems depend on the demonstrated long life and precision of BEI PSSC encoders to point telescopes, antennas, lasers, and solar arrays. Many scanner designs depend on BEI PSSC encoders to provide stable, accurate sweeps and movement over the life of the instrument.

BEI PSSC has often engineered and produced limited quantities of precision encoders for specialized applications, such as the Hubble Space Telescope and NPOESS Weather Satellites; we have also produced many designs in quantities of hundreds to thousands to meet production requirements, such as accelerometers for Sikorsky and IR scanners for the F-35 Joint Strike Fighter. We have been on the cutting edge of development for satellites, major aircraft, and military systems.

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### DIFFERENTIATORS

- BEI PSSC is the leader in the high-performance encoder market offering proven mission critical solutions.
- BEI PSSC offers Engineering, Manufacturing, and Quality capability for design & development of customized solutions.
- BEI PSSC brings the most mature product heritage and pedigree demanded by customers for mission assurance.
- BEI PSSC has developed a modular encoder architecture to minimize development costs, collapse lead-time, and reduce technical risk.
- BEI PSSC’s management team and skilled work force, attuned to the most stringent U.S. Government requirements.

### ENCODERS — ACCELEROMETERS — SCANNERS

- **POSITION**
- **ACCELERATION**
- **CONTROL**

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BEI PSSC is proud to introduce the next generation of modular absolute encoders. The nanoSeries® absolute optical encoders incorporate the latest technology and decades of industry leading knowledge in space, military, and commercial encoder design. These bearingless kit encoders and our new housed encoder feature game changing tangential and radial alignment error reporting making precise mounting of the code disk and readhead fast and easy. BEI PSSC's nanoSeries® models include a self-calibration feature to assure accurate performance over time and under various mounting conditions. Repeatable radial disk mounting error is compensated for, and the auto-calibration feature can support full or partial revolution systems.

ARA
- Designed for elite space, this encoder meets environmental specs that require resistance to temperature, radiation, and vacuum
- Single or Dual readheads, a code disk/hub assembly, and a remote electronics CCA box
- Up to 4 axes supported by a single remote electronics CCA box
- Fully redundant electronics optional

AIME-II
- Single Readhead, no remote electronics, small form factor
- Optical, mechanical, electrical & protocol compatible with ARA encoder for migration from lab to space
- Lower cost commercial parts
- Intended for High Performance terrestrial applications

TRACKER
- Single Readhead, no remote electronics, small form factor
- Intended for cost-driven terrestrial lab, field, military, or commercial space applications
- Radiation-tolerant COTS electronics or screened to GSFC EEE-INST-002 Level 1 or 2
**nanoSeries® True Absolute ENCODERS**

If you are reading this you probably think you have a good idea of what a rotary encoder does. BEI PSSC’s line of *nanoSeries®* absolute kit encoders is about to broaden your definition of position sensor capabilities.

### Obtain and Maintain Extraordinary Accuracy

- **In-Situ Encoder Calibration**
  - Uses proprietary Auto-Calibration algorithms in order to obtain maximum accuracy
  - Calibrate over 360° or limited angle
  - Single readhead self-calibration can detect and correct 1st harmonic axis alignment errors
  - Dual readhead configuration can accommodate inherently unstable spindles
  - Compensates for radial disk mounting error to ensure that the encoder is providing accurate position

- **More Robust / Less Delicate (De-Risk Intricate Payload Integrations)**
  - Utilizing a courser code disk pattern with **Dynamic Merge Correction** results in a resilient system while maintaining exceptional accuracy
  - Large Air Gap

### More than Just Rotary Position

**Precise Alignment in both Radial and Tangential Directions**

- **Radial Sensor**
  - Encoder generated signal representing relative readhead and disk radial alignment error
  - Sensitive to motion between readhead and disk
  - Exhibits outstanding linearity within the ± 0.003 inch range

- **Tangential Sensor**
  - Encoder generated signal representing relative readhead and disk tangential alignment error

- **Extensive diagnostic telemetry data available**
  - On-orbit monitoring
  - Ability to provide spindle diagnostics through trend of bearing runout
  - Easily identify and characterize system variation throughout manufacturing and system integration
  - Provides debug and troubleshooting capabilities beyond the performance of the encoder

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*Beware of Encoder Manufacturers who fail to Acknowledge Spindle Error. These are detrimental to Encoder Accuracy.*

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*Delivers never before available information to the customer that aids installation, system integration and troubleshooting for the life of the mission...even on orbit*
Ultimate precision and repeatability
- Supports extreme-performance position control
  - 28-bit absolute position output, 1 arcsec (4.85µrad) RMS accuracy
  - Latency-controlled processing & complete data output up to 8kHz
- Self-calibrating with repeatable disk mounting error compensation
- Radial & tangential translation of the code pattern (runout) is detected and can be queried

Designed for elite space
- Radiation tolerant ICs
- GSFC EEE-INST-002 Level 1 or 2 EEE parts
- Low-outgassing, vacuum compatible materials
- Controlled LED output power for long-life missions
- Position, Health, Status, & CRC stamped serial LVDS output
- Existing Structural, Power, Thermal, EEE Parts Stress, & Radiation analyses
- Alignment & Telemetry diagnostic information for mission support value
- Full redundancy capable

Versatile, Adaptable, and Modular
- Disk can be scaled to fit available OD or ID
- Readhead can be mounted from OD (standard) or ID
- Disk size from 3” – 7.25” standard, custom sizes available
- Single or dual readheads per axis
  - Self-calibration over a wide sweep angle can detect & correct repeatable disk mounting error with a single readhead
  - Dual readhead configuration available for applications where axis alignment is subject to change & re-calibration is not feasible
- Cable exit direction can be specified
- Remote CCA can be housed or customer-hosted
  - Supports single axis or multiple axes with 1 or 2 readheads per axis
  - 3U standard, 4” x 4” & custom CCA layouts
nanoSeries® ARA

Designed, engineered and fully supported for the Prime’s mission
- Components stocked to support rapid turn-around/production lead times
- Installation eased with alignment reporting, test box, PC software, and available tooling
- Optical, mechanical, electrical & protocol compatible with AIME-II encoder for migration from lab to space
- Available interpretation of extensive diagnostic telemetry

ARA Modular Configurations and Options

<table>
<thead>
<tr>
<th>Remote Electronics</th>
<th>Axes option for Single Readhead</th>
<th>Axes option for Dual Readheads</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” x 4” CCA</td>
<td></td>
<td></td>
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<tr>
<td>3U Standard CCA (160mm x 100mm)</td>
<td>1 Axis:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Axis:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Axis:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Axis:</td>
<td>(All shown without redundancy)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Housed CCA Options</th>
<th>Code Disk Diameter</th>
<th>Other Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single CCA</td>
<td></td>
<td>• Stainless or Titanium Housings</td>
</tr>
<tr>
<td>Redundant CCA</td>
<td></td>
<td>• Readhead Cable Length</td>
</tr>
</tbody>
</table>

- 3.0”-7.25” OD Standard Configuration; Other sizes available as special order.
**Kit Encoder:**

<table>
<thead>
<tr>
<th></th>
<th>ARA</th>
<th>AIME-II</th>
<th>TRACKER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intended Market</strong></td>
<td>Space</td>
<td>Comm/Mil</td>
<td>Comm/Space</td>
</tr>
<tr>
<td><strong>Intended Usage</strong></td>
<td>High performance space applications and sensors where precision is critical</td>
<td>Commercial and military applications. Rapid prototyping for ARA configurations; unit not intended for space flight</td>
<td>Small form-factor space applications and sensors</td>
</tr>
<tr>
<td><strong>Space Rated</strong></td>
<td>All space applications</td>
<td>No, prototype unit for ARA</td>
<td>Lower commercial and defense space</td>
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<tr>
<td><strong>True Absolute Position</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Resolution (quanta)</strong></td>
<td>28</td>
<td>28</td>
<td>24</td>
</tr>
<tr>
<td><strong>ENOB (bits)</strong></td>
<td>&gt;24</td>
<td>&gt;24</td>
<td>24</td>
</tr>
<tr>
<td><strong>Accuracy (arcseconds RMS)</strong></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;2.5&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Number of Readheads</strong></td>
<td>1 or 2</td>
<td>1</td>
<td>1</td>
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<tr>
<td><strong>Auto-Calibrating</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>1&lt;sup&gt;st&lt;/sup&gt; Harmonic Error Correction</strong></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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<tr>
<td><strong>Partial Revolution Calibration</strong></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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<tr>
<td><strong>End-User Installation</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>Alignment Mode</strong></td>
<td>2-Axis&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>2-Axis&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>1-Axis (Radial)&lt;sup&gt;(2)&lt;/sup&gt;</td>
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<td><strong>Reported Degrees of Freedom</strong></td>
<td>3 DOF</td>
<td>3 DOF</td>
<td>2 DOF</td>
</tr>
<tr>
<td></td>
<td>Rotary position</td>
<td>Rotary position</td>
<td>Rotary position</td>
</tr>
<tr>
<td></td>
<td>Radial Alignment</td>
<td>Radial Alignment</td>
<td>Radial Alignment</td>
</tr>
<tr>
<td></td>
<td>Tangential Alignment</td>
<td>Tangential Alignment</td>
<td></td>
</tr>
<tr>
<td><strong>Radial Range</strong></td>
<td>Radial Range is ±0.004” with 13-bit resolution</td>
<td>Radial range is ±0.004” with 13-bit resolution</td>
<td>Radial range is ±0.004” with 14-bit resolution</td>
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<tr>
<td><strong>Diagnostic Telemetry</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>Low Outgassing</strong></td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
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<tr>
<td><strong>Radiation Tolerance krad (Si)</strong></td>
<td>100</td>
<td>10</td>
<td>50/100&lt;sup&gt;(4)&lt;/sup&gt;</td>
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<tr>
<td><strong>Remote Electronics Box</strong></td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Max Sample Rate (Hz)</strong></td>
<td>8000</td>
<td>16000</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Operating Temp. (°C)</strong></td>
<td>-40 – 73</td>
<td>-40 – 85</td>
<td>-40 – 85</td>
</tr>
<tr>
<td><strong>Storage Temp. (°C)</strong></td>
<td>-55 – 90</td>
<td>-55 – 90</td>
<td>-55 – 90</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>ISS&lt;sup&gt;(6)&lt;/sup&gt;</td>
<td>ISS&lt;sup&gt;(6)&lt;/sup&gt;</td>
<td>SPI&lt;sup&gt;(5)&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Power (W)</strong></td>
<td>&lt;4.75</td>
<td>&lt;1.5</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Excludes 1-cycle error due to disk centering  
<sup>(2)</sup> See Technical Bulletin MM-252  
<sup>(3)</sup> See Technical Bulletin MM-247  
<sup>(4)</sup> Depends on parts selection  
<sup>(5)</sup> See Technical Bulletin MM-253  
<sup>(6)</sup> See Technical Bulletin MM-248
The Absolute Intuitive Modular Encoder (AIME-II) is a high resolution, single read station, absolute optical encoder available in our standard array of disk diameters. The encoder comes equipped with in situ auto-calibration capability and repeatable disk mounting error compensation. The encoder may be calibrated in full revolution as well as partial angle designs with as few as 10 deg swept arc, making it an excellent choice for gimbal applications.

**Extreme Performance**
- 28-bit True Absolute Position Output
- Effective Number of Bits >24
- <1 arcsec (4.85 μrad) RMS Accuracy
- Auto-calibration over a wide sweep angle can detect & correct repeatable disk mounting error with a single readhead
- Latency-controlled processing up to 16kHz

**Easy to Install Kit Encoder**
- Mounting and Alignment on a piloted shaft
- 3 degrees of freedom
  - Rotary position, Radial and Tangential Alignment
- Radial & Tangential Translation of the code pattern (runout) is detected and can be queried
- Radial range of ±0.004” with 13-bit resolution
- No external electronics box

**Rapid Prototype Encoder for ARA**
- Reduce development time by using the AIME-II as your engineering development unit
  - Optical, mechanical, electrical & protocol compatible with ARA encoder for migration from lab to space
- Standard components held in stock at BEI PSSC for rapid delivery

**Versatile, Adaptable, and Modular**
- All Electronics Contained in Read Station
- Disk can be scaled to fit available OD or ID
- Readhead can be mounted from OD (standard) or ID
- Disk size from 3” – 7.25” standard, custom sizes available
- Cable exit direction can be specified
The nanoSeries® TRACKER true absolute kit encoder is the solution to the space industry’s push for better, faster, cheaper. This single readhead, no remote electronics, small form factor kit encoder will exceed your expectations. Intended for terrestrial lab, field, military, or cost-driven space applications.

Better
- 24-Bit True Absolute Position Output
- Effective Number of Bits =24
- <2.5 arcsec (12.1µrad) RMS Accuracy (excludes 1-cycle error)
- In-Situ Auto-Calibration 360° or Limited Angle
- Latency-controlled Processing & Interface up to 1 kHz
- Vacuum Compatible

Faster
- Modular design
- Standard components in stock for rapid delivery
- Easy to install
  - Mounting and alignment on a loose pilot shaft
  - Rotary Position & Radial Alignment reporting facilitates accurate alignment of disk pattern to rotational axis to minimize disk centering error

Cheaper
- Lower cost option
- Radiation-tolerant COTS electronics

Versatile, Adaptable, and Modular
- All Electronics Contained in Read Station
- Disk can be scaled to fit available OD or ID
- Readhead can be mounted from OD (standard) or ID
- Disk size from 3” – 7.25” standard, custom sizes available
- Cable exit direction can be specified

Read station and code disk shown on test stand
nanoSeries® Housed nSH/80

Features:
- Housed Optical Encoder
- Absolute Non-Volatile Serial Output
- Resolution up to 30-bits
- Accuracy to 0.5 Arc-seconds
- All Electronics Contained in Unit
- Light Weight 9.0 lb (Max)
- Sample Rate up to 8.0 kHz
- Angular velocity up to 5 RPS
- Running Torque = 15.0 oz-in max @ 25°C
- Bearings Rated life of $10^9$ revolutions (Min)
- Optional Internal and External Couplings
- Bearings Can Support Payloads up to 50 lb
- Operating Temperature Range -40 to +75°C
- The nanoSeries® nSH/80 can be configured as a drop in replacement for the legacy Microseries µS/80 housed encoders.
- The Optional Tachometer feature reports real-time position data.
- The Tachometer outputs $2^{18}$ counts per revolution and consists of two square waves in quadrature.
- The Tachometer is Operational up to 30 RPM.

nanoSeries® Housed Encoders are thin, through-hole, absolute, optical encoders. They have substantially better accuracy than other shaft angle digitizers. These encoders are designed for applications where high resolution, minimum height, and insensitivity to power interruptions are desired. The nSH/80 family of encoders incorporates BEI PSSC’s latest technology with AIME-II read stations. The AIME-II modular design reduces build complexity, lead time, and cost while providing overall performance improvements when compared to legacy Microseries encoder systems. The nSH/80 Encoder options include LCRS read mode or LCNS update mode and ultimately provides a modern replacement for the Microseries µS/80 housed encoders operating in these modes.

Typical applications include aerospace/weapon systems, radar/optical tracking systems, and astronomical telescopes. Mechanical Couplings are available.

### ENCODER PROPERTIES

<table>
<thead>
<tr>
<th>Model</th>
<th>Stations</th>
<th>Resolution (Quanta)</th>
<th>Resolution (ENOB)</th>
<th>RMS Accuracy (Min)</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>nSH28/80</td>
<td>1</td>
<td>28 bits</td>
<td>24 bits</td>
<td>2.0 arc-sec</td>
<td>2.2W</td>
</tr>
<tr>
<td>nSH29/80</td>
<td>2</td>
<td>29 bits</td>
<td>25 bits</td>
<td>0.8 arc-sec</td>
<td>2.9W</td>
</tr>
<tr>
<td>nSH30/80</td>
<td>4</td>
<td>30 bits</td>
<td>26 bits</td>
<td>0.5 arc-sec</td>
<td>5.0W</td>
</tr>
</tbody>
</table>
Looking for a different size or a shafted version? Let BEI PSSC’s engineering staff work with you to develop the perfect match in size and capabilities for your application.
<table>
<thead>
<tr>
<th>DECIMAL</th>
<th>BINARY</th>
<th>ANGLE/BIT</th>
<th>RADIAN/BIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$2^0$</td>
<td>360 DEG.</td>
<td>6283.1853/07 MILLIRADIAN/BIT</td>
</tr>
<tr>
<td>2</td>
<td>$2^1$</td>
<td>180</td>
<td>3141.5926/54</td>
</tr>
<tr>
<td>4</td>
<td>$2^2$</td>
<td>90</td>
<td>1570.7963/27</td>
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<tr>
<td>8</td>
<td>$2^3$</td>
<td>45</td>
<td>785.3081/63</td>
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<td>16</td>
<td>$2^4$</td>
<td>22.5</td>
<td>392.6990/82</td>
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<td>32</td>
<td>$2^5$</td>
<td>11.25</td>
<td>196.3495/41</td>
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<td>64</td>
<td>$2^6$</td>
<td>5.625</td>
<td>98.1747/70</td>
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<tr>
<td>128</td>
<td>$2^7$</td>
<td>2.8125</td>
<td>49.0873/85</td>
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<tr>
<td>256</td>
<td>$2^8$</td>
<td>1.40625</td>
<td>24.5436/93</td>
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<tr>
<td>512</td>
<td>$2^9$</td>
<td>0.703125</td>
<td>12.2718/46</td>
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<tr>
<td>1024</td>
<td>$2^{10}$</td>
<td>0.3515625</td>
<td>6.1359/23</td>
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<tr>
<td>2048</td>
<td>$2^{11}$</td>
<td>0.17578125</td>
<td>3.0679/62</td>
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<tr>
<td>4096</td>
<td>$2^{12}$</td>
<td>0.087890625</td>
<td>1.5339/81</td>
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<tr>
<td>8192</td>
<td>$2^{13}$</td>
<td>0.0439453125</td>
<td>0.7669/90</td>
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<tr>
<td>16384</td>
<td>$2^{14}$</td>
<td>0.02197265625</td>
<td>0.3834/95</td>
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<tr>
<td>32768</td>
<td>$2^{15}$</td>
<td>0.010986328125</td>
<td>0.1917/48</td>
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<td>65536</td>
<td>$2^{16}$</td>
<td>0.0054931640625</td>
<td>0.0958/74</td>
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<td>131072</td>
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**PRODUCTS**

- Servo Accelerometers -- Absolute Encoders --
- Inertial Angular Displacement Sensors --
- Incremental Encoders --
- Integrated Encoder/Motors -- Servo Systems

**SMALL ANGLE APPROXIMATIONS**

<table>
<thead>
<tr>
<th>ANGLE</th>
<th>CHORD LENGTH FOR 1 INCH RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCESO ND</td>
<td>MICRORADIAN/ BIT</td>
</tr>
<tr>
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<td>1.00</td>
</tr>
<tr>
<td>1.00</td>
<td>4.85</td>
</tr>
<tr>
<td>5.00</td>
<td>24.24</td>
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<tr>
<td>10.00</td>
<td>48.48</td>
</tr>
<tr>
<td>10.31</td>
<td>50.00</td>
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<tr>
<td>20.00</td>
<td>96.96</td>
</tr>
<tr>
<td>30.00</td>
<td>145.44</td>
</tr>
<tr>
<td>60.00</td>
<td>290.89</td>
</tr>
</tbody>
</table>

**USEFUL ANGULAR & LINEAR COMPARISONS**

- 360 DEGREES = 2π RADIANS
- 1 RADIANS = 57.29577951 DEGREES
- 1 DEGREE = 0.017453293 RADIANS
- 1 MINUTE = 0.2908821 MILLIRADIAN
- 1 SECOND = 4.8481368 MICRORADIANS
- 1 MILLIMETER = 0.03937007874 INCH
- 1 INCH = 25.4 MILLIMETERS

E-mail: Sales@beiprecision.com

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