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Application Note for Aircraft/Aerospace

Introduction

This Application Note was developed to assist engineers and technicians with the process of selecting, installing, and using Firstmark Controls position transducers for aircraft and aerospace applications. It details why, where, and how Firstmark Controls miniature and subminiature position transducers are used in aircraft/aerospace environments.

Known also as string pots, yo yo pots, cable displacement transducers, and draw wire transducers, Firstmark Controls position transducers were first developed in 1968 to support NASA flight test programs. Since that time, these products have been used in an extensive number of aviation and space projects ranging from general aviation to commercial aircraft and from Formula 1 aircraft racing teams to environmental systems for space habitats. [Contact us](#) for a representative list of aircraft/aerospace customers and programs.

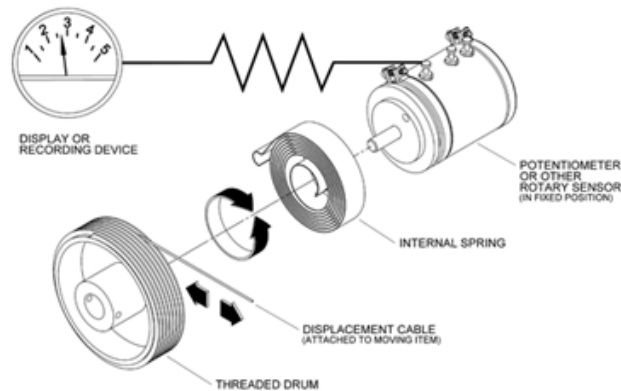
Product Technology Summary

Firstmark Controls position transducers are cable-actuated displacement-sensing devices. The majority of aircraft/aerospace applications use the analog electrical output provided by precision potentiometers, but synchros, resolvers, and encoders are also available.

Figure 1.0 shows how a position transducer works. Operationally, the products work by mounting in a fixed position and attaching the displacement cable to a moving object such as an aileron or landing gear component. As movement occurs, the cable extracts and retracts.

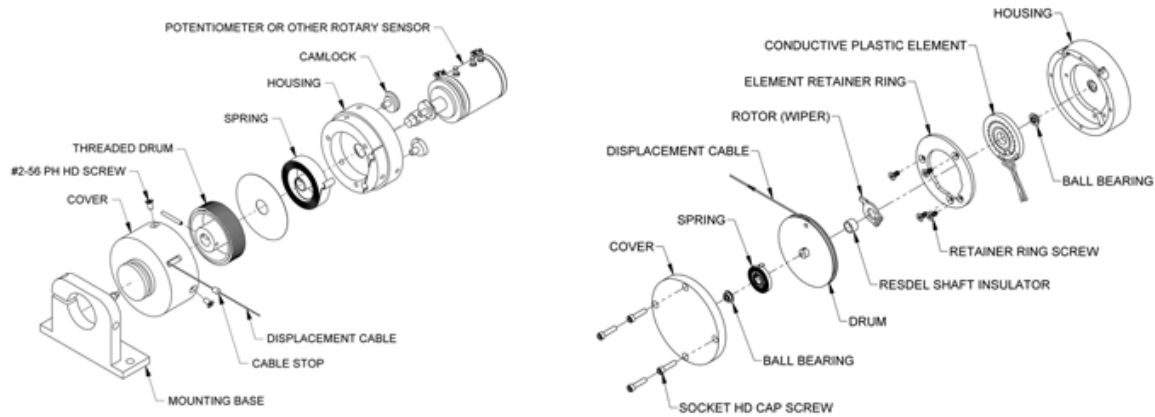
An internal power spring maintains cable tension. The threaded cable drum rotates a precision encoder, potentiometer, servo, or synchro that produces an electrical output proportional to the cable travel. Depending on the mounting arrangement and signal conditioning, the electrical output can indicate any number of lengths, motions, angles, or rates.

Figure 1.0: How a Position Transducer Works



Series 160 Position Transducer

Series 173 Position Transducer



Benefits

Before discussing where and how to use Firstmark Controls position transducers, let's look at what benefits these products bring to position measurement challenges and why you might want to consider the products for your application.

Safety

Probably the foremost benefit of using Firstmark Controls position transducers in aerospace applications is the additional safety factor that exists with these products relative to other choices available. The predominant alternatives to these types of transducers are:

1. Rod-and-cylinder transducers based on a number of technologies including variable resistive (potentiometric), magnetic induction, and magnetostriction.
2. Non-contact transducers using laser, Hall effect, ultrasonic, or other technologies. The safety benefit of a cable-actuated position transducer over a rod-and-cylinder device is that a cable-actuated position transducer has no inflexible components that have the potential to bind, bend, or otherwise disrupt the free movement of the object being monitored. Rod-and-cylinder products need to be precisely aligned and mounted to ensure long-life and disruption-free operation. Mounting errors, non-linear application movement, and simple accidents can cause the rod-and-cylinder device to malfunction and restrict the movement of the application. If the application is a flight control surface or other critical part, this restriction of movement can have serious consequences.

The inherent flexibility of a cable-actuated position transducer eliminates any binding or bending problems. Should a mounting or product malfunction occur, the displacement cable connection assembly can be designed to have a minimum breaking strength of less than 10 lbs (44.48N).

While non-contact transducers do not present a restriction of movement hazard, they do present difficulties in ensuring data integrity due to the dirty environments aircraft and aerospace vehicles are exposed to. Leaking hydraulic and lubricating fluids, smoke, mist, and other visual and atmospheric elements reduce or eliminate the effectiveness of non-contact technologies. The result is data that cannot be relied upon and possible safety consequences if a control or feedback loop is involved.

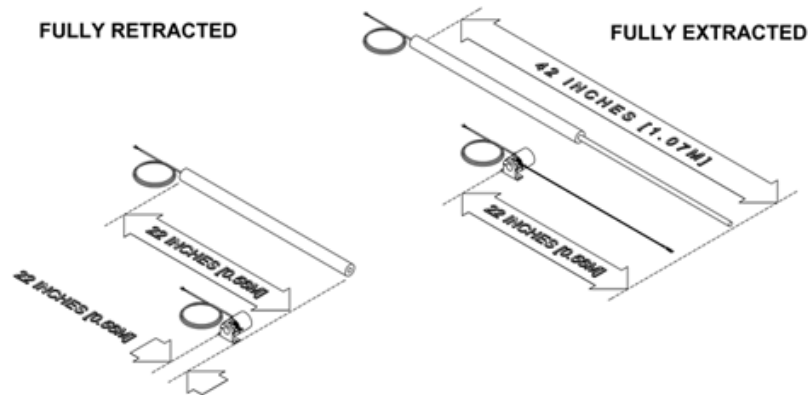
Small Size and Light Weight

The realities of physics mandate that size and weight be considered in nearly every engineering design. This is especially true in the aircraft and aerospace world. Because the significant aspect of the cable-actuated position transducer is a stainless steel cable, Firstmark Controls products have an inherent size and weight advantage compared to other choices.

Rod-and-cylinder products require room to store the rod and cylinder when the product is in its fully retracted state. For example, a typical rod-and-cylinder solution requires 42 inches (1.07 m) of operating space to measure 20 inches (0.51 m). A Firstmark Controls product can measure the same distance using less than 22 inches (0.56 m). When fully retracted, the rod-and-cylinder product takes up over 20 inches (0.51 m) of linear space. The Firstmark Controls product takes up less than 2 inches (0.05 m). See Figure 2.0.

Correspondingly, a rod-and-cylinder design will weigh significantly more than the Firstmark Controls product. A representative comparison for products with a 20-inch (0.51-m) range show rod-and-cylinder designs weighing 22 to 32 oz. (0.62 to 0.91 kg) while the Firstmark Controls product weighs around 3 oz (0.09 kg).

Figure 2.0: Comparison — Rod-and-Cylinder vs Cable Position Transducer



While a non-contact sensor may seem to provide slight size and weight advantages over a cable position transducer, often that advantage is outweighed once the non-contact sensor electronics and signal conditioning are taken into account.

Mounting Flexibility

The flexible cable combined with innovative mounting bases and mechanisms enable these position transducers to be mounted in accordance with your application requirements. There is no need to re-design your project or product. This flexibility is particularly useful when measuring flight control surfaces that simultaneously rotate and extend or when monitoring landing gear components that are moving in three dimensions. It is also useful when tight spaces provide no room for the transducer. Cable pulleys can be used to re-route the displacement cable through conduit and other channels, letting the transducer be placed remotely from the measurement location.

Ease of Installation

Quick-connect displacement cable connectors and varied mounting arrangements make the products easy to install and remove. This saves time in setup as well as reduces time spent at the design station and in the machine shop creating specialized installation fixtures.

Accuracy

Most Firstmark Controls products use threaded cable drums and precision potentiometers (providing infinite resolution), high-resolution encoders, servos, or synchros. Firstmark Controls's threaded cable drum design ensures the cable is laid in the same place each cycle. Non-threaded drums allow the cable to wind over itself in a haphazard fashion and reduce repeatability. These Firstmark Controls design features combined with precision-machined aluminum parts and assembly by skilled technicians result in unparalleled repeatability and resolution. Accuracy for a 30-inch (0.76 m) Series 161 unit has been shown to be better than $\pm 0.025\%$ of full-scale output.

Durability

Using high-quality precision sensing elements and anodized machined aluminum with ball-bearing-mounted shafts, Firstmark Controls position transducers will often outlast the aircraft or aerospace vehicle itself. Many products have been [environmentally qualified to DO-160D / ED-14D requirements](#).

Uses

Due to the sensitive nature of many aircraft/aerospace projects, we frequently never know how our products are used. Nevertheless, for over 40 years, we have come to recognize the most frequent uses of our products:

- structural testing
- landing gear
- elevators
- rudders
- ailerons
- air speed brakes

- level indicators
- actuator
- feedback
- human factors (cockpit controls)
- ordnance
- delivery
- systems
- space/missile/satellite
- applications
- crash testing
- payload displacement

Representative Applications

Below are a few recent applications of Firstmark Controls position transducers with notes on product usage. Contact us if you would like more details on these applications.

NASA: High-Temperature Component Load Test and Bell Crank Angle

Figure 3.0: High-Temperature Load Test

Numerous Firstmark Controls position transducers are used to measure deflection during component load measurement at high temperatures. The position transducers are located outside of the high-temperature chamber where the loading occurs. A hole in the chamber allows the displacement cable to be connected to the component under test. See Figure 3.0.

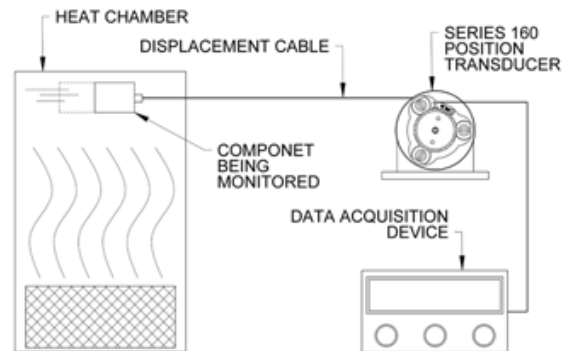
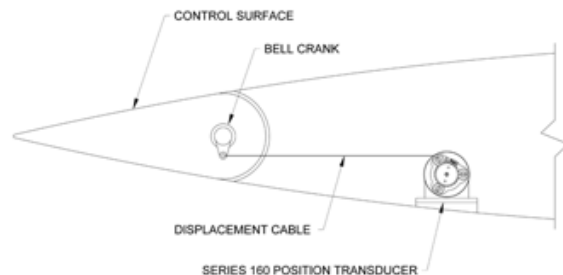


Figure 3.1: Bell Crank Angle

Series 160 products are also used to measure flight control surface angles using a bell crank. This type of installation allows rotary motion to be measured with a linear measuring device. See Figure 3.1.



By locating the position transducers on both the flight control surfaces and cockpit controls, actuation delay, non-proportional control, and pilot-induced oscillations may be monitored.

Military Fighter Speed Brake

A Series 173 product with a 3-inch (76.2-mm) range was used to measure the angle of an aircraft speed brake for a military fighter aircraft. The speed brake operated at relatively high velocity and required that the position transducer be provided with high cable tension.

Business Jet Landing Gear

Series 160 position transducers were outfitted on the landing gear of a large business jet to obtain displacement data during takeoff, landing, and gear stowage. Data was used to verify the landing gear performance.

Space Station Environment Control

A modified Series 162 position transducer is used as an ammonia tank level sensor for a Space Station environmental control system. The position transducer is in a nitrogen atmosphere and attached to a collapsible metal bellows. A low-profile sensor was critical for this application and a custom cable-redirection pulley is used to change the cable direction 90°.

Simulator Data Acquisition

Over twenty Series 150, 173, 160, 161, and 162 products were used in series of data acquisition flight sessions to acquire flight control and related information. The information was then used to develop FAA Class C and D flight simulators for pilot training and certification.

UAV Actuator Feedback

A high-altitude UAV (unmanned air vehicle) was outfitted with two Series 173 units to provide position feedback to wing-tip-mounted actuators. The actuators were used to torque the wing such that the entire outer wing section acted as a flight control surface. Series 150 products were also used to provide feedback on the V-tail flight control surfaces.

Product Usage Notes

Which Series To Use

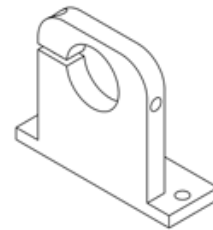
In general, the product size, displacement, and resolution will determine which Firstmark Controls position transducer is best suited to your application. An exception to this guideline is when increased cable tension is required for very-high-frequency-response applications. Series 150, 17X, and 180 products are not available with ultra-high cable tension and therefore ultra-high cable tension requirements must be met with Series 16X products.

Position Transducer Mounts

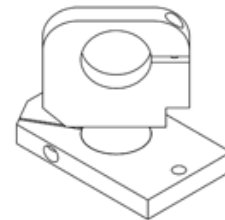
Mounting of Firstmark Controls products is simple using a choice of mounting bases and designed-in mounting flexibility. Rotation ability of most bases allows precise alignment of the product after it has been mounted.

Series 6, 160, 161, 162, 161H, and 161H

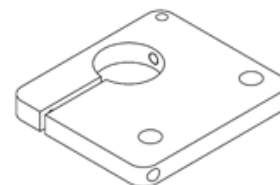
Standard Base (part number 160015) - Allows 360° rotation of the position transducer about the cover.



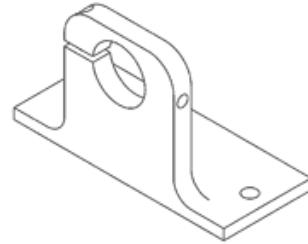
Universal Base (part number 160030) - Similar to the standard base but with the added capability for 360° rotation about the base itself.



Flat Base (part number 160040L) - Mounts the position transducer in a prone position. Provides 360° rotation about the cover.



Big Foot Base (part number 160015-13 or 160015-15) - Similar to the standard base but with a wider mounting platform for quicker mounting.



Steering Column Base (part number 160015-G1) - Allows easy mounting of the position transducer to vehicle steering columns for measuring fore-and-aft steering wheel deflection. Attaches to the steering column using hose clamps or similar mechanism.

Series 150 through 180

- **Integrated Mounting Capability** - All products come with #2-56 mounting screwholes.

- **Series 173 Mounting Base (part number 173015)** -The Series 173 product is available with an upright base that allows 90° rotation about the cover.

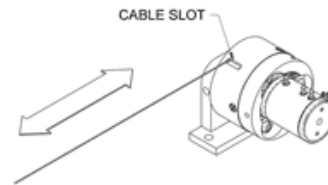


Other Mounting Methods

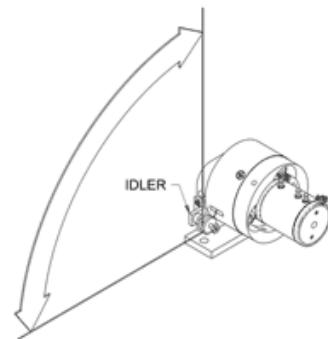
- **Magnetic Base** - In some environments, quick and clean mounting and dis-mounting can be accomplished by using magnetic bases.
- **Double-Sided Tape** - Double-sided tape provides a relatively secure and fast method of mounting the position transducers.
- **Industrial Adhesives** - Adhesives can be directly applied to the rugged anodized aluminum cases and the application. This is particularly useful in a fast-paced test environment. Custom Mounts - Custom mounts and configurations can be developed if your application has unique requirements.

Accessories

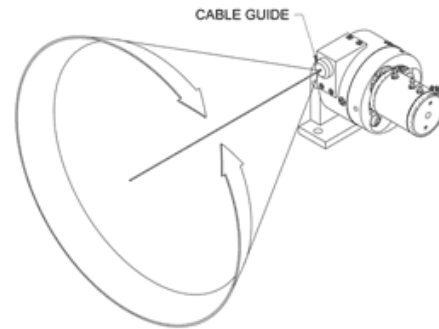
- **Cable Guide (part number 160045)** - Prevents the cable from departing the threaded cable drum. Recommended when straight cable motion cannot be guaranteed. Allows cable movement with-in a 20° cone, providing quick setup for three-dimensional movement applications such as landing gear. For Series 16X products only. See Figure 4.0.



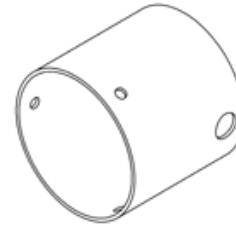
- **Idler (part number 160022 or 161022)** - Compensates for off-center cable travel when non-linear motion is created at the cable point of contact. Compensates for up to 90° of off-center misalignment. For Series 16X products only. See Figure 4.0.



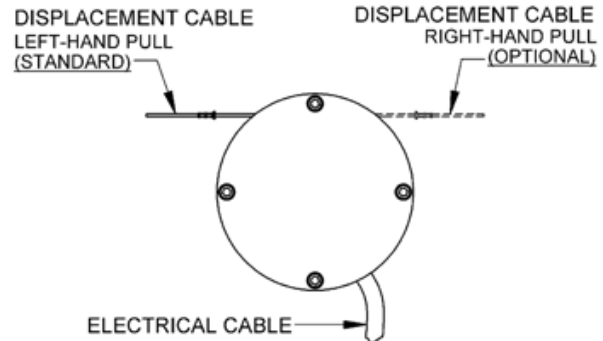
- **Pulley** - An Idler or pulley can be used to remotely position the transducer in high-temperature areas as well as to allow measurement through conduits and similar inaccessible areas.



- **Potentiometer Cover (part number 160060)** -Protects the potentiometer on Series 16X products in adverse environments.



- **Cable Pull** - Series 150, 173, 174, 175, and 180 products provide a choice of either left-hand or right-hand displacement cable pull that provides increased mounting flexibility.

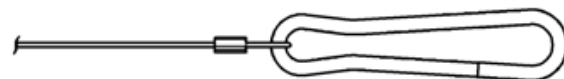


Displacement Cable Attachment

- **Swivel (part number 160026)** - Rotatable connector with easy-connect clasp; minimum breaking strength is less than the displacement cable.



- **Line Connector (part number 217)** - Non-rotatable connector with more rugged construction than the Swivel; minimum breaking strength exceeds the displacement cable.



- **Crimped Ball (part number 160034)** - 1/8-inch (3.175-mm) or 3/16-inch (4.7625-mm) diameter stainless steel ball swagged onto displacement cable for placement into specialized connector located on the application fixture.



- **Custom Connectors** - Unique application- specific connectors have been developed including magnetic, movable, and screw-in connectors.

- **Connecting to Aircraft Flight Control Cable** - One method of attaching the displacement cable to an aircraft flight control cable is to use a small Adel clamp. This clamp installs and removes easily without damaging the flight control cable.
- **Locating the Swivel or Line Connector** - If you use the Swivel (part number 160026) or Line Connector (part number 217) that comes standard with every Firstmark Controls position transducer, you will need to crimp the brass Eyelet (part number 160032) at the position of your choice. To crimp the Eyelet, loop the displacement cable through the Eyelet, through the Swivel or Line Connector, and then back through the Eyelet. Crimp the Eyelet using a 4-pronged electrical connector crimping tool or equivalent. See Figure 4.1 on prior page.

NOTE: If you need to cut uncoated displacement cable, you should anneal the cable with a flame at the cutting point to ensure the cable does not fray after cutting.

Other Considerations

- **Displacement Cable Construction** -The standard displacement cable used is of 7 x 7 stainless steel construction with a minimum breaking strength of 40 lbs. (178 N). It has a diameter of 0.018-inch (0.457 mm). A larger 0.027-inch (0.686-mm) diameter cable with 90-lb. (400 N) minimum breaking strength is available for applications using ultra-high cable tension (greater than 56 oz. (15.57 N)). This type of cable is used infrequently in aircraft/aerospace applications.
- **Synchros, Servos, and Encoders** -Historically, most aircraft and aerospace applications specify precision potentiometers as the sensing element. Standard and custom synchros, servos, and encoders may also be specified.
- **Custom Designs** - If your application has unique requirements not met by our standard products, please contact us. We have extensive experience modifying existing products and developing new products to meet demanding requirements. Some examples include high-frequency-response chest and knee displacement transducers for anthropomorphic dummies, low-profile products for space vehicle mounting, and custom signal conditioning for flight test programs.

More Information

To learn more about products and accessories not mentioned in this Application Note, visit the [Literature Room](#) or the [data sheet](#) for mounting bases and accessories

Conclusion

If you have any questions not answered by this Application Note or would like to discuss your application, please contact us by phone, fax, or e-mail. Let us know if you would like more information on these products.

A representative list of aircraft and aerospace vehicles where Firstmark Controls position transducers have been used:

- military fighter, attack, and cargo aircraft
- commercial aircraft
- trainers
- drones/RPVs/UAVs
- helicopters
- STOL/VSTOL aircraft
- racing aircraft
- general aviation
- experimental aircraft
- space vehicles
- missiles
- high-speed rail
- ground testing (static, dynamic, and crash)
- flight simulators

Additional Resources

- [Calculators](#)
- [Frequently Asked Questions \(FAQs\)](#)
- [String Potentiometer and String Encoder Engineering Guide](#)
- [Sensor Total Cost of Ownership](#)
- [Application Note for Ground Vehicles/Transportation](#)
- [Application Note for Draw Wire Transducer Accuracy](#)
- [Application Note for Motorsports](#)
- [Position Transducer Data Sheets](#)
- [Position Measurement & Control Archives](#)

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