Application Note for Motorsports

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

Introduction

There may be no other sport today that melds technology with competition more than motorsports. Whether it is Formula 1, NASCAR, Drag, Indy, Kart, or Rally competitions, the hundreds of pounds of precision and intricate equipment is as important as the talents of the teams working and improving the guts of the car. The slightest tweak can shave milliseconds off a car's or motorcycle's lap time. That may not seem like much to the everyday commuter, but for race vehicles, that variance can spell the difference between first and second place.

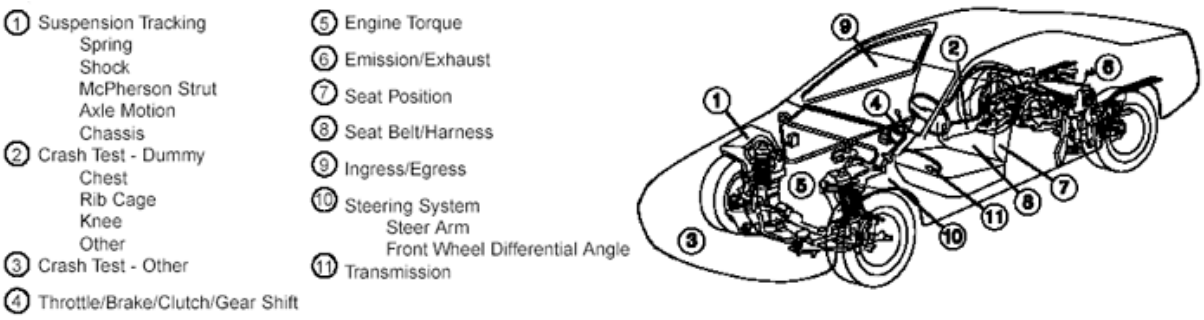

Figure 1 - Firstmark Controls parts, highlighted above, collect critical performance data to help drivers and engineers evaluate and improve their times and technology.

New technology and design modifications are created to give drivers performance advantages. However, without accurate data collection, quantifying the effectiveness of a new part or a changed design is difficult. Fortunately, technology exists to accurately document the movement of every instrument and component in the vehicle. From brake and gas pedal displacement to air foil deflection, valuable data can be gathered to fine-tune both the driver's performance and the vehicle's capabilities. For many motorsports teams, the use of Firstmark Controls position transducers and air data products are an integral part of this data collecting process. The strategic use of position transducers and air data products gives racing teams the data to perform a complete analysis.

Firstmark Controls Position Transducer

Position transducers provide valuable data on race vehicle component use. This information is sent to a data collection system for analysis by the driver's team. Depending on the team's budget, data can be transmitted wirelessly in real time to team computers for immediate analysis.

While each component is unique, position transducer cables are generally connected with a loop sleeve and secured with a screw. In most cases, the position transducer cable only needs to travel in one direction from the zero position, such as pedal movement. Final calibration is usually made by the data system. Data acquisition experts select specific position transducers to ensure the draw wire tension does not influence the user's action. For example, Firstmark Controls's Series 170 transducers have low tension that does not interfere when a driver depresses a brake or gas pedal.

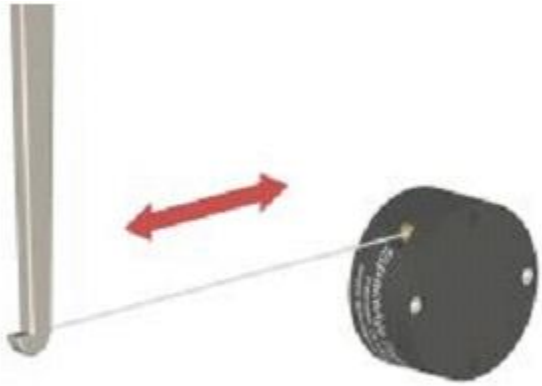

Figure 2 - A position transducers draw wire moves with components to collect position data over time

An area where position transducer mounting requires a little variation is on the steering wheel. Steering wheel data can use position transducers instead of the traditional rotary potentiometer attached to the steering gear box. For this situation, a draw wire position transducer can be drum mounted to the steering column with 50% of the travel distance extended.

The following sections detail how teams use position transducers with specific components.

Steering Wheel

In a race, the steering wheel holds the key to both victory and safety. Smart use of the steering wheel, in conjunction with braking and accelerating, can maneuver a race vehicle past opponents and around obstacles without losing time on the course. When a mistake is made or when bad habits creep in, it's up to the driver and his or her technical staff to analyze how the steering wheel was used when a problem arose.

Motorsports teams use position transducers to accurately collect data about the rotational position of the steering wheel. The value of this is reflected both in practice to monitor habits and during the race to examine responses during critical junctures. Position transducer data also acts as a constant monitor of vehicle upkeep. If the wheel does not feel as responsive to the driver, exact data about steering wheel movement determines if there is a problem in the steering column or if parts need to be lubricated.

In addition to tracking data regarding steering wheel position, position transducers can be used to determine the best steering column angle for each driver's preference.

Brake/Throttle Pedals (Driver Foot Controls)

Starting and stopping are the basics of any race. When it comes to motorsports, the driver's control of the brake and gas pedal dictates starting and stopping and also assists in avoiding

hazards and safely passing opponents. The effectiveness of fuel injectors and other additives, as well as the conditions of brake pads and braking mechanisms, all contribute to the driver's success and safety. Careful analysis of brake and gas pedal usage can give quite a peek into the car's overall technical health - and the driver's performance.

Motorsports technicians use the flexibility of cable-based position transducers to monitor pedal positions. On a mechanical level, transducer data can tell teams how a car responds when specific pedal displacements occur. If there is an indication that more or less displacement is required than normal, it immediately throws up a cautionary flag for teams to analyze the vehicle's health. From the perspective of the driver, transducer data can offer insight into the exact actions that took place when something went wrong - or right - in a race.

Suspension

The suspension is important to the safety of any driver and more so race vehicle drivers. The reaction of a suspension to high-speed turns, wall collisions, off-road bumps and hills, and the acceleration/braking process can mean the difference between victory and defeat - or in some cases, life and death. Analysis of suspension reaction during practice and testing gives mechanical teams the ability to overhaul problems, test performance of new tweaks, and maximize the risk/reward of a suspension system.

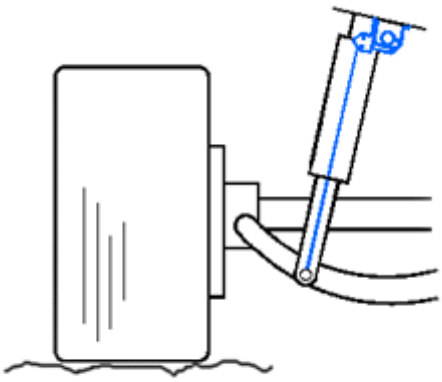

Figure 3 - Position transducers collect suspension data to evaluate driver and vehicle performance during different circumstances

Position transducers attach to the suspension's springs and dampers to collect response data during movement. This data can be applied to a variety of different scenarios, but the general purpose remains the same: how is the suspension holding up under the most extreme of circumstances? Transducer data can give teams a quick indicator if a certain spring or damper is not performing well, or if a different amount of suspension system may fit in better with a driver's style.

Airfoil

The position of a car's airfoil is key to the vehicle's performance under the influence of drag. When the airfoil deflects by even a small margin of 1°, its spoiling effect is reduced, resulting in slower speeds. While it does not likely affect drivers on daily commutes, this small force can mean the difference between winning and losing. By using position transducers to monitor the airfoil, teams can optimize a vehicle's response to airflow and minimize drag and optimize downforce.

For testing and monitoring purposes, a position transducer is typically mounted on the car bumper or frame with the displacement cable attached to the airfoil. As the vehicle experiences different drag forces at various speeds and turns, data is collected to note the exact amount of deflection experienced by the airfoil. Once the maximum deflection has been found in the data, the circumstances (speed, turn angle, etc.) that created that deflection can be determined and adjustments to the airfoil can be made accordingly. Race teams also use air data products to collect valuable information about static and dynamic air pressure changes to further optimize the use of the airfoil. For more about air pressure data, see the following section.

Unique Motorsports Benefits of Firstmark Controls Position Transducers

Position transducers are used for many different things - aerospace, traditional car needs, industrial mechanical systems - but few situations will duplicate the severe conditions of motorsports. Besides the intense thermal conditions produced beneath a car's hood, race cars undergo severe vibrations, high-impact collisions, harsh turns, and other circumstances that could upset a delicate sensor. Firstmark Controls position transducers come with design benefits that thrive in these extreme conditions.

For obvious reasons, driver safety is of the highest concern to any racing team. When it comes to safety, position transducers have an advantage over other types of sensors simply from the draw-wire mechanism. Sensors such as rod-based transducers have many more parts that could be prone to shattering during an impact. If a sensor shatters, the debris could find its way into key systems, damaging the vehicle internally and potentially putting the driver at risk. Firstmark Controls position transducers are not only durable, they are compact with a design that houses the sensor, the cable retraction mechanism, and the displacement cable.

Position transducer parts are extremely flexible and can even survive a high-speed crash, as seen in Figure 6. In the event of on-the-fly maintenance, the position transducer's lightweight and compact nature, along with the ease of use of the draw-wire mechanism, allows it to be easily replaced or repaired without fear of interference or damage to other components.

Figure 6 - Even after a high-speed collision during a NASCAR practice lap, Firstmark Controls position transducers are still intact.

Position transducers come with another design benefit: a cable failsafe mechanism. Each Firstmark Controls position transducer cable is connected to a component designed to break away during a crash or cable failure. This failsafe either cuts the wire completely or causes a cable snap back. For position transducers usually used in motorsports, such as the *Series 17X* units, the relatively low tension on the cable ensures that the transducer itself is not destroyed and salvageable for further use with some minor part replacement.

There is a significant size and a slight weight advantage for position transducers in relation to other types of sensors, but the true beauty in their use lies in the flexibility and durability. Because of the cable-based draw-wire system, position transducers can provide measuring data in an accommodating manner. With the thinness of the high-strength cable, the cable can run across a variety of surfaces without any problems. Firstmark Controls cables are made of stranded stainless steel to withstand extreme vibration and environments.
In addition, Firstmark Controls position transducers have high temperature thresholds (as high as +125° C (+257° F)) - perfect for the extreme thermal conditions produced by engines and other car parts.

Because of the displacement cable tension produced by the cable retraction mechanism, position transducer cables are taut to avoid cable sag, thus providing consistent data for the racing team even when the cable is run through awkward positions beneath the engine hood. Other design factors contributing to the accuracy of Firstmark Controls position transducers include displacement cable pre-stretching to effectively eliminate cable stretch error, a threaded drum to ensure repeatability, and a direct cable connection to the drum to avoid problems stemming from vibration, shock, and backlash. These features ensure a high repeatability that is critical when pit crews analyze data live during a race or test run.

Firstmark Controls Position Transducers Versus Other Sensors

In the world of data collection for motorsports components, teams will often employ position transducers in favour of LVDTs, rotary sensors, and rod/cylinder potentiometers. Two of the biggest reasons for this are the overall durability of a position transducer (both thermally and mechanically) and the flexibility of the draw wire design. For components located under the hood, these traits are key to keeping the sensors undamaged and active.

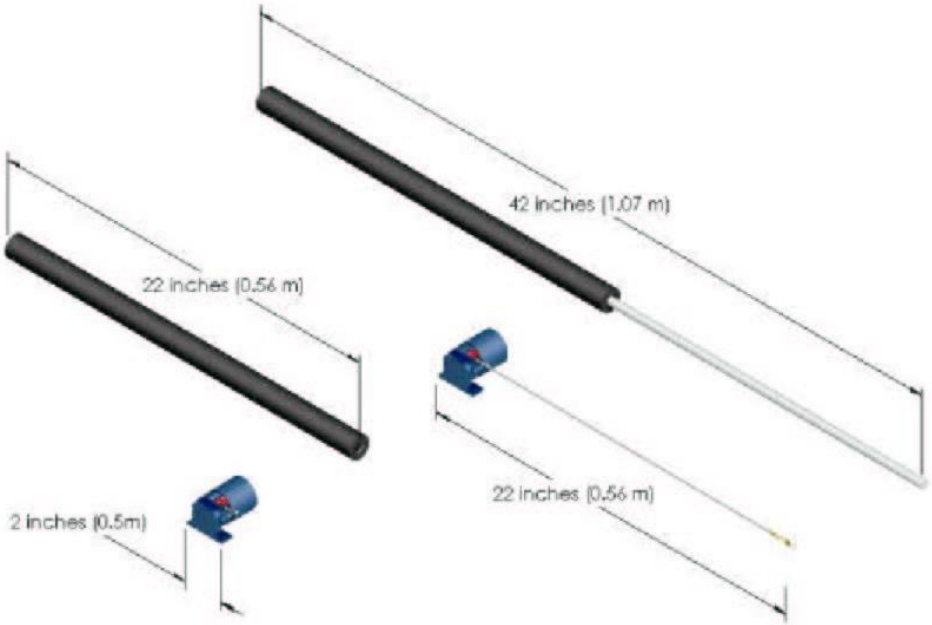

Figure 7 – Firstmark Controls products take up less than many times the size of a rod based transducer when fully retracted,

Firstmark Controls Position Transducers Versus LVDTs

LVDTs require electronic connection through either direct integration or a signal conditioner box. This additional electronic integration increases the amount of at-risk components for data collection, causing LVDTs to be environmentally sensitive. Considering the extreme

conditions under the hood of a car during a race, as well as the unpredictable nature of bumps, collisions, sharp turns, and sudden acceleration/braking, electrical components can be easily affected during a race. LVDT data can thus prove to be unreliable while the vehicle is in motion. In addition, the complex electronics involved with LVDTs tend to cause them to be more expensive than standard position transducers.

Firstmark Controls Position Transducers Versus Other Rod/Cylinder-Based Transducers

Because of their elongated body, rod/cylinder-based transducers such as LVDTs and linear potentiometers are subject to bending and/or breaking depending on the environmental circumstances. For example, the stiff and brittle nature of rod/cylinder-based transducers used for suspensions or near the axles could deform to the point of uselessness or shatter when a car crashes or experiences any other type of severe impact that produces harsh vibration. Rod/cyliner-based transducers require precise alignment - a difficult situation considering the intricate designs of many car components, as well as the limited space available. Vibrations are also a concern when using a rod-based transducer, as severe vibrations can knock the rod-based transducer out of alignment and cause improper data. In a worst-case scenario, the shattering, bending, or misalignment of a rod-based transducer's elongated body could interfere with a variety of systems to create a potential safety threat to the driver and the vehicle.

Firstmark Controls Position Transducers Versus Rotary Sensors

Rotary sensors are typically used for gathering steering wheel information. Position transducers can be mounted onto the steering column for the same application; while standard rotary sensors have some similar attributes, such as infinite resolution and operating temperature, there are several features favouring position transducers. Standard rotary sensors can have an error of less than 1° of rotation, but the accuracy is still based on overall rotation. For example, a rotation of 220° produces an error of 0.2% while a rotation of 100° produces an error of 1%. Position transducer error is a set value (generally 0.5%) that does not fluctuate based on distance travelled.

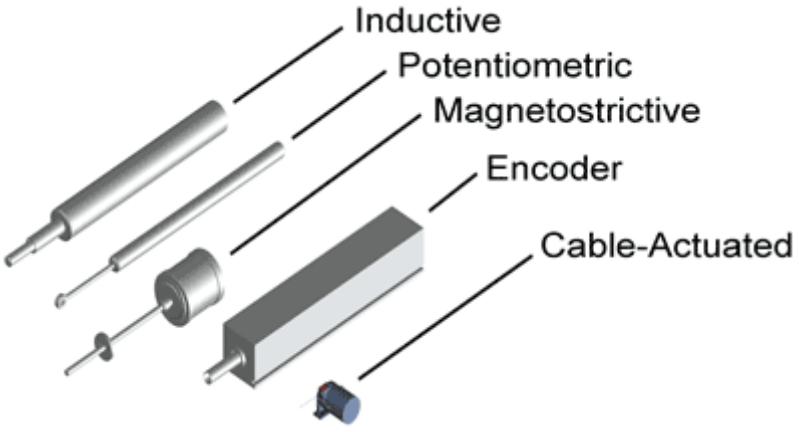

Figure 8 - Position transducers are considerably smaller and lighter than other measuring devices

However, the greatest advantage for cable actuated position transducers comes where it counts the most: safety. Rotary and rod based sensors have a rigid connection from the sensor to the measuring point. When this system is the steering column or brake pedal, parts from the sensor could cause interference with the vehicle’s mechanism and lead into a

catastrophic situation. With both a cable failsafe function and external mounting of SpaceAge's miniature position transducers , the chances for interference are far less.

SpaceAge Control Air Data Products

The changes in air pressure affect the speed of a race car in a number of ways. Two of the most prominent examples of how the change in air pressure can affect car velocity are in the areas of downward force and the airflow boundary layer. The efficiency of the car's airfoil dictates how much the vertical force caused by air can be negated, canceling out lift forces that may create control problems for the driver and adding a downward force, giving the car a tighter grip on the track for more responsive control and easier turns. This force is caused by a change in static and dynamic air pressure. To optimize the use of the airfoil, teams must collect data about this change in air pressure. By using SpaceAge Control air data products, teams can monitor the change in static and dynamic air pressure while adjusting the mounting and angle of the airfoil, along with testing different airfoils, to determine what design optimizes downforce and drag.

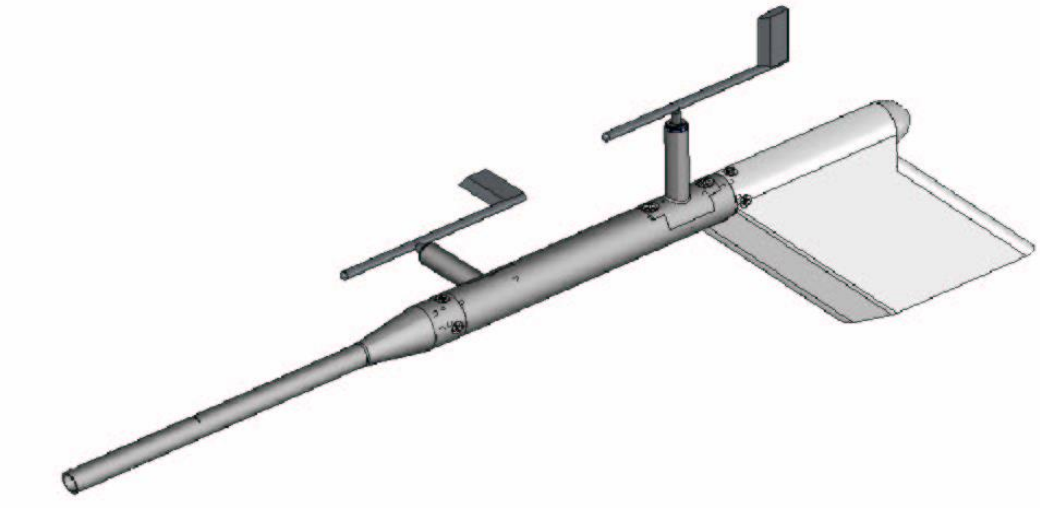

Figure 5 - Air data products, such as the pictured mini air data boom, provide race teams air pressure data to determine the best way to streamline drag

In a similar vein, cars experience a natural boundary layer in the airflow when traveling at high speeds. Within the boundary layer, static air pressure dominates over dynamic air pressure, causing molecules to stop moving. The greater the size of the boundary layer, the greater the chance for overall drag on the race car, thus reducing the driver's speed and hurting his or her overall chances to win. The effects of a boundary layer can be negated through a variety of methods. Teams may design the car to have gradual transitions, use a spoiler, or add a Gurney flap. Regardless of the method used, the team still must test its effectiveness. SpaceAge Control air data products give teams exact data on the changes in static and dynamic air pressure. Using this data, teams can assess what design changes are working or whether or not a Gurney flap needs to be changed.

Unique Benefits of SpaceAge Control Air Data Products

Because of the simple nature of pitot static tubes, one might think that there is no need to use a pre-fabricated air data collector for motorsports teams. However, engineered air data

products, such as SpaceAge Control 100386 vane, come with a variety of benefits for the user.
SpaceAge Control air data products use a combination of aluminum and stainless steel to maximize fatigue resistance and strength. The sturdiness of the materials allows SpaceAge Control air data products to work at speeds exceeding 400 knots. On the racetrack, the air data products have been used successfully by a variety of professional motorsports teams across a variety of racing leagues. SpaceAge Control uses wind tunnel tests to aid in the calibration of air data products and provides technical support to clients with nearly 40 years of air data measurement experience.

Conclusion

A representative list of ground vehicle and transportation applications where Firstmark Controls position transducers have been used:

- Rail-based transportation
- Utility vehicles
- Earthmoving equipment
- Light, medium, and heavy trucks
- Racing: Indy, NASCAR, Formula 1, Rally, DTM and others
- Bus and public transport
- Motorcycles
- Passenger cars
- Recreation vehicles
- Military vehicles
- Agricultural vehicles
- Monorails
- Snowmobiles and snow-moving equipment

Additional Resources

- Position Transducer Solution Guide
- Position Transducer Data Sheets
- Position Transducer Installation Guide
- Application Note Sensor Total Cost of Ownership
- Application Note for Aircraft/Aerospace
- Application Note for Draw Wire Transducer Accuracy
- Position Measurement & Control Archives

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:

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