Side Slip Sensor
Model: TrueSlip

User Manual

Michigan Scientific Corporation

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Contents

TrueSlip
Side Slip
Sensor

- Side Slip Sensor
- Various Mounting Options Available
- CAN Signal
- Works in a variety of light conditions
- Works in a variety of road conditions
- Non-contact optical sensor
- IP67 rated

Specifications

Speed Range	1 mi/h to 200 mi/h (1.6 km/h to 320 km/h)
Angle Range	±45 °
Slip Angle Resolution	≤ 0.1° @ >20 mi/h (32 km/h)
Measured Angle Accuracy	≤ 0.2° @ >20 mi/h (32 km/h)
Measurement frequency	≤ 40 Hz
Working Distance	200 mm ±50 mm (8 in ±2 in)
Signal Output	CAN 2.0
Input power voltage range	8 VDC to 18 VDC
Environmental Rating	IP67
Technology	Optical Flow
Signal Outputs	CAN 2.0 and Serial
Illumination	Internal LED @ 850 nm IR

The Michigan Scientific Corporation (MSC) TrueSlip sensor measures the slip angle of a tire and wheel while undergoing cornering maneuvers under normal and severe operation of a vehicle. It has been designed to work in conjunction with the MSC Wheel Force Transducer system or as a standalone device. It measures slip angle as defined by the Society of Automobile Engineers (SAE) method, which is the calculation of the arctangent of the lateral velocity divided by the longitudinal velocity.

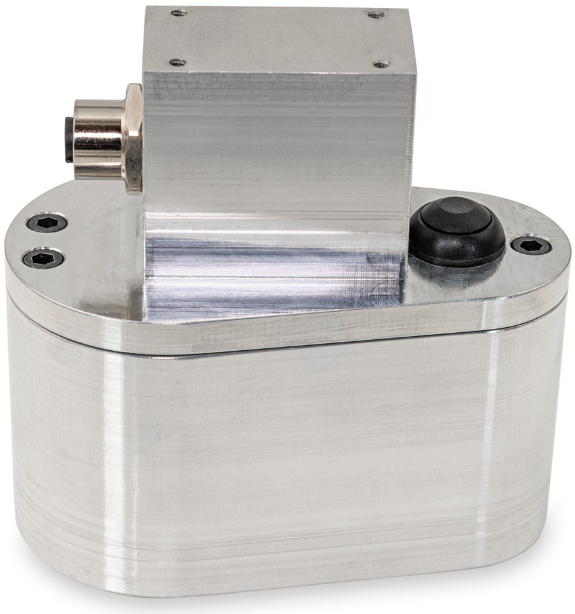
The patented design utilizes Optical-Flow technology that captures sequential images of a road surface and determines the velocity in each of these directions from statistical calculations. The lateral speed is divided by the longitudinal speed and the arctangent of this ratio is calculated and then output as CAN Bus data for recording. Appropriate low-pass FIR filtering and data integrity checking is also performed. These calculations are made for output sample rate of 1000 Hz. The time delay due to the FIR filter is fixed at 94 ms.

Slip angle data from the MSC sensor have been measured in a variety of vehicle operating conditions. These include a number of dry and wet asphalt and concrete roads, ice, sand, and gravel, and at a very large range of actual road and laboratory simulated speeds in both the cornering and longitudinal directions.

The sensor is designed with an integrated infrared light source. This makes it insensitive to external lighting and shadowing conditions. It functions in bright sunlight, as well as total darkness. This wavelength is barely visible to human sight, but should not be directly stared at for any length of time.

TrueSlip Sensor

The patented design of the TrueSlip utilizes Optical-Flow technology that captures sequential images of a road surface. The images are processed and used to calculate the slip angle in real time.



Slip Ring

The SR20AW/E512/AX7 Slip Rings are used with Slip Angle Sensors when being used with MSC Wheel Force Transducers or a Wheel Mounting Kit. It is an instrument-quality, rugged twenty circuit weatherproof slip ring with a 512-pulse encoder which is mounted to the amplifier package of the WFT. The 'AX7' Slip Ring has 63 N · m moment capacity (from bearing center-line) and has side mounting holes for installation of the mounting bracket.

Slip Ring Mounting Bracket

The mounting bracket for SR20AW/E512/AX7 Slip Ring.

TrueSlip Cable

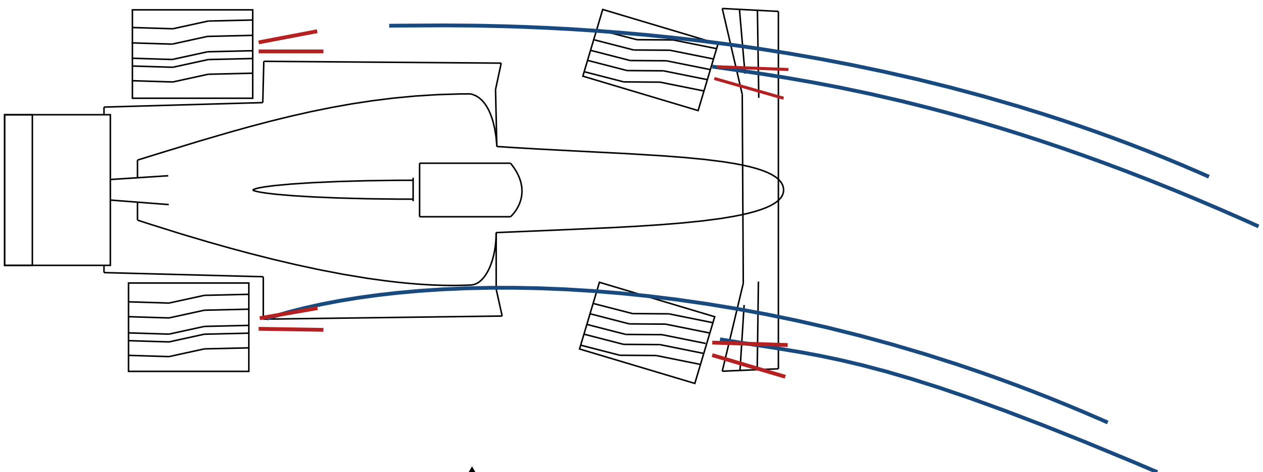
One end of the cable has an M12 connector for attachment to the TrueSlip sensor. The other end has an Auxiliary (cigarette) plug for DC power and a DB9 connector for CAN signal output.

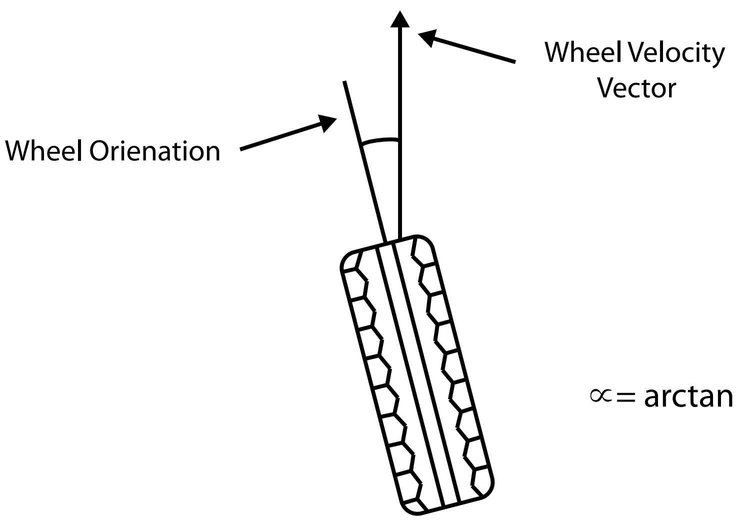
L-Bracket

The orientation of the holes in the bracket pilots the TrueSlip lid in four different directions. This allows the TrueSlip to be mounted to the front, back, or either side of the vehicle while the front of the TrueSlip remains facing the direction of travel.

Definition of Slip Angle

Rolling tires on a vehicle that are aligned and centered tend to produce forces that keep the vehicle going in a straight line. When a vehicle is steered to traverse a bend in the road, the front tires produce a force perpendicular to the direction they are pointed. It is this force that alters the direction of travel of the car in order to follow the roadway.





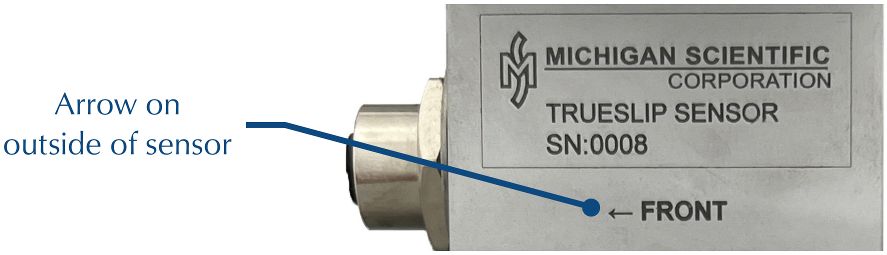
$$\propto = \arctan\left(\frac{\text{wheel lateral velocity}}{\text{wheel longitudinal velocity}}\right)$$

This action also produces a small velocity in the same perpendicular direction. The slip angle is defined by the Society of Automotive Engineers (SAE) as the arctangent of the lateral velocity divided by the longitudinal velocity. The TrueSlip sensor measures each of these velocities and calculates this slip angle every ms. This produces the 1000 Hz output slip angle data which is outputted via CAN Bus.

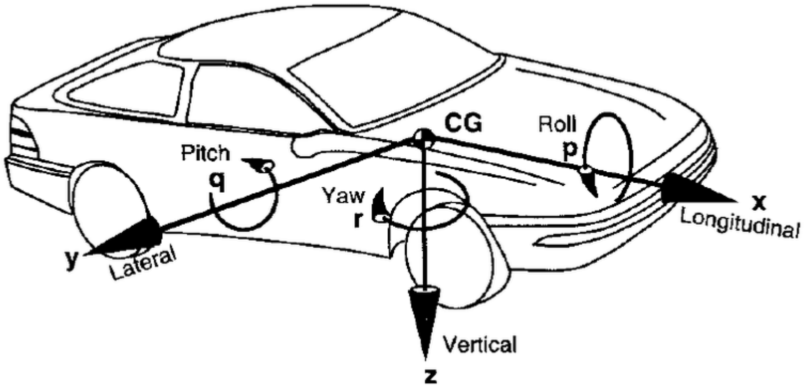
It is important to note that a cornering vehicle has different slip angles at each tire/wheel. This is due to the differences in steering angles of the tires and also the over-steer/under-steer characteristics of the vehicle. This makes it important to understand total vehicle performance characteristics.

Zero Slip Angle

The TrueSlip sensor calculates and outputs the slip angle from simultaneous measurements of longitudinal (X) velocity in the direction of the arrow on the outside of the sensor, and lateral (Y) velocity in the horizontal plane perpendicular to the direction of the arrow using the SAE coordinate system, shown below. The arrows



indicate positive values.



An automobile traveling along a road surface is rarely oriented precisely in a level, flat, horizontal plane, and therefore rarely operates at zero slip angle. Straight road surfaces are intentionally crowned with the high point in the center of the roadway in order to allow rainwater to runoff without forming puddles. Curved surfaces are often elevated on one side to counter centrifugal cornering forces. Hills and valleys also cause significant departures from level. Even wind forces can cause significant departure from straight-level travel. A slip angle sensor will respond to these disturbances as departures from zero slip.

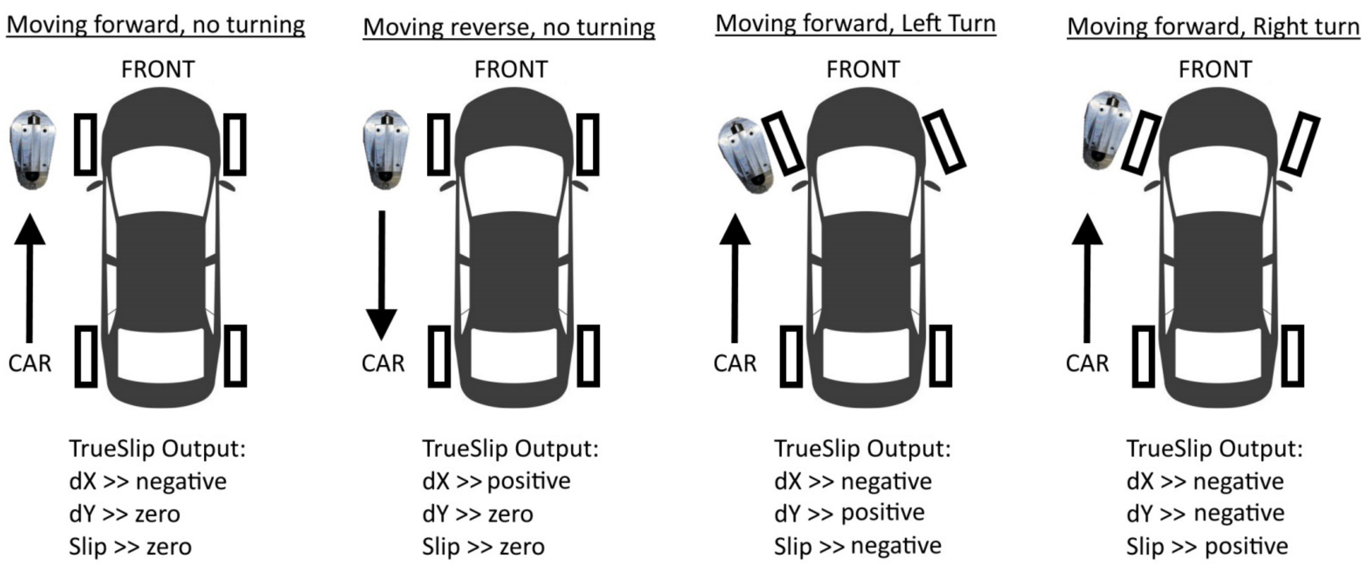
In addition, automobile mechanical settings and features can also create tire slip. Wheel camber and toe settings create tire slip. Tires often have a slight conical shape, referred to as conicity. Steel tire belts under the tread surfaces have angled reinforcements which also cause a slight steering disturbance called ply-steer. All of these disturbances can cause slight slip angles even for a vehicle traveling down a straight level roadway. It is not uncommon to observe a slip angle of a half degree or more on a straight level road at highway speeds. For these reasons and more, it is worthwhile to determine a zero offset value for the vehicle conditions being tested. This value can then be subtracted from slip angle data where appropriate.

Coordinate System and Location on Vehicle

When mounted on the right-hand (RH) side of the vehicle with the arrow on the sensor pointing in the direction of travel, the TrueSlip sensor produces a positive slip angle when slipping to the right since the lateral speed is positive. When mounted on the left-hand (LH) side of the vehicle with the arrow pointing in the direction of travel, it produces a negative slip angle when slipping to the left since the lateral speed is negative. These signs can be altered if the direction of the arrow is not considered when mounting the devices. It is important for the tester to note these conditions when setting up the vehicle.

There is a slight improvement in the aerodynamic drag of the sensor when pointing in the forward direction. This is expected to be negligible for all but high-speed racing applications. Disruptions in airflow due to tire spin, under-body air flow, wheel vent area, and body aerodynamics can easily overcome the slight effect of the sensor aerodynamics. It is generally easier to keep the sensor mounted to the slip ring when moving the location from left to right, and/or to keep all sensors mounted consistently regardless of intended location. This makes it important to always note the direction of the arrow when testing, and to apply the appropriate sign conventions when processing the data.

The diagram below shows the expected polarities of the TrueSlip sensor with different car movements.



Body Mount Installation

Required Tools

3/32 in Allen wrench

7/16 in crescent wrench

Full System

Mount Construction

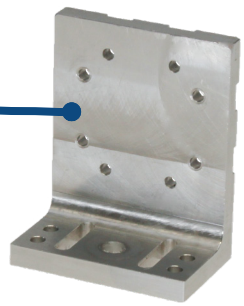
Turn the handle on the adjustable arm counter-clockwise.

Insert the ball head of the plate into the arm.

Turn handle clockwise to tighten.

Repeat with other two arms.

True Slip Connection



Pilot the long end of the L-Bracket to the lid of the TrueSlip.

Use four #4-40 x 5/16 in screws to connect.

Notes

Orient the front of the TrueSlip to the left side of the L-Bracket if intending to mount on the driver's side of the vehicle

Align the short end of the L-Bracket with the hole in the plate of the mount.

Place the washer on top of the L-Bracket and secure with the 1/4 in - 20 bolt.

For redundancy, place the nut on the back of the bolt and turn clockwise to fasten.

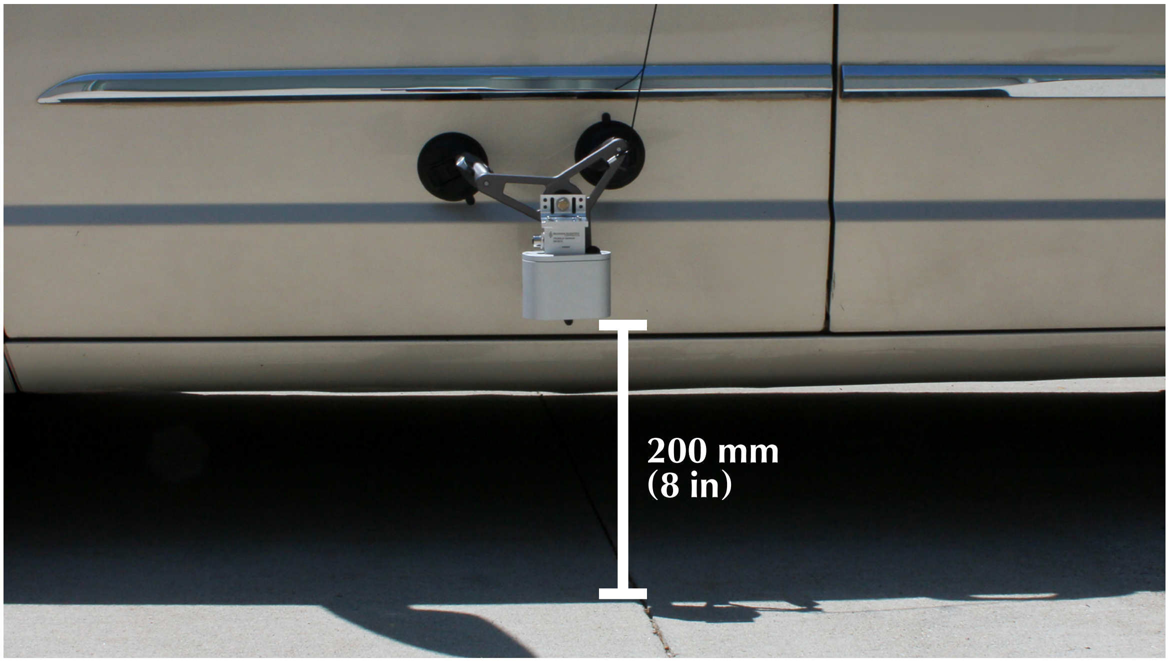
Body Mount Installation

Lift the latch on the adjustable arms to release the suction cup.

Orient the mount onto the body of the vehicle.

- Ensure the “front” of the TrueSlip is facing the front of the vehicle.
- Ensure the bottom surface of the TrueSlip is 200 mm (8 in) above the ground.

For each arm, apply pressure and push in the latch to secure the mount to the vehicle.



Notes

Thoroughly clean vehicle mounting surface before installation.

Once the suction cups are secure, turn the handle on the arm counter-clockwise a single turn.

- Move the arms to orient the TrueSlip parallel to the ground.
- Turn the handles clockwise to tighten the arms into position.

Secondary Restraint Attachment

Different lengths of cables are provided to be used as a secondary restraint.

It is recommend to have two cables attached to different contact points on the vehicle.

Notes

Attachment points should be selected so that if the suction cups fail, the TrueSlip will not contact the wheel or road surface.

To secure to the mount:

Thread the cable into on of the cutouts on the plate.

Insert one end of the cable through the loop on the other end of the cable.

Pull to tighten.

Fasten the loose end of the cable to a contact point on the vehicle.

Vehicle Body Mounting

TrueSlip can also be mounted directly to the front or rear of the vehicle, as shown. The distance from the bottom of the TrueSlip body to the road surface should be set at 8 in (200 mm) for best accuracy.

Wheel Mount Application

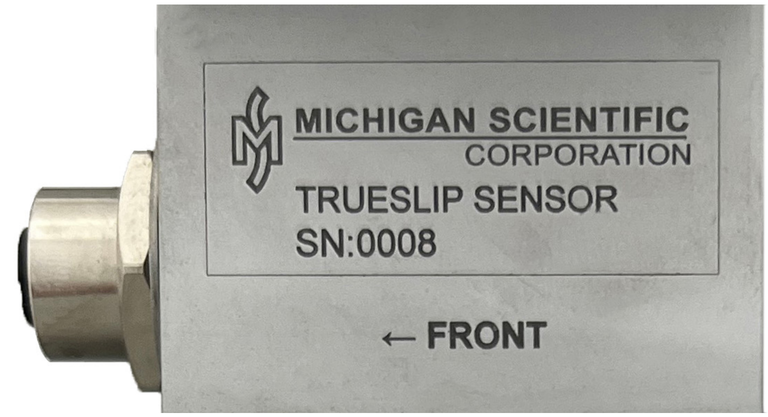
There are two options for mounting TrueSlip in a Wheel Application.

Use with a Michigan Scientific Wheel Force Transducer. This utilizes the WFT Slip Ring as the mounting point. This requires a SR20AW/E512/AX7 Slip Ring.

Use alone on a wheel. This requires are Wheel Mounting Kit, which includes extended lugnuts, wheel mounting plate, SR/AX bearing, and anti-rotation rod.

Both wheel application types will install the same way.

Install mounting bracket to Slip Ring or SR/AX Bearing with four #4-40 screws as shown. The orientation of the mounting bracket will depend on which side of the vehicle that it will be installed on. Orient the FRONT arrow towards the front of the vehicle.



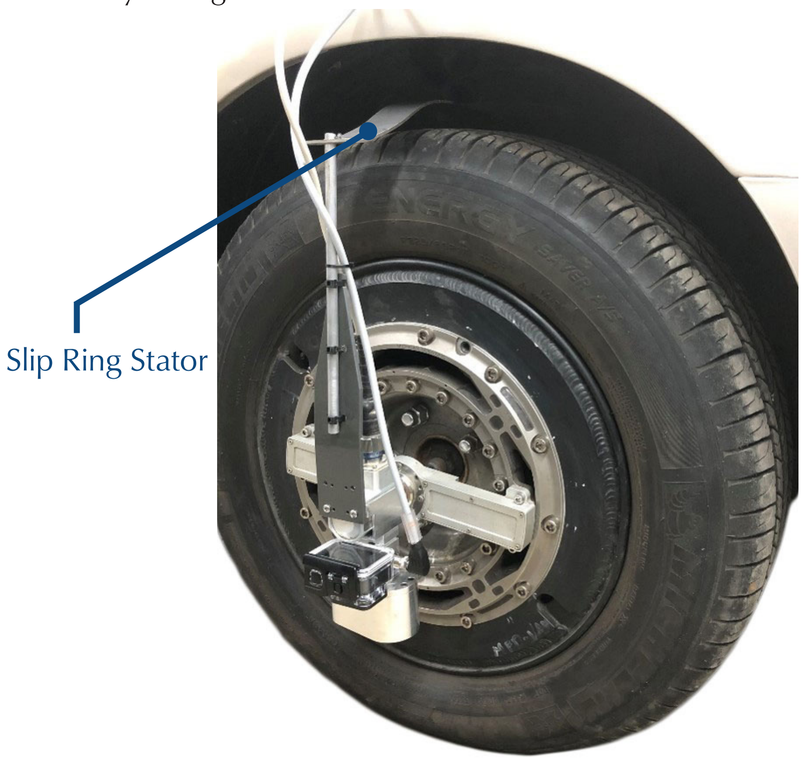
Install the mounting bracket onto the Slip Ring or SR/AX Bearing with two #8-32 screws and two #6-32 x 0.25 in bolts.

#8-32 x 9/16 in Screws

#6-32 x 0.25 in Bolt

Anti-Rotation Restraint

The Slip Ring Stator (non-rotating part of slip ring) or SR/AX Bearing Stator should have minimal movement with respect to the vehicle body throughout the test.



Stator Restraint for Rear (Non-Steering) Wheels

Michigan Scientific provides a MVSR (Magnetic Vehicle Stator Restraint) and restraint rod with each Wheel Force Transducer System.

The MVSR and restraint rod should be used to prevent the slip ring from rotating on non-steering wheels or straight line tests. The MVSR should be attached to the vehicle body with the magnet backing and should be placed directly above the slip ring. Slide the restraint rod into the 5/8 in (16 mm) hole in the MVSR and attached the plastic portion of the restraint rod to the Slip Ring with two 8-32 x 9/16″ Phillips head bolts. These bolts should be installed with lubricant and should be tightened firmly with a screwdriver.

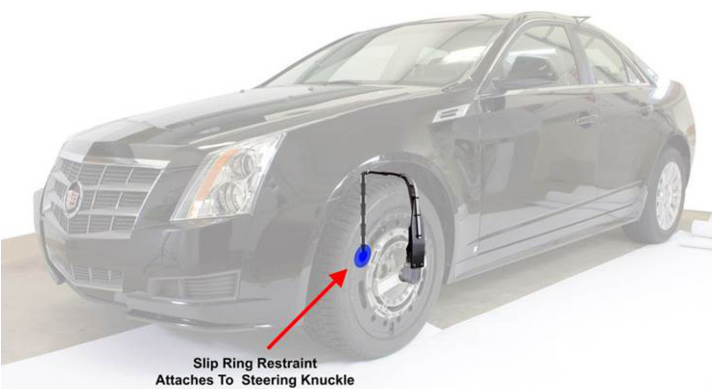
Use a digital protractor or level to check if the slip ring stator is vertical. As needed, make adjustment to the MVSR placement so that the slip ring is vertical. Once the MVSR is in the proper location, tape should be used to further secure the MVSR to the vehicle body. If the car body is non-ferrous, strong tape alone can be used to hold the MVSR in place.

Stator Restraints for Front (Steering) Wheels

For front (steering) wheels it is important to keep the TrueSlip Sensor vertical throughout the test for best accuracy. This can be achieved by using an over-the-wheel bracket.

Over-the-Wheel Bracket

The over-the-wheel slip ring stator bracket will have to be custom-made by the user. The reason the bracket must be custom is that the attachment points for every vehicle are unique, so there is no universal type over the wheel bracket. The over-the-wheel bracket should be stiff, yet lightweight. Below are examples of over-the-wheel brackets.



Cable Connections

Connect the M12 connector of the provided cable to the TrueSlip Sensor. Route the cable into the vehicle cab near the power source and data recorder. The provided cable has an Auxiliary (cigarette lighter) plug for power connection and a DB9 connector for CAN signal output.

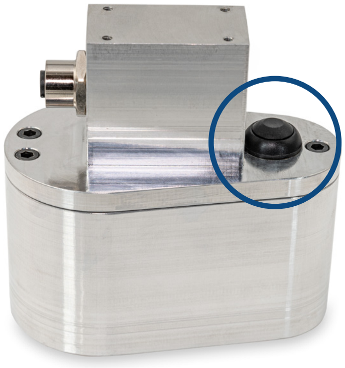
Connect the Auxiliary (cigarette lighter) plug to a DC power source. The input is 18 V max. Connect the DB9 connector to the data acquisition CAN input. The DB9 connector pin-out follows the industry standard. See appendix for details.

Connecting Multiple TrueSlip Devices

Each TrueSlip sensor must be powered individually. An Auxiliary (cigarette lighter) plug from each TrueSlip cable must be plugged in and powered. A splitter can be used, as shown below, or the power cables can be hard-wired together.

TrueSlip Set-Up

The single button on the TrueSlip sensor is used to turn it on. The button LED should illuminate once it is powered on. This indicates that the sensor is powered and the illumination LEDs are illuminating the road surface.



Once turned on, the Longitudinal (X) velocity and Lateral (Y) velocity will be active.

Notes

The Slip Angle output will also be active, but is held at zero until a minimum of 2 mi/h (3.2 km/h) longitudinal speed is met.

Slip Angle Zero Setting

A TrueSlip sensor may report a slip angle value that is not zero degrees while driving a vehicle in what appears to be a straight line on a level surface. The physical mounting hardware for slip angle transducers on a vehicle may have angles, locations, and construction variabilities that give sensor positions that differ slightly from orthogonal to the vehicle or tire. This will then alter the physical zero point for the transducer.

In addition, a rubber-tired vehicle, even while traveling along a straight level surface, will develop some amount of slip at each tire due to rolling resistance. This will create a slip angle when there is unequal weight distribution among each of the tires in the vehicle.

Road conditions such as crown, slight curvature, side winds, and aerodynamic forces due to the driving speed, can also result in a slip value that is offset from zero on what appears as straight and level.

A zero offset is particularly true for the front wheels. Front wheels are generally designed to have some amount of caster, camber, and toe-in for optimizing handling, drive-ability, and stability during normal driving. Suspension geometry often is designed with a 'king pin angle' that differs from true vertical by a degree and more.

As small steering corrections are made, even to maintain a straight path, the camber and the caster angles will change with the steering angle. Depending on the suspension design, rear tires positions may also have some amount of built in small angular offsets from zero.

Because of variabilities such as these, a sustained offset slip angle of a degree or more can easily be indicated as the vehicle moves along a straight road surface.

The value for zero slip can only be determined after the Slip Angle Sensor has been mounted on a vehicle and operated under typical driving conditions. This final zero offset must be determined with a physical test of the completed test setup on a straight, level surface. This value should then be subtracted from the reported slip angle for each subsequent sampled data point. This correction can either be included as part of the data acquisition setup, which is possible for some data recorders, or through post-processing after the data has been recorded for recorders that do not have this capability.

Zero Offset Test Procedure

The measurement site varies with road surfaces that are available. It's best to have a surface with a sustained straight and level portion that is at least several hundred feet long or more. Side winds greater than 5 mi/h should be avoided.

The vehicle should be loaded to the test weight, with the proper distribution of mass in the vehicle, including driver and passengers. Some amount of normal driving should be conducted prior to entering the measurement portion to adjust frictional and damping conditions to their center positions. Speed should be constant and is best to be over 10 mph for consistent sensor output, but below 20 mph in order to minimize aerodynamic effects. Care should be taken to avoid braking and sudden steer or throttle changes, to maintain a consistent speed while recording the zero set point data.

Almost all straight roads are crowned near the center in order to provide water runoff during heavy rains. If a truly level surface in both longitudinal and side slopes cannot be found, it may be possible to find a road surface with minimal crown that can be driven with the vehicle centered over the crown to minimize any side slope effect. Even a Vehicle Dynamic Test site, which likely has a slight tilt for water drainage, will have a direction of travel that has no side slope, though there will be a slight uphill-downhill grade.

The sensor slip angle output should be averaged for all samples measured over this appropriate portion of the surface to give the value for the ‘Slip Angle Offset’. This offset should be expected to remain consistent for all subsequent recordings that use the same setup conditions. This value should be noted for each sensor and subtracted from subsequent measurements of slip angle when reporting measured values.

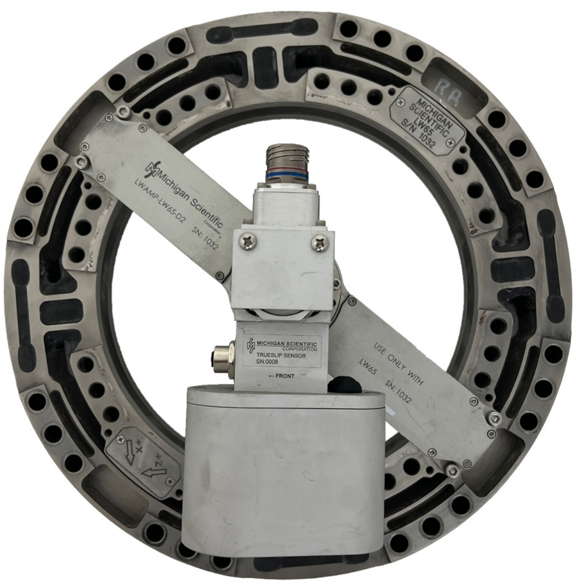
TrueSlip CAN Outputs

Each TrueSlip sensor outputs Slip Angle Data via CAN Bus. The Slip Angle output is held at zero until a minimum Longitudinal velocity of 2 mi/h (3.4 km/h) velocity is reached. For best results, the bottom of the TrueSlip housing should be 8 in (200 mm) from the road surface.

The Slip Angle units are Degrees.

DBC File (for CAN output) and Position Identification

Each TrueSlip sensor is hard-coded to a Position Identifier. The sensors can be set-upset up as Position 1 (POS1) through Position 6 (POS6). Their Position identifier will be labeled on the outside housing as shown below.



The CAN database file is generated and provided by Michigan Scientific as a .dbc file (see appendix) which will work with up to six TrueSlip sensors. When installing the sensors, take note of the TrueSlip sensor position number and location on the vehicle, so the data can be properly assigned.

The CAN database file can be e-mailed by Michigan Scientific and is also located in the Appendix of this manual.

Signal Delay

The Slip Angle (SlipAngle_20Hz) has a fixed signal delay of 94 ms. When correlating the TrueSlip data with data from other sensors, the fixed time delay should be accounted for, either with post processing or with time correction in the data acquisition

Operating Distance to Road Surface

The TrueSlip sensor is set to focus at an operating distance of 8 in (200 mm ±50 mm) from the bottom of the sensor rim to the road surface. This distance has been optimized for typical passenger car sized tires. It can operate correctly over a range of distances ±2 in (±50 mm) from this number. If the tire and wheel sizes planned for use result in a measurement significantly different from this value, spacers must be added between the sensor and the slip ring or bearing in order to move the sensor within this proper focus range.

Velocity Calibration

The TrueSlip sensor is an optical device which captures and compares features of sequential road surface images for optical flow analysis. These images are processed statistically to determine a delta X displacement and a delta Y displacement. When these displacements are divided by the time between samples, a speed in each direction is calculated. The optical magnification of the image is an important factor in determining absolute speed.

However, the sensor is intended to operate only as a slip angle sensor. Since the slip angle is defined as the arctangent of the lateral speed/longitudinal speed, the absolute calibration factor does not affect the slip angle. The slip angle is correct for any distance from the surface, as long as the image remains within the acceptable focus distance. (200 mm ±50 mm)

Resonances and Mounting Frequencies

The mounting frequency of the TrueSlip mounted on a slip ring with no restraint has been measured. In the direction of rotation, of course, there is no restraint, so there is no resonance other than from gravity pulling the sensor into the vertical position. In the lateral and vertical directions there is a resonance that was measured to be around 80 Hz. This represents the mass of the sensor on the combined stiffness of the slip ring spindle and the mounting system connecting to the wheel. Adding the restraint creates an additional resonant system in the rotational direction, and can also influence the resonant systems in the lateral and vertical directions.

The restraint rod can act like a piano string and can create resonant motion in the longitudinal direction, as well as in the lateral and vertical directions. This can create vibratory output from the sensor at various frequencies. This has been measured in some typical configurations. Like a piano string, the frequency varies with the length of the vibrating rod. This depends on the length of the rod between the slip ring and the MVSR. The measured values ranged from 30 Hz to 50 Hz, and also included the 80 Hz vibration from the unrestrained condition. Keeping this length as short as possible results in frequencies that are the highest. It also can help to apply one or two ounces of damping material such as non-drying duct seal (such as Gardener Bender DS-110) to the lower portions of the restraint rod and to attach the data cable to the top of the restraint rod with a zip tie.

In most cases, vibrations at these frequencies are of little interest in automobile testing as they generally have negligible effect on vehicle path. The on-board TrueSlip data processing includes FIR filtering to minimize any of these. This has a low pass bandwidth of 0 Hz to 20 Hz and also a transition band of 20 Hz to 40 Hz. This results in a total time delay of 94 ms in the CAN Bus output data. This delay can be eliminated during post-processing if it is important.

Optical Sensor Drop-out Filter

There may be occasional instances where there is momentary loss of information from the optical sensor. These can come from a surface irregularity with no contrast such as new tar strips in the road surface, flying debris ejected from the tire patch, or reflections from flat water puddles. The software in the sensor can detect many of these events, and hold the signal until usable data returns. These are usually only a few ms duration and the output value is held constant during this time. This may result in a corresponding delay in the signal. Time delays from these events are not predictable, but rarely occur on most driving surfaces.

Illumination

The TrueSlip sensor is self-illuminated with internal LEDs which put out Infrared light at 850 nm. The power switch on the body turns on both the sensor and the illumination LEDs. The sensor does not require ambient lighting. The sensor body acts as heat sink for high-power LEDs, therefore the body gets warm.

WARNING

Dangerous to human eye, do NOT look directly into the bottom of TrueSlip.

Cable Diagram and Connector Pin Out

Sensor Side

Main Connector: NorComp 859-009-203R004

Main cable: TE Connectivity 2273102-3

Pin	Description
NorComp 859-008-203R004	
1	Ground
2	DC power IN
3	CANL
4	CANH
5	Ground
6	Ground
7	No connection
8	No connection

Vehicle Side: CAN Data Out

DB9 female receptacle from sensor (p/n Moex p/n 1731140100)

Pin	Description
1	Ground
2	CANL
7	CANH

DBC File

```
VERSION ""

NS_ :
		NS_DESC_
		CM_
		BA_DEF_
		BA_
		VAL_
		CAT_DEF_
		CAT_
		FILTER
		BA_DEF_DEF_
		EV_DATA_
		ENVVAR_DATA_
		SGTYPE_
		SGTYPE_VAL_
		BA_DEF_SGTYPE_
		BA_SGTYPE_
		SIG_TYPE_REF_
		VAL_TABLE_
		SIG_GROUP_
		SIG_VALTYPE_
		SIGTYPE_VALTYPE_
		BO_TX_BU_
		BA_DEF_REL_
		BA_REL_
		BA_DEF_DEF_REL_
		BU_SG_REL_
		BU_EV_REL_
		BU_BO_REL_
		SG_MUL_VAL_
BS_:
BU_:
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 SG_ Pos1_SlipAngle_20Hz : 0|16@1- (0.0013733329264,0) [-45|44.9986] "Degrees" Vector__XXX

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 SG_ Pos4_SlipAngle_20Hz : 0|16@1- (0.0013733329264,0) [-45|44.9986] "Degrees" Vector__XXX

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SG_ Pos5_SlipAngle_20Hz : 0|16@1- (0.0013733329264,0) [-45|44.9986] "Degrees" Vector__XXX

BO_ 6 Pos6_SlipAngle_Signals: 8 Vector__XXX
SG_ Pos6_SlipAngle_20Hz : 0|16@1- (0.0013733329264,0) [-45|44.9986] "Degrees" Vector__XXX
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