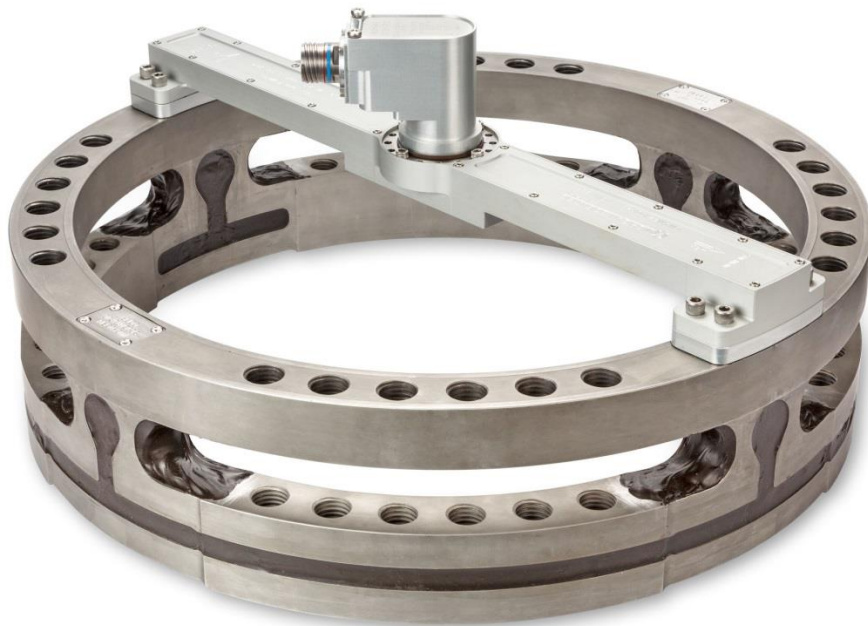


Michigan Scientific Corporation

Wheel Force Transducer System



Model: LW-2T-60K-S

For Heavy Trucks



September 2022

Revision 3.5

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Introduction

The Michigan Scientific Wheel Force Transducer system is a 6-axes transducer that measures forces and moments on a vehicle wheel. It offers quick setup and accurate measurement of force and moment inputs on a vehicle hub.

The transducer mounts between the tire and vehicle hub. A modified wheel rim is used to adapt to the vehicle's tire, and a hub adapter is used to mount it to the vehicle spindle. All forces and moments on the wheel must pass through the transducer before being transferred to the vehicle hub.

Six independent strain gage bridges measure the forces and moments. The transducer is designed to have low cross talk between channels and to be insensitive to temperature change and magnetic fields. Signal conditioning is mounted close by the transducer to boost the signal from the rotating side of the slip ring. The signal conditioning amplifier package digitizes the Transducer signals and also contains X & Z accelerometers on the center of rotation.

A consequence of incorporating the sensing elements within the vehicle's wheel is that the transducer's coordinate system (a.k.a. wheel coordinates) rotates with respect to the vehicle's spindle. For those users interested in wheel loads per se this is fine. However, having the load data measured with respect to rotating wheel coordinates is not convenient for those users interested in the loads introduced into the vehicle. It is instead preferred to have the load data with respect to spindle coordinates. To transform the wheel coordinate data into spindle coordinate data, angular position of the wheel with respect to the spindle must be known. The 20-circuit slip ring contains a 512-pulse optical encoder. The encoder provides angular position information needed for both the coordinate transformation and velocity calculations.

Coordinate transformation and the user interface is handled by the CT2 electronics. A zero procedure automates the transducer-offset adjustment. Options allow the transducer to be used in both rotating or non-rotation modes and control bridge excitation. The user selects wheel location for the transducer and corrections will be made to keep the output in a global vehicle coordinate system. Error checking is in place to alert the user if the system is out of tolerance. Corrections are made for cross axis sensitivity. Finally, a shunt procedure calculates output sensitivities and allows the user to record shunt values. Signal outputs can be ± 10 volt analog or via CAN bus. Communication to the CT2 for setup is through an Ethernet connection and an embedded web page. These features are discussed on the following pages.

Specifications

LW-2T-60K-S		
6-Axis Wheel Force Transducer		
Stainless Steel		
Capacities		
LW-2T-60K-S		
Maximum Force Capacity	[Fx, Fz]	60,000 lb (264 kN)
	[Fy] at Tire Patch	30,000 lb (132 kN)
Maximum Torque Capacity	[Mx, My, Mz]	60,000 lb-ft (81 kN-m)
Transducer	6 independent full strain gage bridges	
Nonlinearity	Less than 1% of full-scale output	
Hysteresis	Less than 1% of full-scale output	
Radial Sensitivity Variation	<1% of radial load	
Temperature Range	-40 to 125 C (-40 to 257 F)	
Insulation Resistance from Bridge to Case	Exceeds 1000 M-ohm	
Vehicle Power Input Voltage	9 to 36 VDC	
Component	lbs	kg
Wheel Load Transducer	57.5	26.1
Amplifier Package with Slip Ring and Encoder	2.5	1.1
CT2 Electronics	2.5	1.1

System Components

The Wheel Load Measurement System is made up of multiple components.

Transducer



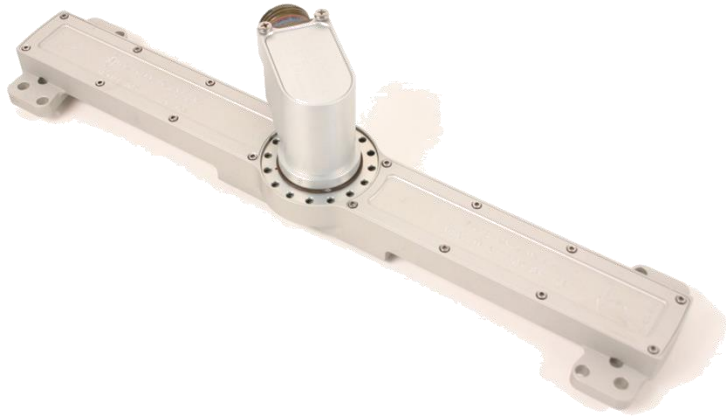
Six Axes Wheel Force Transducer. Each transducer has 6 full bridge strain gage outputs, one for each force, and one for each moment.

CT2 Electronics



CT2 Electronics. This is the User Interface for WFT System. See page **Error! Bookmark not defined.** for operating instructions.

Amplifier



The amplifier provides excitation and amplification for the 6 transducer strain gage bridges. The amplifier package contains internal $\pm 55g$ (D1 amplifiers) or $\pm 100g$ (D2 amplifiers) X & Z direction accelerometers. The amplifier digitizes the transducer, encoder, and accelerometer signals before they pass through the slip ring. The D1 amplifiers have a fixed smart sensor. The D2 amplifiers have a removable smart sensor. The smart sensor contains all the calibration information, off-set values, and CT2 webpage settings for the WFT it is mated with.

Slip Ring



An instrument quality rugged twenty circuit weatherproof Slip ring with 512-pulse encoder is mounted to the amplifier package. The SR20AW/E512/AX LS7 slip rings have the lowest profile available. SR20AW/E512/AX7 slip rings can also be used. These 'AX7' slip rings have 63 N.m moment capacity (from bearing center-line) while the 'LS7' slip rings have 13 N.m moment capacity. AX7 slip rings are better for harsh off-road application or if something needs to be mounted to the slip ring during testing.

Signal Cable



Signal Cable connects from the slip ring to the CT2 Electronics in Spinning Applications. The standard cable length is 12m (40ft). Cable lengths up to 15m available.

Power Cable



Power Supply cable. This cable is supplied from the factory with no connector on one end. An active fuse is located in the CT2 electronics. The white lead is for 9-36 VDC power high. The black lead is power ground.

Signal Breakout Box



Analog Signal Breakout Box

Ethernet Cable



Ethernet Communications Cable connects the CT2 to a computer to access the embedded CT2 webpage.

CAN Bus Cable



CAN Bus Signal output cable. They can be made with DB9 or eDAQ connectors on them. They are available in 4 to 1, 2 to 1 (shown above), and 1 to 1 arrangements. With 4 WFTs, the max sample rate with 4 to 1 cables is 550 Hz. With 4 WFTs, the max sample rate with two 2 to 1 cables is 1024Hz.

CT2 Grounding Cable



CT2 Chassis Grounding cable (4 ft/1.2m length).

Rim Adapters



The rim adapter replaces the production rim and mounts to the transducer. These rim adapters are machined from forged 6061-T6 Aluminum.

Hub Adapter



The hub adapter mounts to the transducer and will bolt to the vehicle axle.

Piloting Ring



The piloting ring is used with the inner/front rim adapter when the system will be installed in a single rim arrangement.

Washer Plate



Washer Plates should be used under the bolt heads when attaching the aluminum rim adapters to the transducer.

Spinning Assembly Instructions

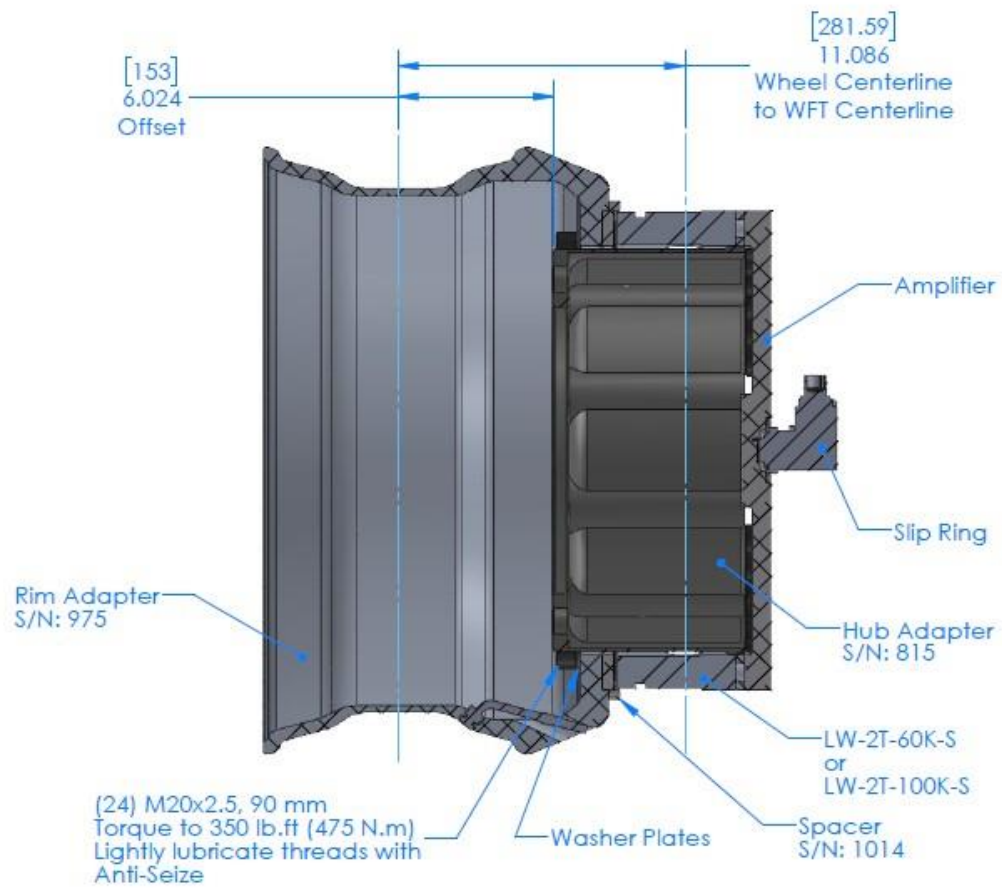
This section of the manual describes the assembly of the transducer, wheel and hub adapters, amplifier package, and slip ring.

Before Assembly

- Be sure that all mating surfaces are free of dirt.
- Inspect mating surfaces for nicks and scratches.
- Use care when assembling the transducer to avoid damage to any part of the system.
- Use care when installing the tire to insure that the adapter mating surfaces and transducer do not get damaged.

If you will be using balance beads for balancing install them at this time. If you will be using weights for balancing, this must be done after the WFT is assembled to the adapters.

Typical Single Wheel Rim Adapter Installation



SECTION A-A

Note: Install the tire onto the rim using the supplied Tire Rim Adapter. Balancing can be done, if desired, after the sensor is installed.



Inside/Front Wheel Rim Adapter



Tire Rim Adapter With Tire

- Place Inside/Front Spacer onto the Wheel Rim Adapter



- Place the Wheel Force Transducer onto Inside/Front Wheel Rim Adapter as shown below. Install four M20x2.5x90 bolts, using anti-seize bolt lubricant. Be sure to use washer plates under the bolt heads when using aluminum rim adapters. The four bolts should each be 90 degrees from each other. These bolts are installed on the Inside surface reaching into assembly and hand tightened as shown.



Wheel Force Transducer LW-2T-60K-S



Wheel Force Transducer Mounted.

(note: Inside Wheel Force Transducer bolts are started hand tight)

- Place the Hub Adapter onto Wheel Force Transducer as shown below. Install twenty-four M20x2.5x45 bolts, using anti-seize bolt lubricant, and tighten to 350 lb.ft (475 N*M) Torque.





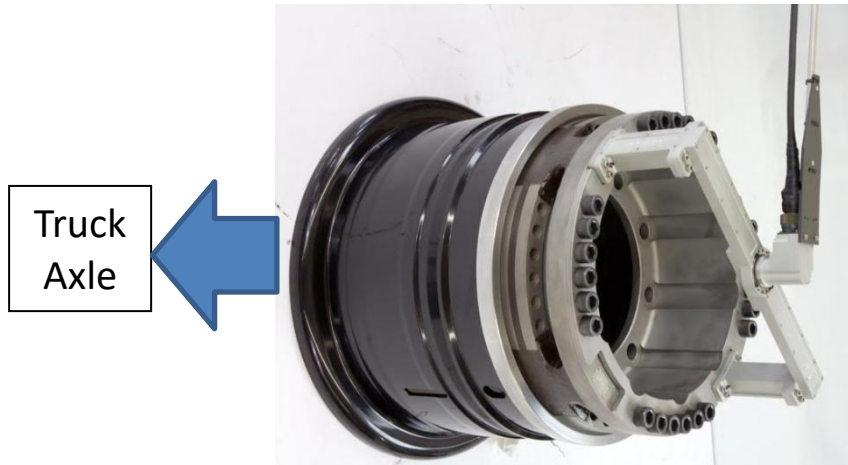
Tightening Hub Adapter to Transducer Bolts with Torque Wrench and Torque multiplier
(note: picture does not show mounted tire. Normal Install will have tire already mounted to Rim)

- Turn the 22x8.25 Single Wheel assembly over on the Hub Adapter Bolt heads and install the remaining twenty M20x2.5x90 bolts, using anti-seize bolt lubricant. Be sure to use washer plates under the bolt heads when install to an aluminum rim adapters. Tighten all twenty four bolts to 350 lb.ft (475 N*M) Torque.



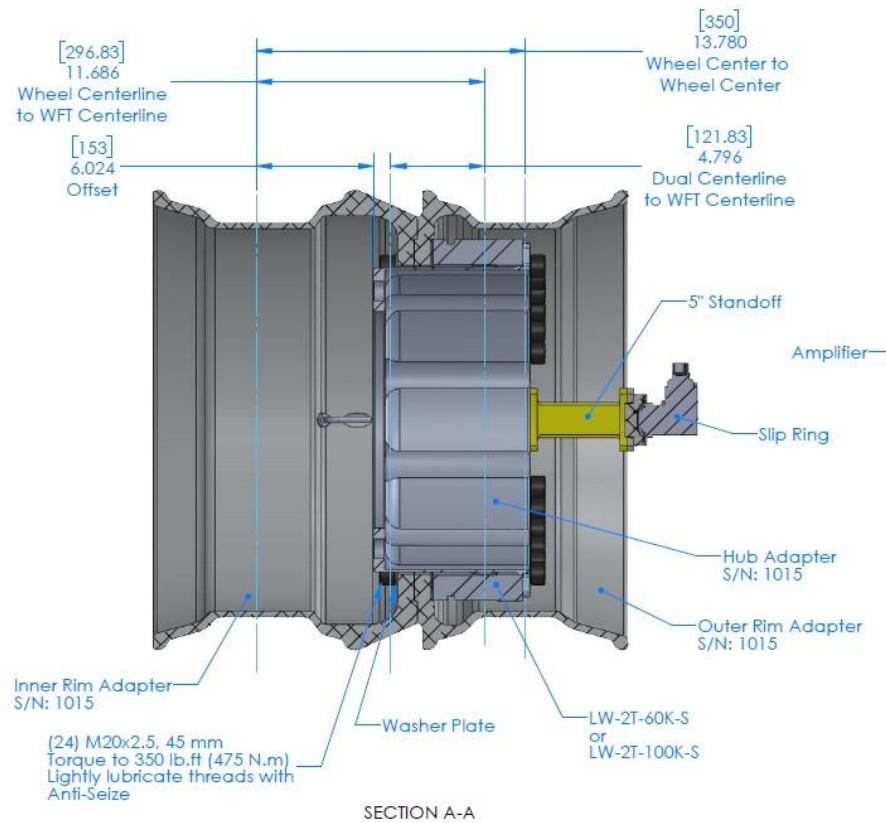
Tightening Inner Transducer Bolts with Torque Wrench and Torque multiplier
(note: picture does not show mounted tire. Normal Install will have tire already mounted to Rim)

- Install the Single Wheel Assembly to the axle. Install ten lug nuts, using anti-seize bolt lubricant, and tighten to customer specified torque. Then proceed to mount the Amplifier/Slip Ring.



Single Wheel Assembly with Amplifier, Slip Ring, Cable, & Stator Restraint installed. See below for further instructions on installing these items.

Typical Dual Wheel Rim Adapter Installation



Note: Install the tire onto the rim using the supplied Tire Rim Adapter. Balancing can be done, if desired, after the transducer is installed.

- Mount the Tires to the Rims



Inside Rim Adapter



Outside Rim Adapter

- Roll Outer rim and tire onto forks of forklift. Then roll the Inner rim and tire onto forks of forklift.
- Align pilots and holes of outer rim adapter and inner rim adapter.
- While holding in place have someone install. Install two $\frac{3}{4}$ "-10 x 1.75" bolts with anti-seize through the outer rim adapter and into the threaded inner rim adapter. These initial bolts will hold the assembly together while remaining bolts can be installed.
- Place WFT into outer rim adapter, align holes of both rim adapters with threaded holes of WFT.
- Install the initial M20x2.5x90mm bolts (with washer plates under the bolt heads for aluminum rims and anti-seize on the threads) through both rim adapters and into threaded WFT.



- Install all the remaining M20x2.5x90mm bolts (with washer plates under the bolt heads for aluminum adapters and a little anti-seize on the threads). A battery impact driver can be used if the clutch is set to the lowest setting, but bolts should be started by hand.



- Insert the hub adapter into the transducer as shown and install twenty four M20x2.5x45mm bolts with a small amount of anti-seize.



- Use a ratchet strap over the top of the tires and secure it to the forklift forks. This will react the torque applied to the bolts while tightening.



- Use a $\frac{1}{2}$ " Drive Torque wrench with Torque Multiplier OR $\frac{3}{4}$ " Drive Torque wrench to tighten all the Rim Side bolts to 350 lb.ft (475 N.m). Use a square pattern as shown below for tightening the bolts equally. If using Torque Multiplier the arm of the Torque Multiplier can rest against the forks as shown.



- Tighten Hub Adapter bolts in the same manner to 350 lb.ft (475 N.m).



- Install installation cones onto 3 of the truck wheel studs. These will help guide the WFT assembly into place.



- Install the dual wheel assembly onto Truck Axle. A Tire dolly, or pallet jack can be used to move the WFT assembly into place.



- Once some wheel nuts have been installed. Remove the installation cones, install remaining wheel nuts, and tighten all wheel nuts to the manufacturer's specifications.

Amplifier Stand-offs

- For dual wheel installation, install Amplifier Stand-offs to the transducer. Make sure all o-rings are in place before installation. Look for dowel pins & holes, as they can only be installed one way. Install $\frac{1}{4}$ -20 x 1.125" bolts provided with a small amount of anti-seize. Use provided washers under the heads of the bolts. Tighten with provided T-handle wrench.



Set of LW-2T-60K-S Amplifier Stand-offs



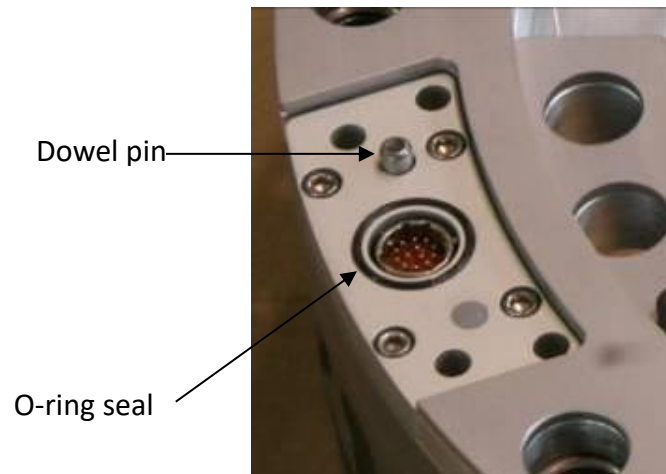
- Install Amplifier Bar to the Amplifier Standoffs. Look for dowel pins & holes, as they can only be installed one way. Install $\frac{1}{4}$ -20 x 0.75" bolts provided with a small amount of anti-seize. Use provided washers under the heads of the bolts. Tighten with provided T-handle wrench.



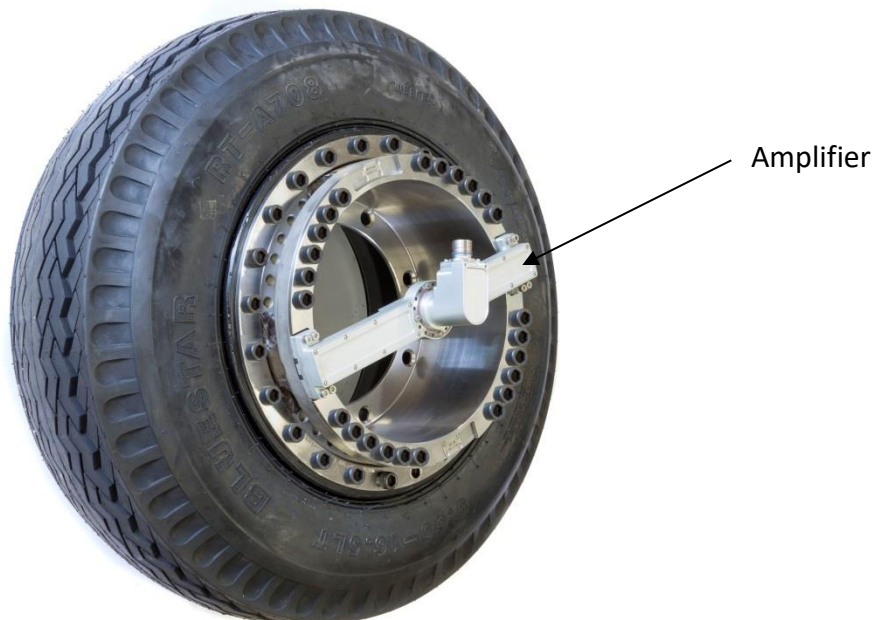
Amplifier Installation

- The amplifier and slip ring assembly is installed after the lug nuts have been tightened. Note that each amplifier and transducer is a matched pair. This is important; data is stored in the amplifier package for each specific transducer.
- O-rings are used to provide weatherproof sealing between the amplifier housing and the transducer. Make sure the O-rings are in their proper place before installing the amplifier package.

- There are dowel pins on the transducer to insure proper orientation of the amplifier housing. Align the dowel pins on the transducer to the dowel pin holes on the amplifier to ensure proper amplifier orientation.



- Secure the amplifier with eight $\frac{1}{4}$ -20 x 1-1/8 inch stainless steel socket-head screws with a small amount of anti-seize on the thread and with provided washers. Tighten $\frac{1}{4}$ "-20 bolts to 5 lb.ft (7 N.m) torque.



Amplifier Mounted

- The slip ring is attached to the amplifier with 8-32 x 3/8-inch screws. Use oil or anti-seize on these fasteners as well. The slip ring has been shipped already

installed on the amplifier housing and is normally left attached to the amplifier housing when measurement system is removed from the vehicle.

Caution! When removing the amplifiers, take care to pull off each side evenly. Failure to do this may cause damage to the dowel pin, amplifier housing or bridge connectors.

Slip Ring Rotational Restraints

The Slip Ring Stator (non-rotating part of slip ring) is the Position Reference for the Wheel Force Transducer System. The Stator should have minimal movement with respect to the vehicle body through-out the test.



Stator Restraints 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" (16mm) hole in the MVSR and attached the plastic portion of the restraint rod to the Slip Ring with two M4x14mm Phillips head bolts. These bolts should be installed with Loctite 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. If a vertical mounting of the slip ring stator cannot be achieved, the angle of the slip ring stator must be measured and entered into the CT2 webpage, see page **Error! Bookmark not defined.**

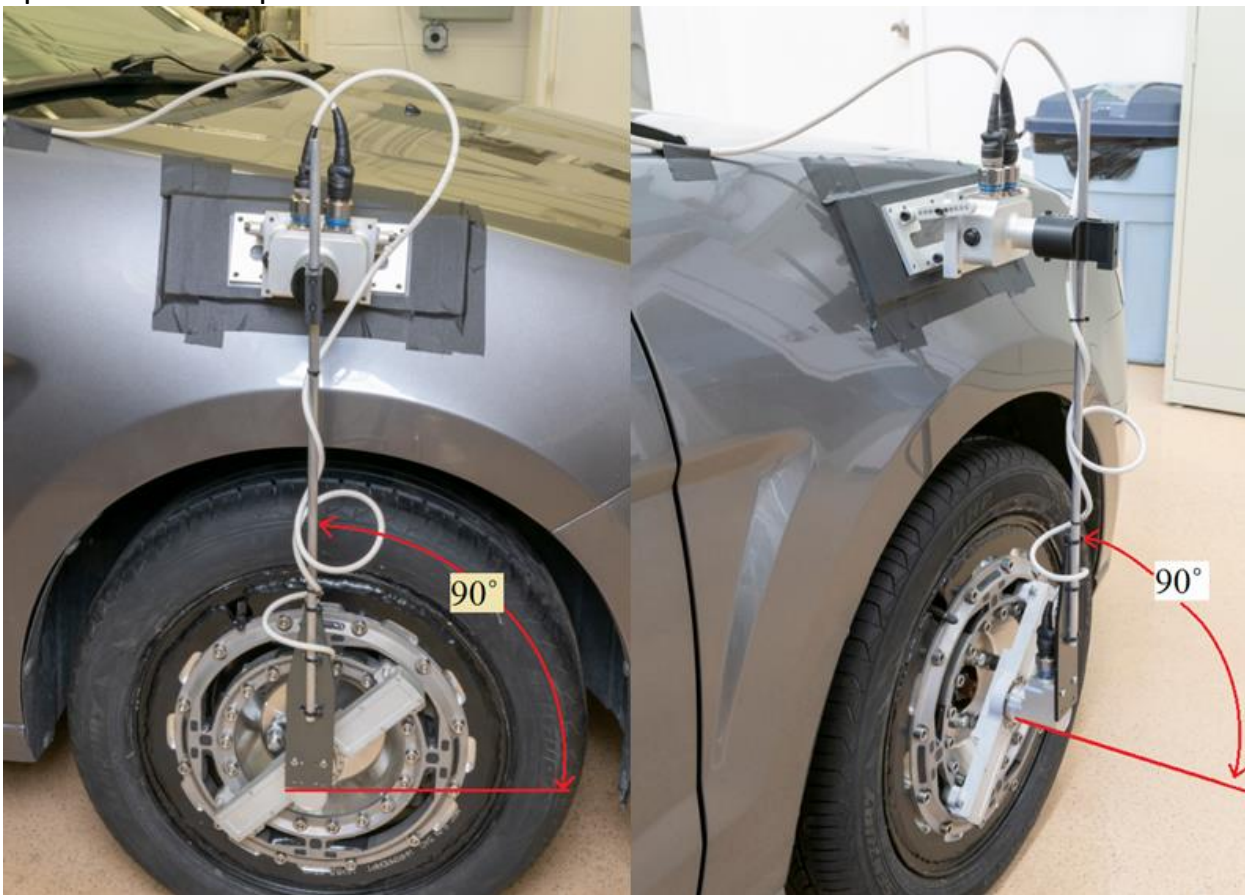
Stator Restraints for Front (Steering) Wheels

For wheels that will be steered during a test, there are three options for stator restraints. (1) MSC Stator Angle Correction Device (SAC), (2) make a custom over the wheel bracket,

or (3) use the post-processing stator angle correction method. One of these methods should be used to prevent an error between X & Z axis while steering.

Stator Angle Correction Device (SAC)

The SAC is the easiest and most accurate of the three methods. The SAC installs to the vehicle just like the MVSR, however the Stator rod is measured as it changes angle with respect to vertical and the wheel rotational angle is automatically corrected before coordinate transformation, preventing any error when steering. The SAC should be zeroed with the wheels straight and stator rod perpendicular to the ground in 2 planes as shown below. Once positioned properly zero the SAC by pressing and holding the button on the side for 2 seconds, and waiting until the button light stops flashing. Detailed SAC operation info is provided in the SAC manual.

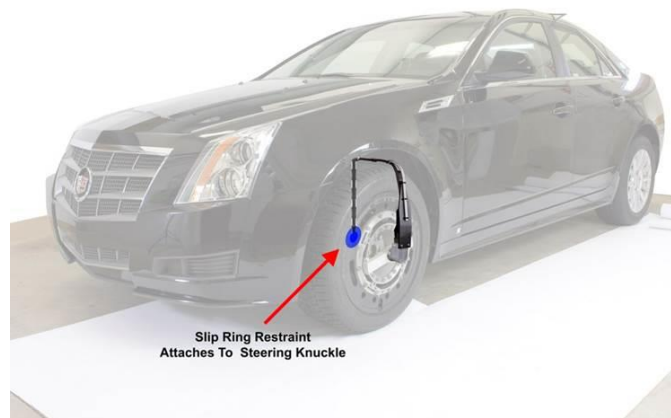


Over the Wheel Bracket

The over the wheel slip ring stator bracket will have to be custom made by the user. The reason for this 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 a couple of examples of over the wheel brackets.

Over the Wheel Bracket

The over the wheel slip ring stator bracket will have to be custom made by the user. The reason for this 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 a couple of examples of over the wheel brackets.

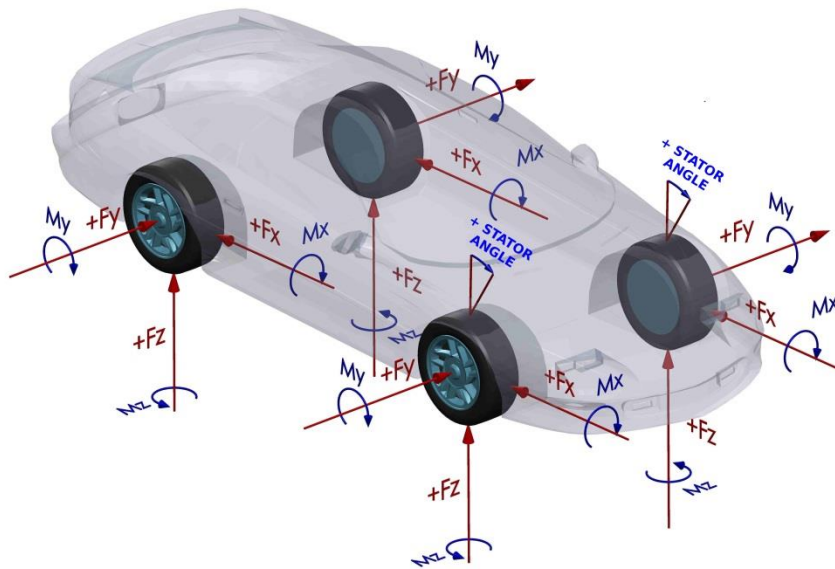


Post processing Stator Angle Correction Method

In some cases an over the wheel bracket can be difficult or impossible (low wheel well clearance) to make. In this case we suggest using stator angle correction. Stator angle correction requires an additional (not provided) transducer on the vehicle that changes output as the wheels steer. The transducer used most commonly are a steering wheel

angle output from the Vehicle CAN Bus or a string potentiometer attached to the tie rod or other steering component.

After the additional transducer is operating, a calibration needs to be performed by the user to establish a relationship between the transducer output and the angle of the slip ring stator as the wheels are steered. Record both transducer output and the slip ring stator angle (measured with digital protractor) 10 different times between right steer lock and left steer lock. The figure below defines positive stator angle for both the right and left sides.



Next take the 10 data points recorded and create a linear regression between the transducer output and stator restraint angle. That will result in the following equation, where m is the slope determined during linear regression and b is the off-set.

Stator Angle = m (transducer output) + b

Next add the following correction equations into your data acquisition as calculated channels, where F_x , F_z , M_x , & M_z are the outputs from the Wheel Force Transducer.

$F_{x\text{corrected}} = F_x \cdot \cos(\text{stator angle}) - F_z \cdot \sin(\text{stator angle})$

$F_{z\text{corrected}} = F_x \cdot \sin(\text{stator angle}) + F_z \cdot \cos(\text{stator angle})$

$M_{x\text{corrected}} = M_x \cdot \cos(\text{stator angle}) - M_z \cdot \sin(\text{stator angle})$

$M_{z\text{corrected}} = M_x \cdot \sin(\text{stator angle}) + M_z \cdot \cos(\text{stator angle})$

Caution: Some data acquisition use radians as the measure of angle, therefore the stator angle needs to be converted to radians before it is used with the above equations.

Spinning Assembly Cable Connections and Signal Outputs

- Connect one end of the 6 meter (20 ft) long cable to the slip ring. The connector is waterproof. For off-road testing, using tape around this connection keeps grit from getting into the connector threads. The connector is difficult to remove if grit enters the threads.
- Connect the other end of the cable to the CT2 electronics.
- Connect the power cable to the CT2 electronics.
- Connect other end of the power cable to a DC voltage source in the range of 9 to 36 volts. The white wire is for power high. The black wire is for power ground. The current draw from the vehicle is less than 1 amp per CT2 at 12 volts and reduces proportionately at higher supply voltages.

CAN Bus Signal Outputs

- If using CAN Bus signal output, connect one end of the CAN Bus cable to the CT2 and the other end to the data acquisition/controller. A .dbc file specific to your test can be downloaded from the CT2 webpage. CAN outputs have a fixed time delay of approximately 25 ms due to internal filtering. See Appendix 4 for exact delay calculation.

Analog Signal Outputs

- If using analog outputs, connect the Analog Signal Break-out Box to the CT2. Then use 10 BNC cables to connect to the data acquisition/controller. CT2 Analog outputs are Floating Single-Ended Outputs.

CT2 Chassis Ground Connection

- In many Spinning application tests the CT2 will perform without noise issue without connection to chassis ground.
- If there is a potential noise issue or the smart sensor cannot be read or written, connect the CT2 to vehicle chassis ground. This can be done in one of the two following ways. Be sure to not create a grounding loop by connection the CT2 and Data Acquisition both to the vehicle chassis.
 - 1 Connect one end of the CT2 Grounding Cable to the banana plug in the back of the CT2 and connect the other end of the cable to the lab power ground.

2 Connect the shield of the CT2 power cable to the lab power ground.

CT2 Power-up

- Turn the power switch on to the CT2. At power-up, the CT2 will automatically read the information stored in the smart sensor of the amplifier. This information includes zero values, shunt calibration values, desired full scale outputs, transducer information, and CT2 webpage settings. Since the calibration information is stored in the Amplifier and not the CT2, the CT2s are interchangeable.
- At this time (if CT2 is in Run mode & Vehicle Coordinates), the force, moment, and position channels are held at zero until the CT2 receives an index pulse.

CT2



Introduction

One CT2 is used for each wheel force transducer. The CT2 is the User Interface. It also performs coordinate transformation, cross-talk correction, zero off-set adjustments, and vehicle position polarity adjustment in real time. The CT2 buttons can initiate a Zero function, a Shunt Calibration function, and be set for Vehicle position of installed WFT. The CT2 also has an embedded webpage to access additional set-up options, configure CAN Bus output, and create a .dbc file.

Main CT2 Set-up Functions

The main set-up functions that should be done at every new test installation and set-up are Position, Zero, and Shunt. These can be done in any order. The position button allows the user to indicate to the CT2 what wheel position the transducer is mounted. The Shunt button performs a Shunt calibration and compares it to the factory Shunt calibration. This verifies that the Transducer and Amplifier are working properly. The Zero adjusts the off-set of each WFT channel. This must be done each time the transducer is re-bolted to the adapters. Details of each main set-up function are described further below.

Important CT2 Website selections

One main set-up function that should be checked in the CT2 Webpage for each Test set-up is the Measurement Origin. The default Measurement Origin is the center of the transducer. See page **Error! Bookmark not defined.**, to change the WFT Measurement Origin. You should also verify that the Coordinate system set in the CT2 webpage matches your desired Measurement Origin. To change see page 54. If being used in a Non-spinning application, you should check the 'For Simulator Use' Box on the CT2 webpage, see page 54.

CT2 Basics

Lights and Controls

All controls located on top of the enclosure are momentary contact switches. They correspond to the labels located on the front panel. Power and position controls are located on the front panel.

Powering Up

Note: It is good practice to first connect all cables to the CT2 electronics before powering it up. If this is not done, possible damage may occur. In addition, the CT2 reads important transducer information, from the amplifier package, at startup. Incorrect offsets and gain settings will be used if this information is not read.

The power switch turns the power on and off. When the CT2 is turned on, it defaults to Run Mode with the Vehicle Coordinates and Bridge Excitation On. This will be indicated by green lights on the front panel. Transducer offsets, sensitivities and other information is read from the smart sensor during power up.

Zero

The Zero light indicates that the module is performing a zeroing sequence, invoked by the Zero button on top of the enclosure. This button is only active during the Setup Mode. The light is also used to indicate an error in the zeroing sequence when used in conjunction with the Fault light. The zeroing sequence records data and calculates an offset value. This offset is recorded into the smart chip located in the amplifier package so it is not lost when power is interrupted or a different CT2 is used. When set to Vehicle Coordinates, the CT2 uses 2 or 8 revolutions of the tire to calculate the offset. If the wheel is not turning when the Zero button is pressed, the calculation will be based off of the next 2 revolutions. If the CT2 senses that the wheel is turning, it uses 8 revolutions to get a better on-road-averaged value. (The is referred to as rolling zero)

Shunt

The *Shunt* light is used to indicate shunt related features. The button located on top of the enclosure can be used to invoke a shunt sequence. The shunt sequence performs a Shunt calibration and compares these field Shunt values to the factory Shunt values. After a successful shunt sequence, the Shunt light turns off and updates the smart sensor. If the field Shunt value and Factory Shunt value differ by more than 2.5%, the fault and Shunt light stay lit. Indicating an issue with the transducer or amplifier.

Mode

The Mode lights indicate whether the module is in Setup or Run Mode. The Mode button on top of the enclosure toggles between the modes. Run mode is used whenever data is being collected. Setup mode is only used when the transducer is being set up or when the operator is checking the transducer offsets. Zero, Shunt, and Position features cannot be accessed unless the CT2 has been switched to Setup mode. In set-up mode coordinate transformation and zero off-set adjustment are not performed.

Bridge Power

The Bridge Power light indicates whether excitation is being supplied to the strain gage bridges. When the light is illuminated, power is being supplied to the bridges. The Bridge Power button on top of the enclosure toggles the bridge power on and off. You can turn off the bridge excitation to check for background noise, however the CT2 has very low noise, so this check is rarely performed.

Coordinates

The wheel and vehicle lights indicate whether the output data is in wheel (non-spinning application) or vehicle (spinning application) coordinates. The button on top of the enclosure toggles from one to the other. Wheel coordinates output the data directly from the wheel. This is used during Non-spinning application like a Simulator or Test Bench. Vehicle coordinates is used for on-vehicle tests where the wheel is spinning. In this case the CT2 uses the encoder signal and performs coordinate transformation in the transducer signals.

Fault

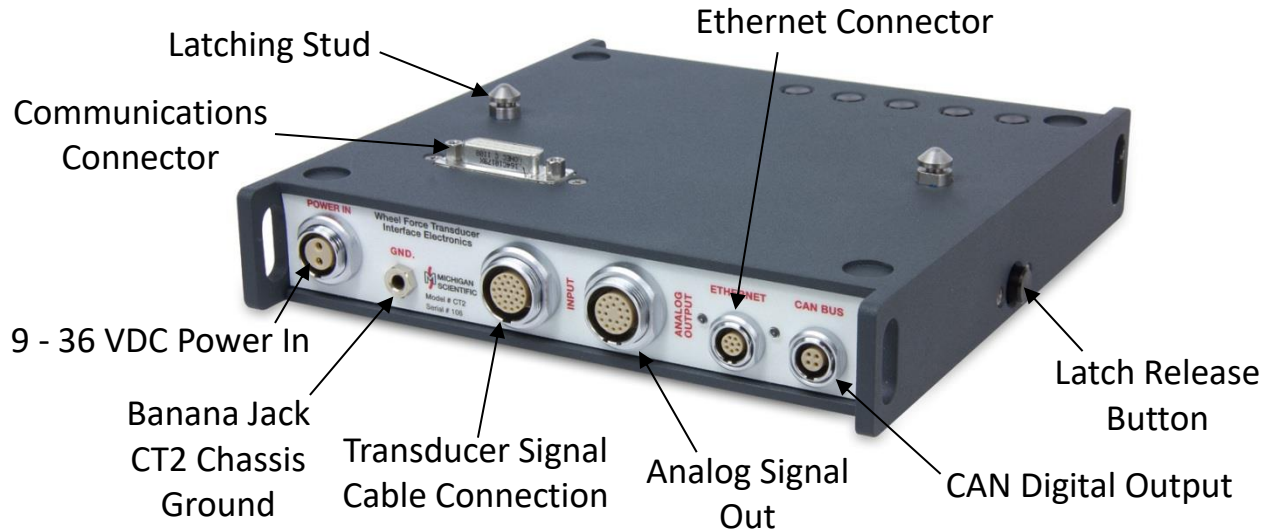
The fault light indicates that there is a problem with the module. It can be lit in conjunction with other lights or by itself. More information is available in the trouble shooting section of this manual.

Position

The position button allows the user to indicate to the CT2 what wheel position the transducer is mounted. Different coordinate transformation equations are used on the right vs. the left side of the vehicle. This information is also used by the CT2 electronics to indicate in the CAN DBC file the identification of data being transmitted. In addition this allows the user to keep track of which electronics is attached to which wheel.

When stacked with one or more other CT2 units, the position information is shared between the CT2 electronics. If two or more CT2 electronics are assigned to the same wheel location, the position lights on those electronics will blink slowly to alert the user.

If two or more CT2 electronics are set to different CAN output rates, the position lights on those electronics will blink fast to alert the user.



CT2 Function Tables

Zero and Shunt Control Function Table				
Zero	Shunt	Mode	Bridge Power	Coordinates
N/A	N/A	Run	On	Wheel
N/A	N/A	Run	On	Vehicle
Stationary	Shunt	Setup	On	Wheel
Rolling	Shunt	Setup	On	Vehicle
N/A	N/A	N/A	Off	N/A

The above table shows different possible zero procedures that result with different Mode and Coordinates settings.

Output Channel; Offset, Sensitivity and Transform Function Table					
Control States			Outputs		
Mode	Coordinates	Bridge	Offset	Sensitivity	Coordinate
Run	Wheel	On	Yes	Yes	No
Run	Vehicle	On	Yes	Yes	Yes
Setup	Wheel	On	No	Yes	No
Setup	Vehicle	On	No	Yes	No
N/A	N/A	Off	No	Yes	No

Sensitivity adjustments are always performed to the data inside the CT2 electronics. Offset adjustment and coordinate transformation are not always performed. The above table summarizes these states.

Multiple CT2s



Each CT2 is used with one Wheel Force Transducer. When using multiple Wheel Force Transducers systems, the CT2 is designed to be stacked. Latch studs are mounted on top of the enclosure and a latching mechanism is mounted on the bottom. When the boxes are set on top of each other, they latch together. A button on each side of enclosure releases the latches. Electrical connections are made via the D-sub connectors mounted on top and bottom of the enclosure. When not stacked it is recommended that the dust covers provided with the enclosure be used to cover the D-sub connectors. This will protect the connectors and reduce the chance of electrical damage to the electronics.

The CT2 electronics communicate with each other using a digital bus interface. This allows the operator to control all of the CT2s with one set of controls. Notice that the control buttons are located on top of the enclosure. When one CT2 is stacked on top of another, the buttons on the lower one are covered. All functions are controlled by the top CT2 at this time.

A base is available to provide better stability and tie down locations. This base also protects the D-sub connector on the bottom CT2.

The power supply cable can be connected to any one of the CT2 electronics. That CT2 will supply power to the rest in the stack, therefore only one power cable is required.

Each CT2 retains its own power switch and must be turned on individually. At power up, the CT2 checks the state of the other boxes and then sets itself to match.

Up to six CT2 electronics can be stacked together. If you want to stack more together, please contact Michigan Scientific to discuss your specific application.

Power Requirements

The CT2 requires 9 to 36 VDC power. Power draw is about 0.75 amp at 13.8 volts for each WFT system.

One power cable will power a stack of CT2s (up to 6)

Signal Outputs

Ten signal outputs are available from each CT2. The channels are for force and moments about the x, y, and z axes, and also Wheel Speed, Wheel position, Acceleration X, and Acceleration Z. In the CT2 webpage you have the option to replace Wheel Speed and Wheel Position with Sine and Cosine Outputs.

This voltage can then be converted to their engineering units by multiplying by the sensitivity listed on the Quick Reference Calibration Sheet supplied with the WFT. Also see Appendix 2 on page **Error! Bookmark not defined..**

Using CAN Signal Outputs

A CAN cable per the customer specification should have been provided with the WFT system. 4 to 1, 2 to 1, or 1 to 1 CAN cables can be provided with either DB9 or Turk connectors (for eDAQ). See more about this in CT2 CAN Bus configuration section, on page 57. Each CT2 must have a cable plugged into the CAN Bus connector. A .dbc file can be created and downloaded from the CT2 webpage. Once the .dbc file is loaded into the data acquisition, and the systems are connected, all the channels will be properly labeled (according to Wheel Position) and scaled (in engineering units). The drawback of using CAN signal outputs is the signal delay. The delay is due to CT2 filtering of the signals to get it to the selected output rate. Delay varies, but at the most common sample rates, 500, 512, 1000, & 1024 Hz is approximately 25 milliseconds. See appendix 4 for exact CAN delay equations on page 78.

Using Analog Signal Outputs

A BNC Analog break-out box has been provided. The default voltage for the Analog output is +/- 10 VDC. This voltage can then be converted to their engineering units by

multiplying by the sensitivity listed on the Quick Reference Calibration Sheet supplied with the WFT. Also see Appendix 2 on page **Error! Bookmark not defined.**

All the analog outputs are single ended and isolated from power ground. See diagram in appendix 1. The CT2 webpage allows the user to replace Wheel Speed and Wheel Position with Sine and Cosine, if desired.

The time delay when using Analog Signal Outputs is 0.12 milliseconds, which is negligible at common WFT sample rates.

Shunt Calibration Sequence

Shunt Sequence - The CT2 calculates an internal gain, used to make output sensitivities match the values programmed into the Smart sensor.

To invoke a shunt sequence.

- Press the *Mode* Button to enter *Setup Mode*
- Press and release the Shunt button.
- The Shunt light will illuminate to indicate a shunt sequence is in progress. Once the Shunt light goes out (about 12 seconds), the shunt sequence is complete.
- Press the *Mode* button to return to *Run Mode*.

If the Shunt light does not go out and the Fault light illuminates, the shunt sequence did not pass. The shunt sequence commands the amplifier package to invoke a shunt calibration resistor at each strain gage bridge in the transducer. The CT2 reads the voltage change, caused by the shunt, and adjusts the gain of each channel to match the sensitivity programmed into the *smart sensor*. This calculated gain is recorded into the smart sensor located in the amplifier package so this information is not lost when power is interrupted or a different CT2 is used. If the calculated gain is more than 2.5% different than what is programmed into the smart sensor, the Fault light will come on indicating a likely problem with the transducer or amplifier.

Note: This sequence can be performed at any time (on the ground or hoisted.) Just be sure not to change load on the WFTs during the Shunt sequence.

Shunt Hold - The CT2 can be commanded to invoke and hold shunt calibration. This can be used to write down the transducer off-sets and shunt voltages.

To invoke the shunt hold:

- Press the *Mode* Button to enter *Setup Mode*

- Press and hold the *Shunt* button until the shunt light starts flashing rapidly (approximately 1 second).
- The *Shunt* light will flash rapidly and the outputs will hold a positive shunt until the shunt button is pressed again.
- Then the system outputs will hold a negative shunt calibration until the shunt button is pressed again.

The Quick Reference calibration sheet lists sensitivity and Delta Shunt values in lbf/lb.ft and N/N.m. If desired, the user may check the sensitivity by recording the outputs during a shunt sequence and calculating the delta Shunt value (magnitude of change from positive shunt to negative shunt, divided by two).

In field checks can be done by comparing WFT Fz output to a scale. To compare to a scale, first record the WFT Fz output when the vehicle is hoisted. This is the weight of the tire, rim adapter, and half the WFT, it will be negative. Then set the vehicle on the ground and record the WFT Fz output. Add the absolute value of these two numbers together and then compare that value to the output of the scales.

Spinning Use System Set-up

The CT2 has a Zero feature that automates the zeroing process. With any zeroing method used below, it is recommended that the transducers be exercised before any zeroing is done. To exercise the transducers, perform a figure 8 maneuver, and two or more hard brake stops.

There are two zeroing procedures for Spinning Applications.

Zeroing on the Hoist

This Zeroing method uses the weight of the wheel and tire to determine the zero offsets. This method is recommended for best accuracy.

Caution: While it does not matter which direction you turn the wheel during the zero sequence, changing the direction of rotation during the zero procedure will cause errors. Remember when turning one wheel on a drive axle, the one on the other side will turn the opposite direction. This is OK as long as the wheel does not change direction of rotation during the sequence.

- Turn on the CT2.
- Lift the tires clear of the ground.
- Press the *Setup Mode* button.

- The blue Setup Mode light will illuminate.
- Press the *Zero* button. Note: The wheel must not be rotating when the *Zero* button is pressed.
- The amber *Zero* light will illuminate.

Caution: *While it is not important that the wheel be turned at a steady rate, do not impart excessive acceleration or deceleration to the wheel while turning it. This may cause calculation errors. To reduce errors, the CT2 uses position-based sampling for this procedure.*

- Rotate the transducer. When rotating the transducer, never apply force to the tire itself. This can cause an error in the zero calculations. Always apply force to the amplifier package only. Rotate in one direction until the amber *Zero* light goes out, this should take 2 revolutions.

Using more than one transducer with stacked CT2s

- You may rotate each transducer independently.
- To zero only one wheel, you will need to turn off the CT2 electronics, on the wheels that you do not want to zero, or un-stack them.

When the CT2 completes the zero procedure, it will write the calculated offset value to the smart sensor located in the amplifier. This way the transducer does not need to be zeroed every time the power is interrupted or if a different CT2 is used with the transducer.

Rolling Zero on the Road

This Zero method uses the weight of the vehicle to determine the zero offsets. The Fy (Lateral) transducer channel may have real, non-zero values during this mode of operation due to toe-in and tire conicity. The My (Torque) may also have a real non-zero value due to drive line torque and brake or seal drag. Use rolling zero only when lower accuracy can be tolerated.

- Press the *Setup Mode* button.
- The blue *Setup Mode* light will illuminate.
- Coast the vehicle along a smooth and level section of road or parking lot.
- Press the *Zero* button.
- The amber *Zero* light will illuminate.

- The CT2 detects that the tires are turning and will use the average of the next 8 revolutions to compute the offset.
- Once the procedure is complete, the light will go out.
- When the CT2 completes the zero procedure, it will write the calculated offset value to the memory chip located in the amplifier. This way the transducer does not need to be zeroed every time the power is interrupted or if a different CT2 is used with the transducer.

Verifying the Zero Procedure

To check the quality of the zero, set the CT2 to *Run* mode and *Vehicle* coordinates. Observe the output from each channel with the wheel lifted off of the ground. The x and y-axes forces should have very little output. While hoisted the Fz force should read the negative weight of the wheel and tire. The My and Mz moments should have little output. The Mx moment should have some output proportional to the weight of the wheel and tire multiplied by the moment arm from the wheel centerline to the transducer centerline. (if the measurement origin is at the default, transducer centerline.)

Spin the wheel and observe the x and z-axes force outputs. There should be very little ripple in the outputs.

Non-Spinning Use – System Set-up

- Operate CT2 in Wheel Coordinates. Fz+ axis should be pointing vertically towards the ground. (If Fz+ axis is not mounted vertically towards the ground, see page 54) Also make sure the 'For Simulator Use' Box is checked in the CT2 webpage, see page 54. A Simulator Cable should be used.
- A Zero in Wheel Coordinates will null out all the channels (zeroing out the static weight of the vehicle), so there are three options to account for the static weight of the vehicle so that the road loads recorded properly match the loads measured on the simulator. They are:
 1. Zero the WFTs after they have been bolted to adapters but before the vehicle has been attached to the hub adapters.
 2. Zero the WFTs once car has been attached to the WFTs and simulator. Then add the static weight of the vehicle to WFT data through a calculated channel. The road data would not have to be modified.

3. Remove static vehicle weight from previously recorded road data. Then zero the WFTs once car has been attached to the WFTs and simulator.

- Analog signal outputs are recommended, because the time delay on the these signal outputs is negligible.
- CAN signal outputs can also be used. They require CAN input on the Simulator controller. If using CAN signal outputs, signal delay must be compensated for in the Simulator software.

Stationary Zero

This Zero method is only used in non-spinning applications, such as a simulator. It allows the user to null the output from the transducer.

- Make sure the CT2 is in Wheel the Coordinates.
- Press the *Setup Mode* button.
- The blue *Setup Mode* light will illuminate.
- Press the *Zero* button.
- The amber *Zero* light will illuminate.
- Once the procedure is complete, the light will go out.
- When the CT2 completes the zero procedure, it will write the calculated offset value to the smart sensor located in the amplifier. This way the transducer does not need to be zeroed every time the power is interrupted or if a different CT2 is used with the transducer.

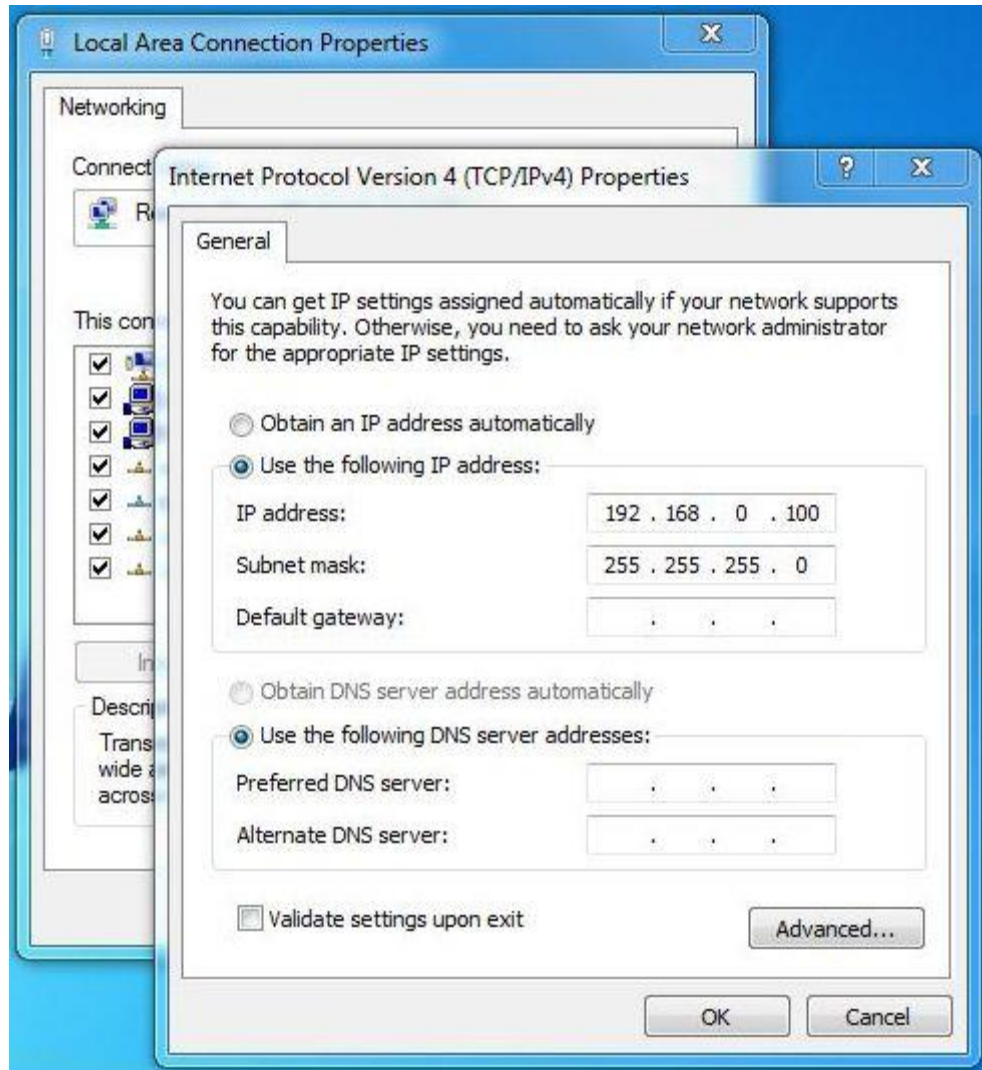
Once the initial setup is accomplished, data collection can continue for several days without readjustment. The vehicle should be lifted occasionally to verify the zero stability.

Web Page Selectable Options

The CT2 contains an embedded web page that can be used to change system settings or select features. This web page is available to any device with an Ethernet port and web browser.

To access the web page.

- Connect the Ethernet cable (provided with appropriate connectors) to one of the CT2s and a computer. Note: To avoid network conflicts wireless networking should be turned off on the computer.
- Change the IP address on the computer's Local Area Connection Properties.



- Pull up a web browser and enter the IP address of the CT2 (192.168.0.28) into the browser
- The web page, shown on the following page, will appear in the web browser

Note: To make system changes, all CT2s must be connected to their respective wheel force transducer and powered up.

CT2 Serial Number

Near the top of the page is a drop down box allowing the user to select CT2 serial numbers, shown below.

CT2 Serial Number:
 2 ▼

The CT2 that the Ethernet cable is connected to will check for the presence other CT2 electronics. These other units need to be stacked together and all units need to be turned on. If other units are present, and turned on, the serial numbers of these units will appear in the pull down menu. Selecting a different serial number allows the user to set up each CT2 separately.

☐ Update All Active CT2 Boxes with these Settings
 Update

If settings for all the CT2 units are to be the same, the "Update All Active CT2 Boxes with these Settings" button can be pressed before the "Update" button is pressed. Updating all units at once avoids the need for the user to go through the settings for each serial number individually if settings for all units are to be the same. The Wheel Force Transducer Information shown below serial number is information for the WFT that is connected to the selected serial number.

Default Coordinates on Power-Up

Here the user can select whether the CT2 powers up in Wheel or Vehicle Coordinates. If the WFTs will mostly be used in Spinning Applications, select Vehicle. If the WFTs will mostly be used in Non-Spinning Applications select Wheel.

Default Coordinates on Power-Up (Updated in all active CT2 boxes):

☐ Wheel ☒ Vehicle

Note: All CT2 electronics, shown in the serial number drop down menu when this setting is changed, will take the new setting even if the "Update All Active CT2 Boxes with these Settings" button is not checked.

Full Scale Velocity

This setting is used to set the full scale velocity of the wheel speed signal derived from the encoder. There are three optional full scale velocities. The full scale velocities are 1,000, 2,000, and 3,000 rpm full scale. The default setting is 2,000 rpm full. The user may also select to replace the position and velocity signals with Sine and Cosine signals.

Full Scale Rotational Velocity:

☐ 1000 RPM
☒ 2000 RPM
☐ 3000 RPM
☐ Replace Velocity/Position Output with Sine/Cosine

Analog Output Sensitivities Options.

The output channels for all systems are scaled as shown below. The CT2 allows the user to choose analog output ranges of $\pm 10V$, $\pm 5V$, $\pm 2.5V$, and $0-5V$. The default output range from factory is $\pm 10V$. If the output voltage range is changed, the Output Channel sensitivities will change as well. For example, if the User set the CT2 box to a output range of $\pm 5V$, the sensitivities below would double. For example, a $\pm 5V$ output range setting for the LW-2T-60K-S would change the X Force output sensitivity to be 60,000 N/V and Y Force to be 30,000 N/V.

NOTE: VERIFY OUTPUT CHANNEL SENSITIVITY BY MONITORING SHUNT CALIBRATION VOLTAGES AND COMPARING THE TO THE SHUNT CALIBRATION EQUIVALENT LOAD. THIS

CAN BE FOUND ON THE CALIBRATION SHEET OF THE TRANSDUCER. CHANNEL SCALING MAY BE SET-UP DIFFERENTLY ON SOME TRANSDUCERS.

Full Scale Output Channel Sensitivities	
	LW-2T-60K-S
X Force	30,000 N/V (6,745 lbs/V)
Y Force	15,000 N/V (3,372 lbs/V)
Z Force	30,000 N/V (6,745 lbs/V)
X Moment	9,000 N-m/V (6,638 lb-ft/V)
Y Moment	9,000 N-m/V (6,638 lb-ft/V) or 3,000 N-m/V (2,222 lb-ft/V)
Z Moment	9,000 N-m/V (6,638 lb-ft/V)
Accel X	100 G
Accel Z	10 G
Velocity	2000 RPM (default setting)
Position	0-360 deg

Changing Analog Output Range

To change the Analog Output range, select the desired Analog output range, Check the Update All box, and click Update on the bottom of the page.

Analog Output Range:

☒ +/- 10V ☐ +/- 5V
☐ +/- 2.5V ☐ 0 to 5V

Note: The Analog outputs use a 16 bit DAC. When a different voltage range other than +/- 10V is selected, the resolution of the data is no longer 16 bits because the CT2 does not utilize the full 16 bit range of the DAC. When using +/- 5 volt range the resolution is reduced to 15 bits. When using +/- 2.5 or 0-5 volts the resolution is 14 bits.

Slip Ring/Encoder Reference Angle

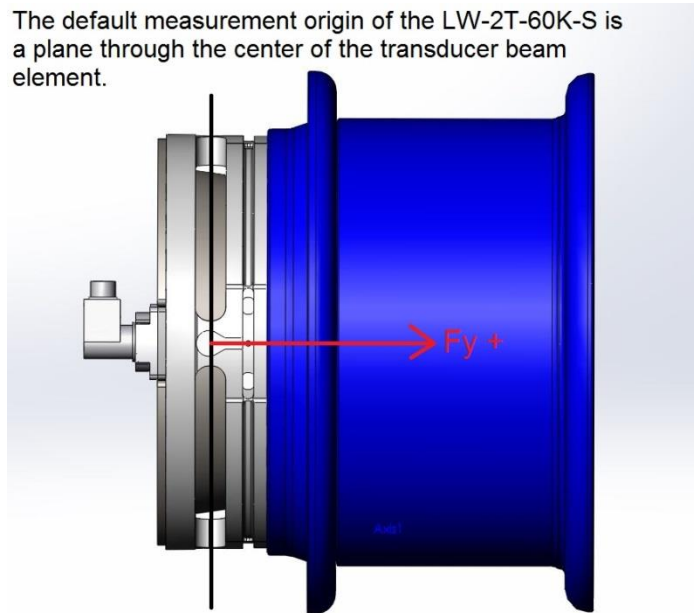
In some situations, the slip ring body cannot be oriented with the cable exiting the top. The slip ring stator is encoder angle reference for the coordinate transformation calculations. If the slip ring cannot be mounted vertically, measure the angle that the slip ring body is from vertical in the clockwise direction. Enter that number into the box shown below. The CT2 uses this information to correct the reference angle when performing the coordinate transformation.

Enter Slip Ring/Encoder Reference Angle:

0.00 Degrees Clockwise from Vertical

Measurement Origin

The default measurement origin of the LW-2T-60K-S & LW-2T-100K-S is the center of rotation and a plane that runs through the center of the transducer beams. The distance to the measurement origin plane to from the inboard edge is 2.712" (68.90 mm). The distance to the measurement origin plane to from the outboard edge is 1.988" (50.48 mm).



To move the measurement origin to the hub face or tire center, input the "a" value in the CT2 webpage. The value of "a" is provided on adapter assembly drawing if MSC made your adapters. Value "a" can also be measured.

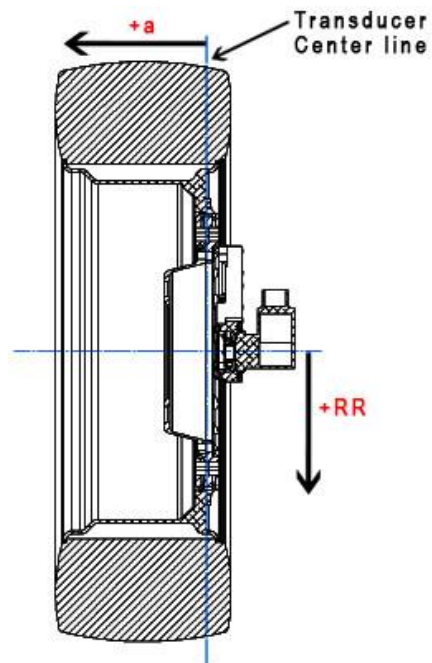
MSC recommends leaving 'RR' value at 0, as this will leave the measurement origin on the center of rotation. While the feature is available, entering the 'RR' will move the measurement origin to the tire patch. Since the Rolling Radius does change dynamically during testing MSC recommends leaving the measurement origin on the center of rotation.

Measurement Origin	Definition of "a" & "RR"
☐ Center of WFT ☒ User Defined with Respect to Center of WFT Units of Entered Values: ☒ Inches ☐ Millimeters Measurement Center Offset along Y-Axis (a): 5.00 (-43 to 43 inches) Rolling Radius (RR): 0.00 (0 to 157 inches)	

To use this option:

- Check the button labeled “User Defined with Respect to Center of WFT”
- Select “Inches” or “Millimeters” to indicate which units will be used.
- Enter an “a” value if moving the origin along the y-axis.
- Enter an “RR” value if moving the origin along the Z-axis.

The image below indicates “a” and “RR” values.

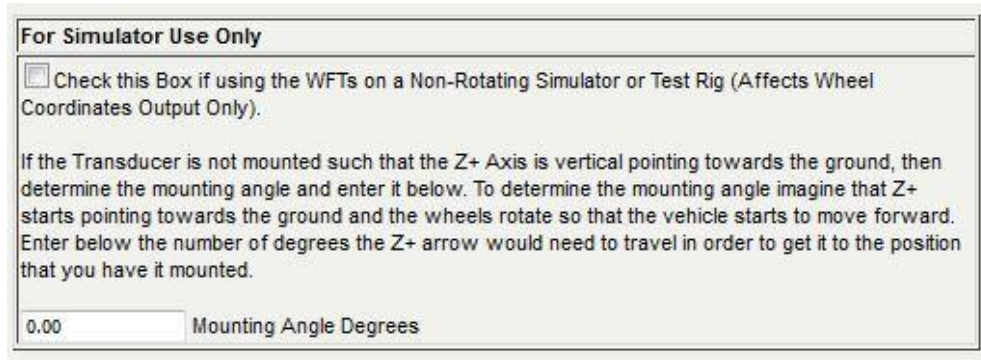


Note: Only the Mx and Mz channels are affected by these calculations. Ignoring force due to acceleration and mass of the WFT system, the forces do not change when the

measurement origin is moved. My is not changed because the location of the tire patch can vary enough to introduce large errors into the calculation.

Non-Spinning Applications

In the CT2 webpage, check the box under the heading “For Simulator Use Only”. Checking this box will allow measurement origin to be moved in Wheel Coordinates. It also allows for the user to enter a ‘Mounting Angle Degrees’



For Simulator Use Only

☐ Check this Box if using the WFTs on a Non-Rotating Simulator or Test Rig (Affects Wheel Coordinates Output Only).

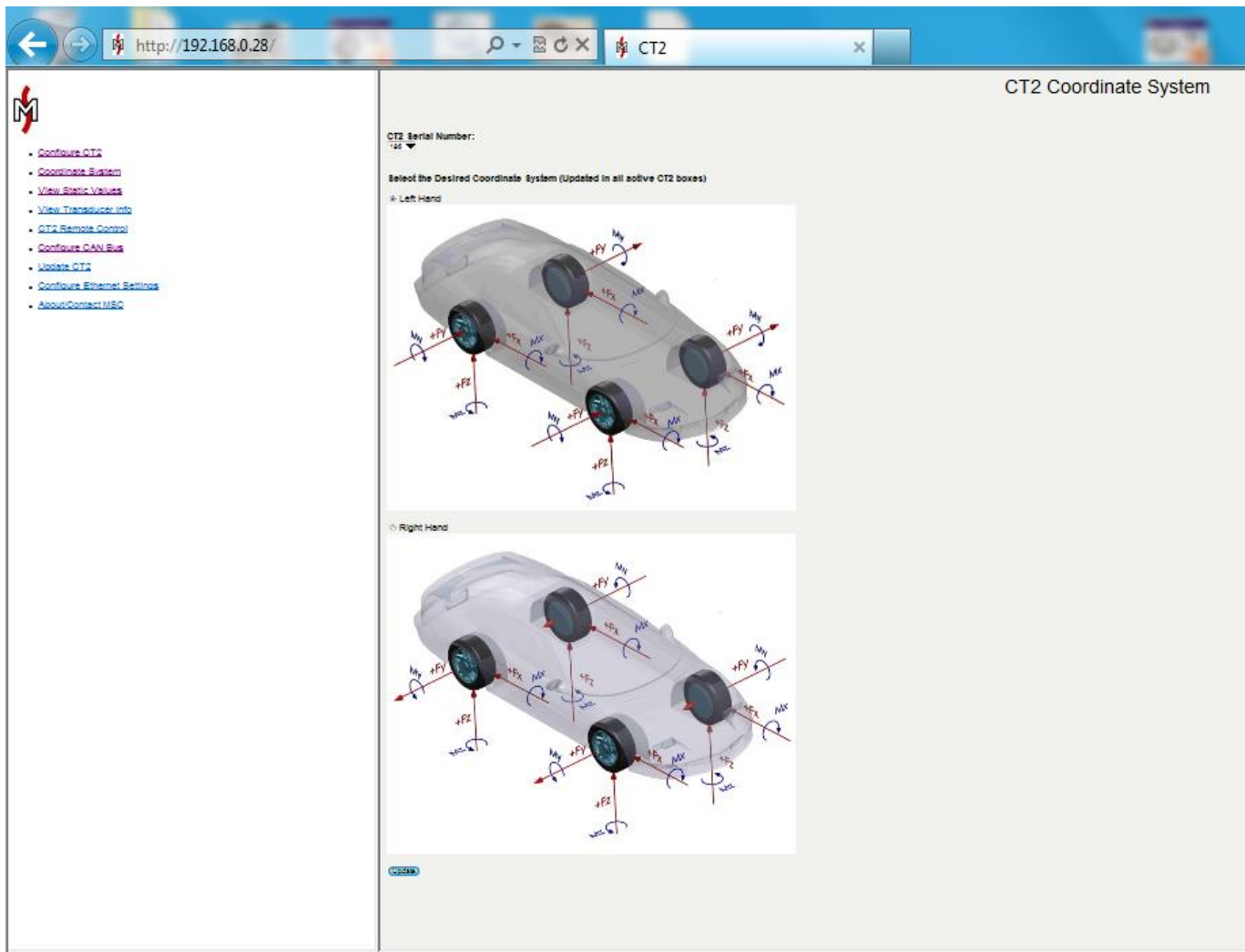
If the Transducer is not mounted such that the Z+ Axis is vertical pointing towards the ground, then determine the mounting angle and enter it below. To determine the mounting angle imagine that Z+ starts pointing towards the ground and the wheels rotate so that the vehicle starts to move forward. Enter below the number of degrees the Z+ arrow would need to travel in order to get it to the position that you have it mounted.

0.00 Mounting Angle Degrees

If the Transducer cannot be mounted with the Z+ arrow pointing vertically towards the ground, enter the angle that the transducer is from vertical as defined in the following manner. "Imagine that the Z+ arrow starts pointing towards the ground and the wheels rotate so the vehicle starts to move forward. How many degrees would the Z+ arrow travel to get it to the position that you have it mounted". Enter that angle.

Changing WFT Coordinate System

The default WFT coordinate system is the Left Hand Coordinate System shown below. In the Coordinate System tab on the CT2 webpage the WFT coordinate system can be switched to a Right Hand Coordinate System by checking the button labeled “Right Hand” then clicking update at the bottom of the page. This will update all CT2 boxes stacked and powered up. The WFT Coordinate System is explained further on page 64.



Static Values

The Web page can be used to view static transducer output values during setup. Select “Static Values” on the upper left side of the web page. The web page displays the static values for all active WFT systems, shown below.



- [Configure CT2](#)
- [Coordinate System](#)
- [View Static Values](#)
- [View Transducer Info](#)
- [CT2 Remote Control](#)
- [Configure CAN Bus](#)
- [Update CT2](#)
- [Configure Ethernet Settings](#)
- [About/Contact MSC](#)

Static Values

Forces: N, Moments: Nm, Acceleration: g

CT2 SN	WFT Pos	X Force	Y Force	Z Force	MX Moment	MY Moment	MZ Moment	Position(Deg.)
273	LF	160.68	32.04	51.57	14.10	0.67	0.00	0.00
270	RF	-93.23	39.52	61.49	4.36	-5.37	4.36	0.16
NA	LM	NA	NA	NA	NA	NA	NA	NA
NA	RM	NA	NA	NA	NA	NA	NA	NA
271	LR	-39.67	5.34	172.58	9.06	10.07	-3.02	0.00
272	RR	126.95	-24.57	-37.69	-6.04	0.34	-13.43	0.00

CT2 SN	WFT Pos	X Accel	Z Accel
273	LF	-0.27	-0.56
270	RF	-0.47	-0.63
NA	LM	NA	NA
NA	RM	NA	NA
271	LR	0.04	-0.49
272	RR	-1.12	-0.69

Note: When in "Vehicle" Mode zero values will be shown until an index pulse is received from the encoder. Please rotate the wheel until actual static force/moment values are displayed.

Page Refresh Rate:

☐ None
☐ 1 Second
☒ 3 Seconds
☐ 5 Seconds

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Refresh rates can be changed by selecting from the options at the bottom of the page.

Transducer Information

Information for each WFT system can be viewed by clicking on "Transducer Info". The CT2 Serial number drop down menu allows the user to select which system the information is for.

Transducer Info

CT2 Serial Number: 703

Report Date: Tue Mar 01 2022
Report Time: 10:44:24 AM

Wheel Force Transducer Information:

Model: LW12.8
Serial Number: 663
Position: LF
Calibration Date: Tue Nov 05 2019

	X Force	Y Force	Z Force
Shunt Cal Value (N)	21017	11731	20967
Factory Scale Factor	1.083	1.012	1.090
Field Scale Factor	1.083	1.012	1.090
Scale Factor % Difference	-0.023	-0.030	-0.017
Analog Full Scale Output (+/- N)	55000	30000	55000
Transducer Offset (Volts)	0.003	0.018	-0.039
Transducer Offset (N)	15.1	53.1	-214.8

	X Moment	Y Moment	Z Moment
Shunt Cal Value (Nm)	3006	3469	3147
Factory Scale Factor	0.900	0.897	0.942
Field Scale Factor	0.900	0.897	0.942
Scale Factor % Difference	0.027	0.027	0.006
Analog Full Scale Output (+/- Nm)	10000	10000	10000
Transducer Offset (Volts)	0.019	0.022	0.005
Transducer Offset (Nm)	19.2	22.0	5.2

Configuration Settings:

Full Scale Rotational Velocity: 2000 RPM

Enter Slip Ring/Encoder Reference Angle: 0.00 Degrees Clockwise from Vertical

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CT2 Remote Control

The CT2 stack can be controlled via the web page by selecting “CT2 Remote Control” at the upper left side of the web page. This allows the buttons on the CT2 to be controlled remotely via the Ethernet connection. This is especially useful when used in the lab because it allows the user to control the CT2 from the control room.

CT2 Remote

Remote Control the CT2(s) Here:

Zero	Shunt	Run/Setup Mode	Bridge Power	Wheel/Vehicle Coordinates	Fault
Off	Off	Run	On	Vehicle	Off
zero	shunt	mode	bridge	coords	
☐ Hold Positive Shunt					

CT2 CAN Bus Configuration

CAN bus data output settings are configured using the “CT2 CAN Bus Configuration” option located on the left side of the web page. Here the Baud Rate, Output Rate, and

Desired Units are set. After making any changes click update and these setting will update for all CT2 boxes that are stacked together.

MSC recommends setting the Baud Rate (CAN Bus Bit Rate) at 1 mbps. This is the amount of data that can be transferred on the CAN Bus. The data acquisition should also be set to 1 mbps.

CT2 CAN Bus Bit Rate (Must Match Data Acquisition CAN Bus Interface Bit Rate):

1 mbps ▼

Note: It is necessary that the CT2 box receive a CAN acknowledge bit from the connected data acquisition system. Do not use passive (listen-only) mode on your data acquisition. If using a 1 mbps Baud rate the following output rates can be used. If a lower Baud rate is used, the output rates must be lowered proportionally.

	With Accelerometers	
	Recommended	
# of CT2 Boxes per CAN Bus @ 1 Mbps	Sample Output Rate (Samples / Sec)	# of Possible Error Retrans.
1	1,750	1
2	1,024	1
4	550	2

If connecting 4 WFTs to one CAN bus (using a 4 to 1 cable) the max sample rate is 550 Hz. If connecting 2 WFTs to one CAN bus (using a 2 to 1 cables) the max sample rate is 1024 Hz.

The CAN Bus data output rate can be adjusted between 250 to 2500 samples per second. Enter your desired output rate. This should match the sample rate selected in the data acquisition.

Digital Data Output Rate (250 to 2,500 Samples/Sec):

500.0 Samples/Second

There is signal delay caused by filtering performed by the CT2 to decimate the data down to the selected output rate. The exact delay depends on output rate selected by is usually around 25 milliseconds. See Appendix 4 for the exact delay. The -3db point of the decimation filter is approximately 40% of the selected output rate.

Select the desired output units. Either lbs/lb.ft or N/N.m can be selected.

Force/Moment Units and Scale Factors Used in CAN Database File:

☒ lbs, lb-ft

☐ N, Nm

There are 3 CAN messages output per sample for each CT2 box. If the accelerometer box is not checked that is reduced to 2 CAN messages.

Output Accelerometers on CAN Interface

☒ Output Accelerometers

CAN Bus Termination

In the table, you can set whether 120 ohm CAN bus termination is supplied per each active CT2 box by checking the CAN Bus Termination Box. Every CAN bus must have 120 ohm end-to-end termination. For 1 CT2 box connected to 1 data acquisition CAN interface, both the CT2 box and the data acquisition should have 120-ohm terminators. Additional CT2 boxes (nodes) connected between the end-to-end points must not have 120-ohm CAN termination. For example, for a 2 to 1 CAN cable, one CAN BUS Termination Box must be checked and the other one must be unchecked. For a 4 to 1 CAN cable, one CAN BUS Termination Box must be checked and the other three must be unchecked. When using two 2 to 1 CAN cables, the user must identify which SN CT2s are connected to each CAN cable. Then the user must uncheck the CAN Bus Termination Box for one of the two CT2s connected to each cable.

Set 11-bit Message Ids: 0x001 to 0x7FF and CAN Bus Termination:

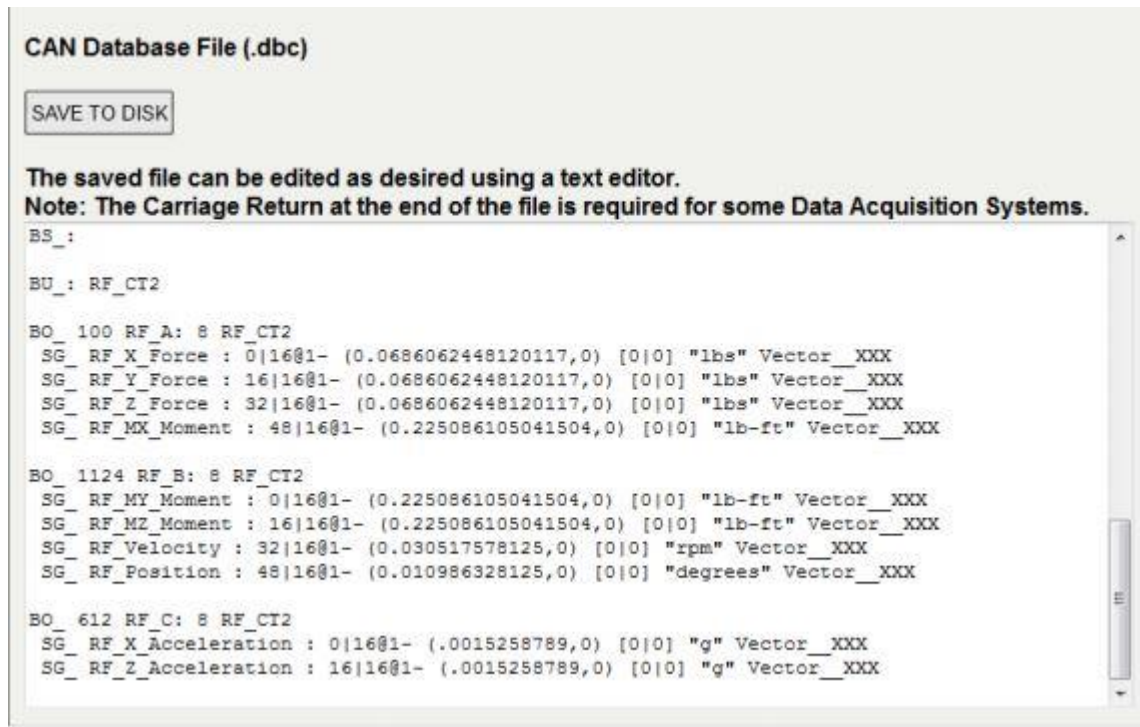
Msg ID(Hex)	Box SN	Box Pos	Msg Channels	CAN Bus Termination
0x 19A	445	LF	FX, FY, FZ, MX	☒
0x 59A	445	LF	MY, MZ, Velocity, Position	
0x 39A	445	LF	X Accel, Z Accel	
0x 1C8	446	RF	FX, FY, FZ, MX	☐
0x 5C8	446	RF	MY, MZ, Velocity, Position	
0x 3C8	446	RF	X Accel, Z Accel	
0xNA	NA	LM	FX, FY, FZ, MX	NA
0xNA	NA	LM	MY, MZ, Velocity, Position	
0xNA	NA	LM	X Accel, Z Accel	
0xNA	NA	RM	FX, FY, FZ, MX	NA
0xNA	NA	RM	MY, MZ, Velocity, Position	
0xNA	NA	RM	X Accel, Z Accel	
0x 10D	452	LR	FX, FY, FZ, MX	☒
0x 50D	452	LR	MY, MZ, Velocity, Position	
0x 30D	452	LR	X Accel, Z Accel	
0x 11E	447	RR	FX, FY, FZ, MX	☐
0x 51E	447	RR	MY, MZ, Velocity, Position	
0x 31E	447	RR	X Accel, Z Accel	

Note: Velocity & Position will be replaced by Sine and Cosine if they are selected.

After all changes are made be sure to click update to save changes.

DBC file creation

A CAN database (.dbc) file is needed by the data acquisition to de-code the digital data sent by the CT2. A .dbc file is created by the CT2, by clicking the 'SAVE TO DISK' button. A window should pop-up enabling you to save the file to your computer. If browser is not up to date or pop-ups have been disabled, this button may not work properly. In that case copy all the text in the text box below and paste it into Notepad. Save the notepad .txt file. Then go back and change the extension of that file from .txt to .dbc. Then the .dbc can be imported to the data acquisition.



Firmware version CT2_D102_D021_D018_E.frm and higher have the CAN message IDs fixed based on Wheel Position. That means you only need 1 .dbc file per WFT model. Previous firmware versions assigned CAN message IDs based on CT2 serial number.

Updating Firmware in CT2

The embedded web page allows the user to easily update firmware without having to send the CT2 back to the factory. This allows updates or repairs to be done in the field.

Update CT2

CT2 Firmware Information & Last 10 History Codes:

CT2 SN	WFT Pos	Loaded Firmware Version	Smart Sensor Version	HC1	HC2	HC3	HC4	HC5	HC6	HC7	HC8	HC9	HC10
NA	LF	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	RF	A110_A106_A103	10	90	21	22	22	22	21	21	21	41	90
NA	LM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	RM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	LR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NA	RR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: Each CT2 must be updated individually using its own Ethernet port.

Upload a New Firmware File to the Highlighted CT2 Above:

Upload Progress:

Writing Progress:

If an update is available, Michigan Scientific will provide an installation file. Save this file in a convenient location.

To update the CT2:

- Connect the Ethernet cable to the electronics to be updated.
- Press the Browse button and select the installation file.
- Press the Upload button
- The file will be uploaded. Follow the prompts on the web page.
- Once complete you will be prompted to cycle power on the CT2.
- Once power has been cycled, the new firmware is ready to be used.

Caution: Do not disconnect the CT2 or power down the computer or CT2 during the update. Possible damage may occur which will require the electronics to be sent back to Michigan Scientific for repair.

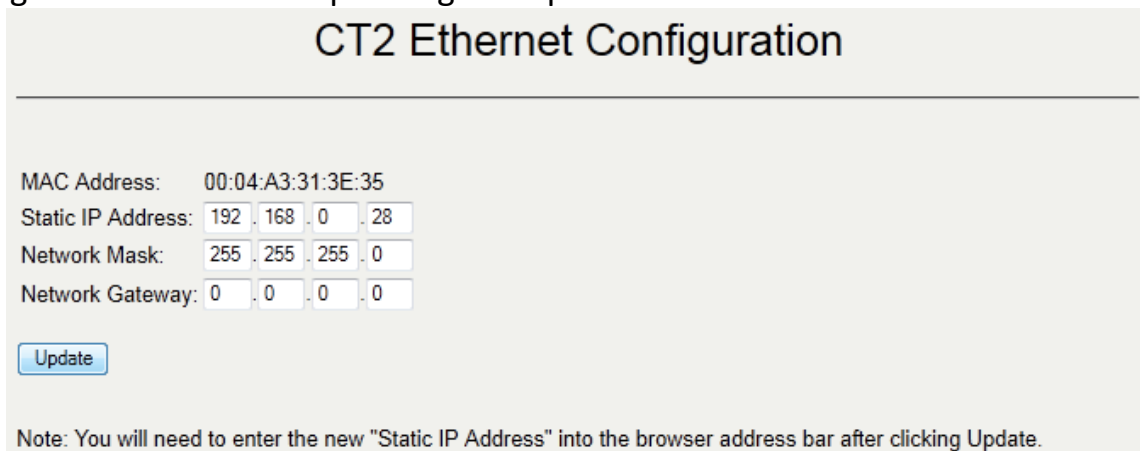
Note: Only the CT2 connected to the Ethernet Cable will be updated. Each CT2 electronics must be updated separately.

Note: Update all CT2 electronics with the same version of firmware before using them in a stacked configuration.

With firmware version CT2_D102_D018_D013_E.frm or higher, MSC can send a calibration file to update the amplifier smart sensor which can be loaded through the CT2. This could be helpful is an amplifier needs to be replaced.

CT2 Ethernet Configuration

Default IP addresses are set at 192.168.0.28 at the factory for all CT2s. A new IP address can be set by going to the "Configure Ethernet Setting" tab located on the left side of the web page. The IP address, Network Mask, and Network Gateway can be changed by entering a new number and pressing the Update button as shown below.



CT2 Ethernet Configuration

MAC Address: 00:04:A3:31:3E:35

Static IP Address: 192 . 168 . 0 . 28

Network Mask: 255 . 255 . 255 . 0

Network Gateway: 0 . 0 . 0 . 0

Note: You will need to enter the new "Static IP Address" into the browser address bar after clicking Update.

In the event that the Ethernet Configuration was changed away from the default setting and not recorded, it can be reset to the defaults shown above.

To reset the Ethernet Configuration Settings to the values shown above,

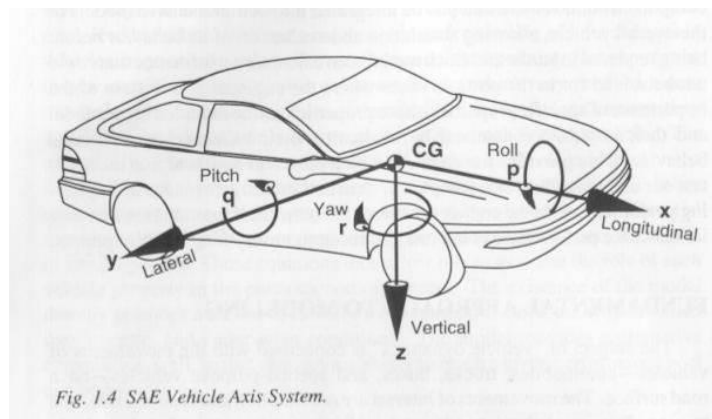
- Shut off the power switch on the CT2
- Press the position button
- Turn on the power switch while continuing to hold the position switch for a minimum of 1 second after the CT2 powers up.
- The Ethernet Configuration Settings will reset to the values shown above.

Sampling Frequency

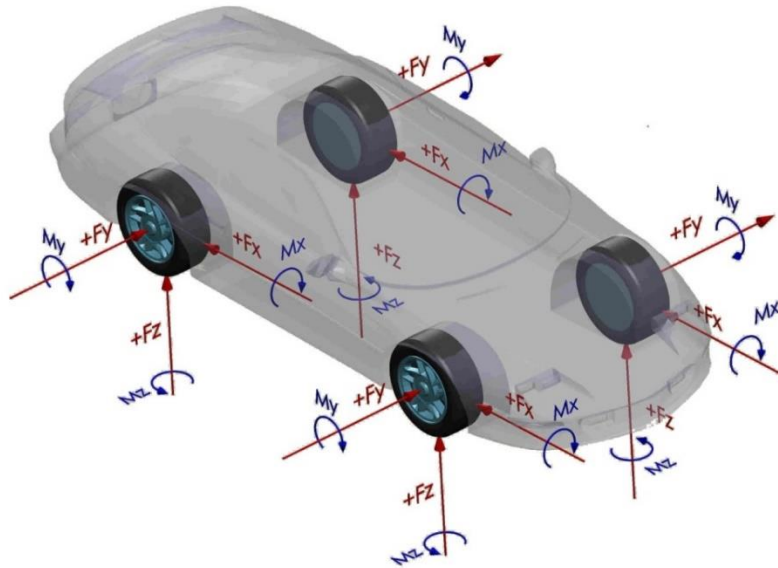
Much of the work done with WFTs for durability with a frequency of interest below 100 Hz. Common sample rates for WFT are 500/512 and 1000/1024 Hz depending on your test.

WFT Coordinate System

The default coordinate system is referred to Left Hand Rule. The Left Hand Rule Coordinate System following SAE Coordinate system. SAE Coordinates define positive X-axis as directed towards the front of the vehicle, positive Y-axis to the driver's right and positive Z-axis into the ground. Associated moments are per *the right hand rule*. See figure below.



The default positive transducer output is defined as a force or moment applied by the spindle to the tire per positive SAE coordinate directions e.g. +Fz WFT data is the spindle forcing the tire down (i.e. tire forcing spindle up). It is good measurement engineering practice to perform a system polarity check on each channel by physically loading the transducer. The following figure shows the default positive direction for force and moment application (i.e. forces applied to the tire in the direction indicated by the arrows will result in a positive output).



With regards to the WFT measurement system, the origin of the SAE coordinate system is placed at the perpendicular intersection of the axis of wheel rotation and an imaginary plane that passes through the centerline of the transducer's spokes.

The WFT channels are defined as:

F_x = Longitudinal Force

F_y = Lateral Force

F_z = Vertical Force

M_x = Roll Moment (Wheel Camber)

M_y = Pitch Moment (Wheel Torque)

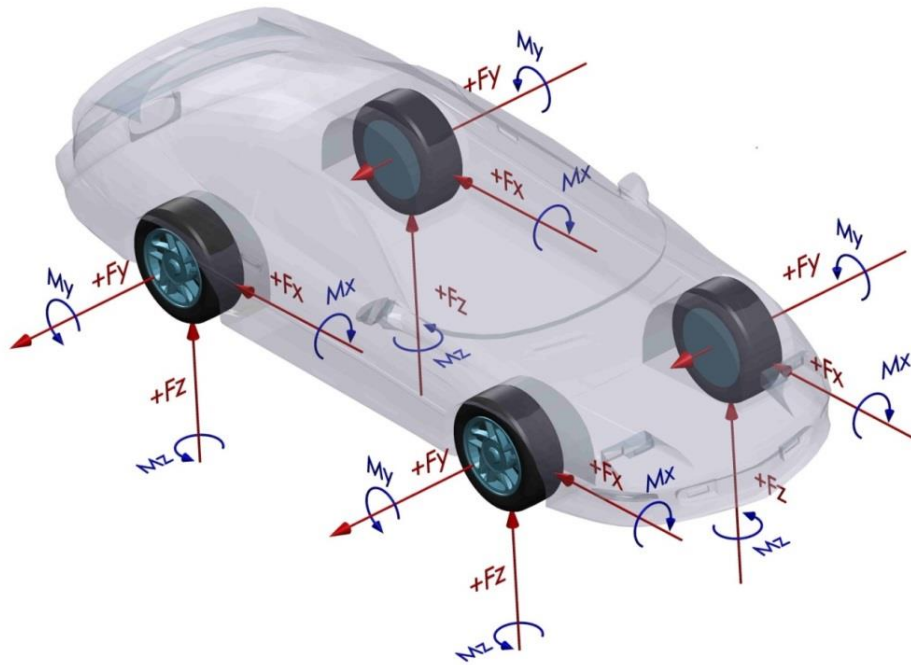
M_z = Yaw Moment (Wheel Steer)

Accel X = Longitudinal Acceleration

Accel Z = Vertical Acceleration

Right Hand Rule Coordinate System (Optional)

An option is provided to change the WFT coordinate system to one that follows the right hand rule. Changing the system to this coordinate system can be done in the CT2 embedded webpage. This optional coordinate system will switch the polarity of the F_y and M_y outputs only. The following figure shows the positive direction for force and moment application (i.e. forces applied to the tire in the direction indicated by the arrows will result in a positive output).



Weatherproofing

The WFT system is IP67 rated when all connectors are mated. When performing off-road testing, MSC recommends using fusion tape over the slip ring to cable connection to keep debris and dirt out of the ratcheting mechanism of the connectors.

Recommended Static Load Rating and Overload

For each WFT model MSC gives recommended static load rating. This is a generalized rating that MSC uses to help customers select the proper WFT. This is calculated by taking the dynamic Fz load rating and dividing by 5. In almost all cases using these rating will prevent transducer overload. However there are extreme cases, for example Supercars & off-road jump maneuvers, that can create overload and damage a transducer, while staying under the recommended Static load rating.

If testing a vehicle capable of inputting extreme loads into the WFT, monitor the Mx channel closely. This should be Mx at the transducer center-line. MSC transducer are rated for 50,000 Mx cycles at full scale. If Mx loads go significant above full scale, the strain gage bridge can be damaged with very low cycles.

Optional Transducer Connector Covers are available for purchase

MSC recommends using connector covers when the amplifier is not installed and the WFTs are on the vehicle. This will prevent debris and moisture from getting in the transducer connector and protect the O-ring. The provided connector covers mount with 1/4"-20 bolts.



Transducer Field Checks

If you suspect the WFT system has been damaged or has some issue, there are a couple of field checks that can be made.

1. Perform a Shunt Calibration. If no fault light comes on, this means the Shunt value is within 2.5% of the Factory Shunt calibration.

2. The transducer off-set is reported on the NIST calibration sheet. If the transducer bridge has some damage, it would likely change the transducer off-set. If the off-set has not changed by less the 0.1 volts, and the WFT passes the Shunt, it should be in good condition

To check the transducer off-set perform the following.

- Remove hub and wheel adapters.
- Set the transducer flat on the bench.
- Connect the amplifier to the transducer.
- Connect the cable to the slip ring and CT2.
- Power up the CT2.
- Press the *Mode* button to put the CT2 into *Setup* mode.
- Record the output for each channel.

Factory Calibration

MSC recommends bi-annual calibrations for all it's Wheel Force Transducers. These can only be performed properly by MSC. MSC can calibrate all WFTs in Charlevoix, MI USA. Calibrations for car to light truck sized WFTs can also be performed in Shanghai, China. Calibration values and cross-axis sensitivity coefficients are programmed into the amplifier smart sensor for each transducer. The wheel force transducer was statically calibrated in an Automated calibration machine with calibration adapters replicating rim and hub adapters.

During manufacturing radial forces were applied around the perimeter of the outer ring at 45° intervals to check for radial uniformity.

Troubleshooting

Symptom	Possible Causes	Solution
CT2 Does not power up when the power switch is turned on.	Power cord not connected to power.	Check that power cord has power supplied to it and try to power up the CT2 again.
	Power supply polarity is incorrect.	Check polarity. See appendix 1. If incorrect, reverse power supply leads and try to power up the CT2 again.
Fault light illuminates at startup	Signal cable not connected properly.	Check signal cable connections. Cycle power, leave box off for 5 seconds before turning back on.
	Smart sensor not read at power-up.	Check polarity, if incorrect, reverse power supply leads and try to power up the CT2 again.
Fault light is flashing	No digital data stream from amplifier	Check signal cable for damage.
Position button flashes slowly	Two CT2s are set to the same vehicle position	Set all CT2s to the proper vehicle position corresponding to the location of the transducer it is connected to.
Position button flashes fast	The CT2s are set to different CAN output rates.	Stack and power all CT2s. Then connect to the CT2 webpage. Under the Configure CAN Bus tab, enter desired setting and hit the update button. This will set all stacked CT2s to the same CAN output rate.
Zero light does not go out.	Did not complete two full revolutions.	Continue rotating wheels.
	Encoder Issue	Try to swap slip ring with another WFT, and re-try.
After zero sequence, Zero light goes out but Fault light illuminates.	Transducer offset greater than 40% Full scale. This indicates a likely problem with transducer or amplifier or possible a very non-flat adapter.	Unbolt the wheel & hub adapter. If offset goes away, check adapters for damage. If offset does not go away swap amplifiers and move smart sensor (See appendix 3) and repeat Shunt sequence. If Shunt now passes, the problem is with the amplifier. If Fault light still comes on with new Shunt sequence, the problem is with the transducer and it must be returned to Michigan Scientific.

Symptom	Possible Causes	Solution
Shunt light does not go out and fault light illuminates after a shunt sequence.	Transducer or amplifier is out of tolerance by 2.5% or more.	Swap amplifiers and move smart sensor (See appendix 3) and repeat Shunt sequence. If Shunt now passes, the problem is with the amplifier. If Fault light still comes on with new Shunt sequence, the problem is with the transducer and it must be returned to Michigan Scientific.
	Force input to the transducer during shunt sequence causes out of tolerance shunt.	Cycle CT2 power, and repeat the shunt sequence being sure to not change load on WFTs.
Data has Sine wave in data for all rotating channel (Fx, Fz, Mx, Mz, Accel X & Accel Z) when the WFT is rotating.	The ZERO is not completed.	Perform zero procedure.
	The CT2 is in SET-UP mode.	Press MODE button on CT2 to move to RUN mode
	CT2 is in WHEEL mode.	Press COORDINATES button on CT2 to move to VEHICLE coordinates.
Data has Sine wave in data for only Fx & Fz OR Mx & Mz.	Internal Encoder Issue	Replace slip ring (which contains encoder)
	Amplifier Issue.	If you have 'D2' type amplifier, switch with another amplifier and swap removeable smart sensors so smart sensor matches transducer SN. See Appendix 3. MSC or MSC's local agent may be able to provide a spare.
	Transducer Bridge Issue.	Send to MSC for repair. Re-zero may temporarily fix the issue. MSC or MSC's local agent may be able to provide a spare.
	CT2 chassis ground not connected to vehicle chassis	Connect one end of a banana plug cable to the CT2 and connect the other end to the vehicle chassis or to data acquisition grounding stud, if the data acquisition is grounded to Chassis, not both. Or connect the shield of the CT2 power cable to the vehicle chassis.

Symptom	Possible Causes	Solution
Channels, which should have no load, have an offset even after the zero procedure is performed.	Slip Ring is not oriented properly. Incorrect zero, direction of wheel rotation was changed during the zero procedure. External forces were imposed during the zero procedure on the hoist. Incorrect zero, on-the-road zero was performed on a rough surface. Data acquisition system has some offset SAC has not been Zeroed.	See "Angle reference incorrect" below Be sure that the wheel is turned only in one direction during the zero procedure. When turning the wheels, be sure to apply force only on the amplifier package. This insures that no forces are imposed through the sensor. Redo the zero procedure. For best accuracy, perform the zero on the hoist. Using CT2 webpage, check the channel outputs and compare to Data Acquisition Outputs. If using SAC, zero it by setting the wheel straight ahead and pressing and holding the SAC button for 2 seconds.
Outputs from CT2 stay zero for all channels even when force is present.	Encoder has not found an index pulse. If using CAN outputs, CAN signal is not synced with Data Acquisition. The bridge power kill feature is invoked. Signal cable from sensor has been disconnected or damaged. If this is the case, the fault light on CT2 box will be flashing. The data acquisition cabling is not connected improperly or damaged.	The output channels stay at zero until the encoder sees an index pulse. Turn tire at least one complete revolution. Check outputs. Make sure CT2 Output Rate is the same as Data Acquisition Sample Rate. Make sure both CT2 and Data Acquisition are set to 1Mbps Baud Rate. Make sure Maximum output rate per CAN Bus is not exceeded. Cycle power on CT2. Check to see if the bridge power light is on. If it is not, press the Bridge Power button. The light should illuminate. Inspect cable for damage. A cable diagram is located in the appendix. Look at WFT outputs with CT2 webpage. If the output is correct, check the cabling or data acquisition setup.

Symptom	Possible Causes	Solution
The channel offsets change during use.	WFT was not exercised. A severe event caused some shifting in the bolted joints between the sensor and adapters. A severe event overloaded the sensor.	Exercise WFT by performing figure 8 and 2 hard brake stops, then re-zero. While it is not common, a severe event could cause some offset in channels. Perform the zero sequence. Check the sensor offsets. Remove the wheel and hub adapters. Change the CT2 to Setup Mode Check the offsets for each channel in CT2 webpage. If the offsets have changed significantly, send the sensor in for checkout and possible repair.
Higher or lower than expected output from one or more channels	Incorrect amplifier package Sensor is damaged. Amplifier package is damaged. Below apply to Analog outputs: The data acquisition system sensitivities are incorrect.	Check that the correct amplifier package is being used with the sensor. Check the sensor offsets and shunt values. Send in for checkout and repair if needed. If you have 'D2' type amplifier, switch with another amplifier and swap removeable smart sensors so smart sensor matches transducer SN. Check data acquisition set-up matches the WFT calibration sheet.
One or more output channels output incorrect polarity.	RF/LF/RR/LR position button not set properly. Slip Ring is not oriented properly Desired Coordinate System not selected. Below apply to Analog outputs: Cable to data acquisition is improperly connected. Sensitivity is incorrect in the data acquisition system.	Check to see position button is correct for each WFT. See "Angle reference incorrect" below Go into CT2 webpage and select desired Coordinate System. Check values in CT2 webpage. If correct, check connections for signal cable to the data acquisition system. Check the voltage from the CT2. If correct, check the sensitivities in the data acquisition system.

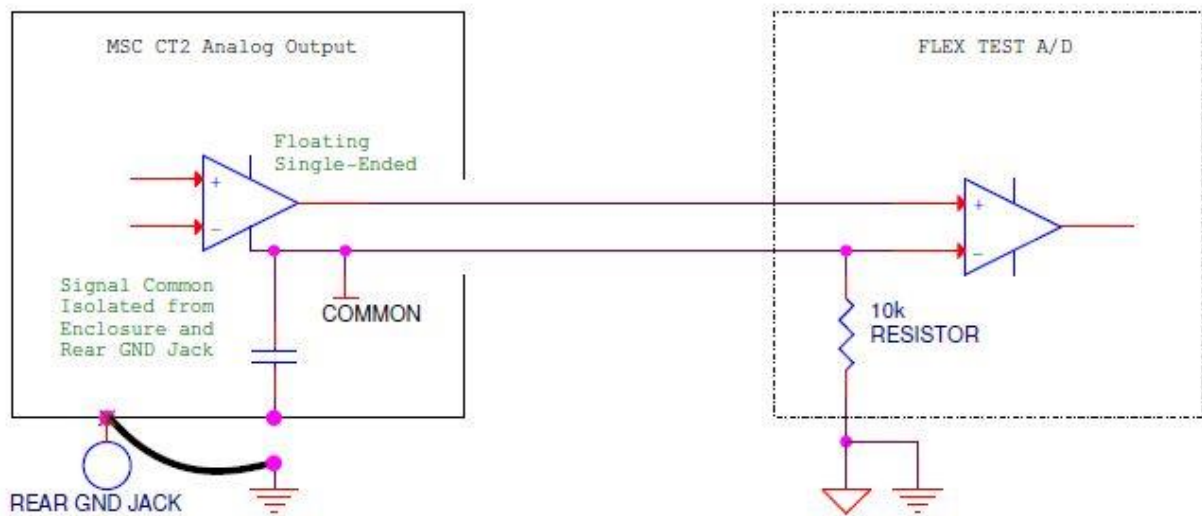
Symptom	Possible Causes	Solution
Angle reference incorrect	Slip Ring is not oriented properly Slip Ring/Encoder Reference Angle entered incorrectly in CT2 webpage SAC has not been zeroed.	Orient the slip ring so that the connector is pointed vertical. The side surfaces of the slip ring should be vertical. Using the CT2 Webpage, first confirm that the Slip Ring/Encoder Reference Angle stored in the smart sensor is correct. If using SAC, zero it by setting the wheel straight ahead and pressing and holding the SAC button for 2 seconds.

Appendix 1- Wiring and Shielding

CT2 Power Connector Pin-Out

Mating Connector for Power:		
1	Ground	Black Wire
2	Power High	White Wire
Case	Shield/Ground	

Proper CT2 Power and Signal Grounding Diagram



Slip Ring to CT2 Cable

WIRING DIAGRAM FOR CT2 w/ DIGAMP

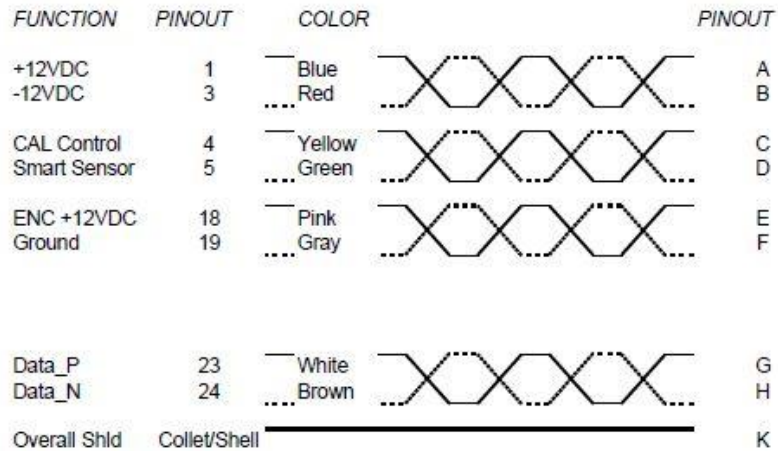
Aug 30, 2012
D. Wheeler

Cable is SAB "07890425" from Series SD200CTP

----- 4x2x24AWG (Paired), Braid Shield, PUR Jacket, 0.25" Overall, Continuous Flex

CT2 Electronics
S23L0C-P26

SR Stator
D38999/26TC98SN



CT2 Signal Out Connector Pin-Out

Circular 20 pin connector	
Pin	Function
1	Fx Low
2	Fx High
3	Fy Low
4	Fy High
5	Fz Low
6	Fz High
7	Mx Low
8	Mx High
9	My Low
10	My High
11	Mz Low
12	Mz High
13	Velocity Low
14	Velocity High
15	Position Low
16	Position High
17	Accel X/ Sine Low
18	Accel X/ Sine High
19	Accel Z / Cosine Low
20	Accel Z / Cosine High

Appendix 2 - Example Quick Reference Calibration Sheet



321 E. Huron St.
Milford, MI 48381
Voice: (248) 685-3939
Fax: (248) 684-5406
www.michsci.com

8500 Ance Road
Charlevoix, MI 49720
Voice: (231) 547-5511
Fax: (231) 547-7070
www.michsci.com

Quick Reference Sheet

Transducer Serial Number: LW-2T-60K-S 262	Calibration Date: 06/27/2022
--	---------------------------------

Wheel Force Transducer Electronics: CT2

Gain and offset adjustments are handled in the CT2. The CT2 uses a shunt calibration sequence to adjust the gain so that the following sensitivities are correct. It is good practice to invoke the Shunt sequence by pressing the Shunt button at the start of each new test set-up. The Shunt sequence also compares the factory Shunt output to the field Shunt output. If these values differ by more than 2.5%, the fault and shunt lights will stay lit. This indicates a likely issue with the transducer or amplifier.

Sensitivity

Fx	1 Volt =	6,744 lb	30,000 N
Fy	1 Volt =	3,372 lb	15,000 N
Fz	1 Volt =	6,744 lb	30,000 N
Mx	1 Volt =	6,638 lb.ft	9,000 N.m
My	1 Volt =	6,638 lb.ft	9,000 N.m
Mz	1 Volt =	6,638 lb.ft	9,000 N.m
Accel X	1 Volt =	10 g	98 m/s ²
Accel Z	1 Volt =	10 g	98 m/s ²

The Sensitivities listed above are the default settings which correspond with a ± 10 Volt Analog Output range. In the CT2 webpage it is possible to change the Analog output range. If the Analog output range is changed the above listed sensitivities will also change correspondingly.

Shunt Calibration

Fx	4.725 V* =	31,867 lb	141,753 N
Fy	4.065 V* =	13,706 lb	60,969 N
Fz	4.670 V* =	31,495 lb	140,095 N
Mx	4.272 V* =	28,360 lb ft	38,452 N.m
My	4.748 V* =	31,517 lb ft	42,732 N.m
Mz	4.258 V* =	28,265 lb ft	38,322 N.m

When recording analog signal outputs, it is good practice to check the delta shunt output for each channel through the data acquisition and compare it to the engineering unit values listed above. If done, this will ensure that each channel is properly connected and scaled in the data acquisition. To calculate the delta shunt output add the absolute value of the positive Shunt output to the absolute value of the negative Shunt output and divide by two. The delta Shunt output you calculated should match the above value within 0.5%.

*Shunt voltage listed is nominal, the actual voltage may vary.

Speed and Position

Speed Sensitivity	1 Volt =	200 RPM
Position Sensitivity	1 Volt =	36 Degrees

The Speed Sensitivity listed above is the default setting (this corresponds to 2000 RPM full scale). The Speed Sensitivity can be changed to 100 or 300 RPM per volt in the CT2 webpage (corresponding to 1000 or 3000 RPM full scale). Check the CT2 webpage for current settings. Speed is updated at each encoder pulse.

Appendix 3 – Changing Amplifier Smart Sensor

Michigan Scientific 'D2' Wheel Force Transducer Amplifiers have a removable smart sensor. The smart sensor contains all the calibration information for the WFT. If an amplifier is damaged, the smart sensor can be removed from the amplifier housing and installed in spare amplifier housing. Then the WFT system can continued to be accurately used.



Use a 3/32" Allen wrench to remove the 2 bolts holding the smart sensor to the amplifier. Remove the smart sensor.



Install the desired smart sensor into the spare amplifier housing, ensuring o-ring stays in place as shown. Install the two #4-40 x 3/16" bolts. The serial number on the smart sensor must match the transducer serial number it is being used with.

Appendix 4 – CAN Signal Delay Calculation

Digital CT2:

Instructions to calculate the time delay of the CT2 system's CAN signal outputs*

For CT2 CAN Output Sample Rate of 250 to 499 Hz:

$$\text{Approximate Through Delay in ms} = ((47.5 / (\text{CAN Data Rate in Hz} * 8)) + 0.001791) * 1000$$

For CT2 CAN Output Sample Rate of 500 to 999 Hz:

$$\text{Approximate Through Delay in ms} = ((47.5 / (\text{CAN Data Rate in Hz} * 4)) + 0.001791) * 1000$$

For CT2 CAN Output Sample Rates ≥ 1000 Hz:

$$\text{Approximate Through Delay in ms} = ((47.5 / (\text{CAN Data Rate in Hz} * 2)) + 0.001791) * 1000$$

***Actual signal delay between Analog channels and WFT CAN signals collected by a data acquisition will vary depending on delay created in the data acquisition system. The data acquisition system could add or subtract from the delay between Analog channels and WFT CAN signals.**

The best way to determine time delay through the data acquisition system is to connect one Analog WFT channel (apply the same filtering as you will use with other analog signals) and the WFT CAN signals. Then perform a Shunt Calibration which gives a step input to both signals. The exact delay between Analog and CAN channels can then be measured.

Notes: