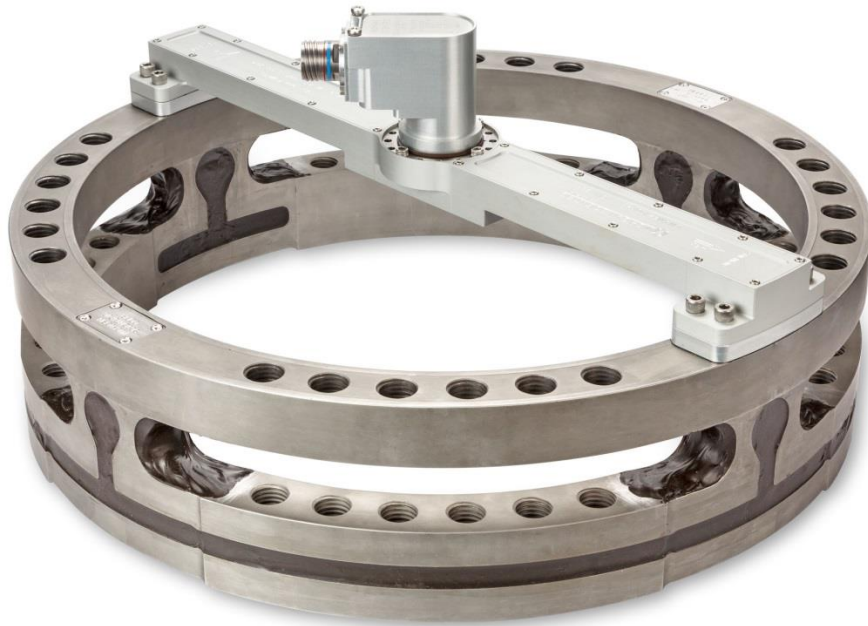


Michigan Scientific Corporation

Wheel Force Transducer System



Model: LW-2T-60K-S

For Heavy Trucks



October 2017

Revision 3.1

Technical Support

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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 vehicles 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 amplifier 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 SAE coordinates. 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, via CAN bus, or Ethernet. 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

MSCLW-2T-60K-S
6-Axis Single or Dual Wheel Load 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)
Full Scale Output (before amplifier)		1mV/V nominal
Transducer		4 arm strain gage bridges
Nonlinearity		Less than 1% of full-scale output
Hysteresis		Less than 1% of full-scale output
Repeatability		Less than 1% of full-scale output
Zero Balance prior to installation		Less than 2% of rated output
Radial Sensitivity Variation		<1% of radial load
Bridge Resistance		700 to 1400 ohm, axis dependent
Temperature Range		-40 to 125 C (-40 to 257 F)
Excitation Voltage		10 VDC
Insulation Resistance from Bridge to Case		Exceeds 1000 M-ohm
Vehicle Power Input Voltage		10 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



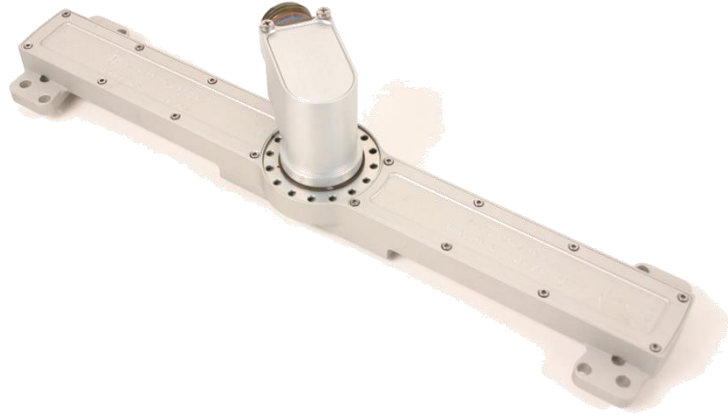
Six Axis Wheel Force Transducer

CT2 Electronics



CT2 Electronics. The dimensions are 7.5in x 1.3in x 7.4in (191mm x 33mm x 188mm). See page 29 for operating instructions.

Amplifier and Slip Ring



The amplifiers have been selected to have low thermal drift and excellent common mode rejection. They have a gain-bandwidth product of 2 MHz. The maximum gain used with the 6-axis Wheel Force transducer is 1000. The resultant 3-dB bandwidth at this gain is 2000 Hz. Channels with gains less than 1000 will have higher bandwidths.

The amplifiers have fixed gain and calibration resistors. These have been selected to match a specific transducer to provide uniform sensitivities among all channels. The resistors have precision accuracy and low temperature coefficients for better measurements.

The amplifier package contains 55g X & Z direction accelerometers. The amplifier package also digitizes the transducer, encoder, and accelerometer signals before they pass through the slip ring.

A Twenty circuit Slip ring with 512-pulse encoder is mounted to the amplifier package.

Signal Cable



Signal Cable connects from the slip ring to the CT2 Electronics (30ft/9m length).

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 Shield of this cable is connected to the CT2 chassis.

Signal Breakout Box



Analog Signal Breakout Box

Ethernet Cable



Ethernet Communications Cable (8 ft/2.4m length).

CAN Bus Cable



Two to One CAN Bus Signal output cable for connection to eDAQ data acquisition system. (8 ft/2.4m length). Michigan Scientific will make a custom CAN cables to connect directly to the CAN Bus port on your data acquisition.

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.

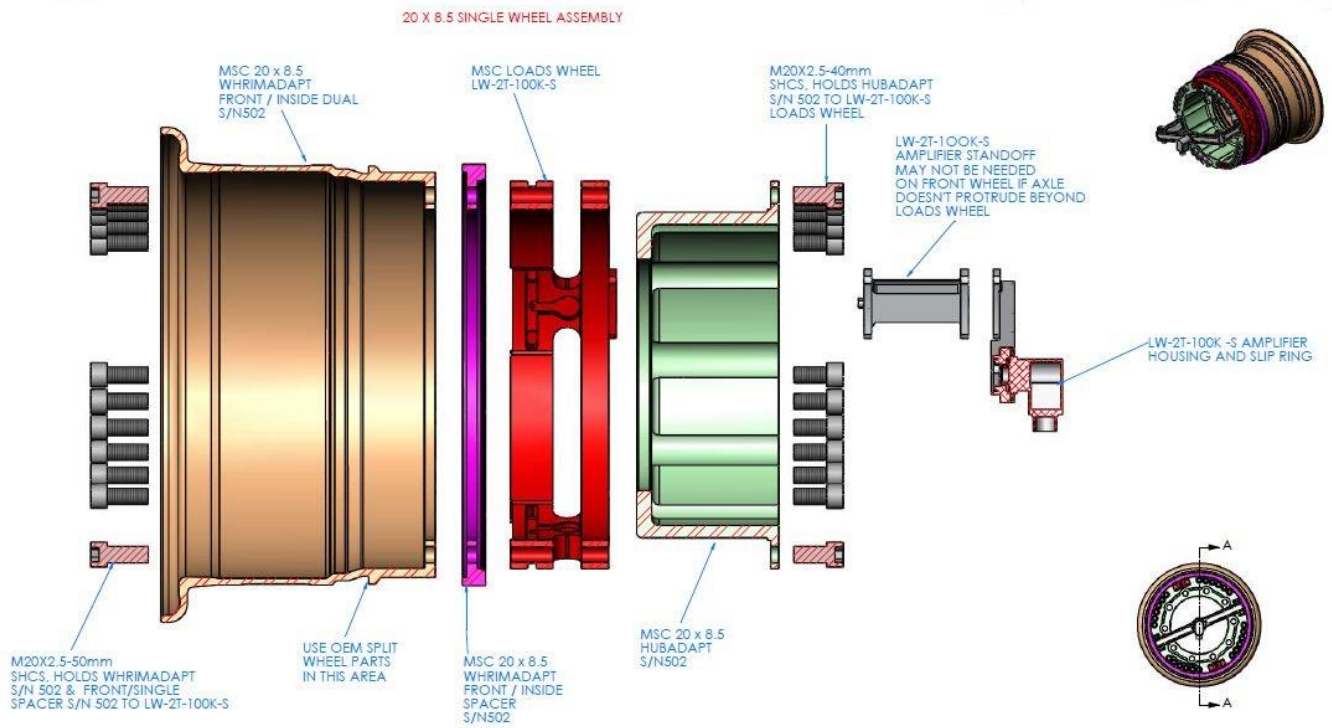
Assembly Instructions

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.
- Place cardboard or wood down where the transducer is being assembled.
- 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.

Typical Single 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 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 335 lb.ft (450 N*M) Torque.





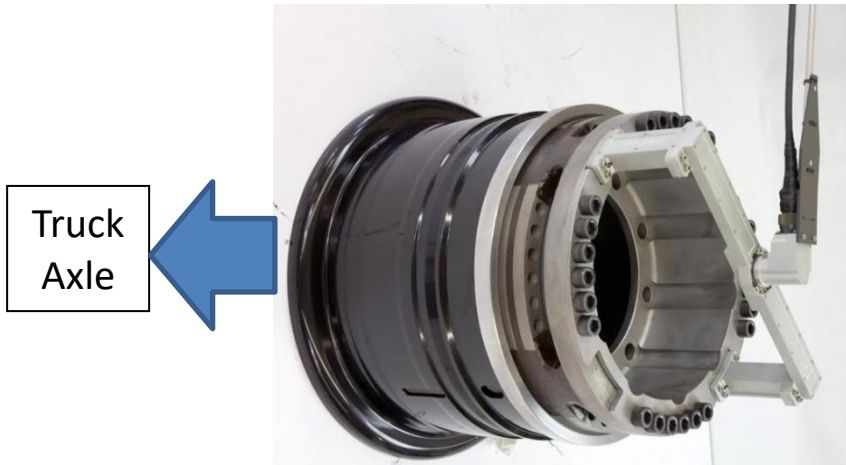
Tightening Hub Adapter to Transducer Bolts with Torque Wrench and Torque multiplier
(note: picture does not show mounted tire. Normal Install will have tire already mounted to Rim)

- 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 335 lb.ft (450 N*M) Torque.



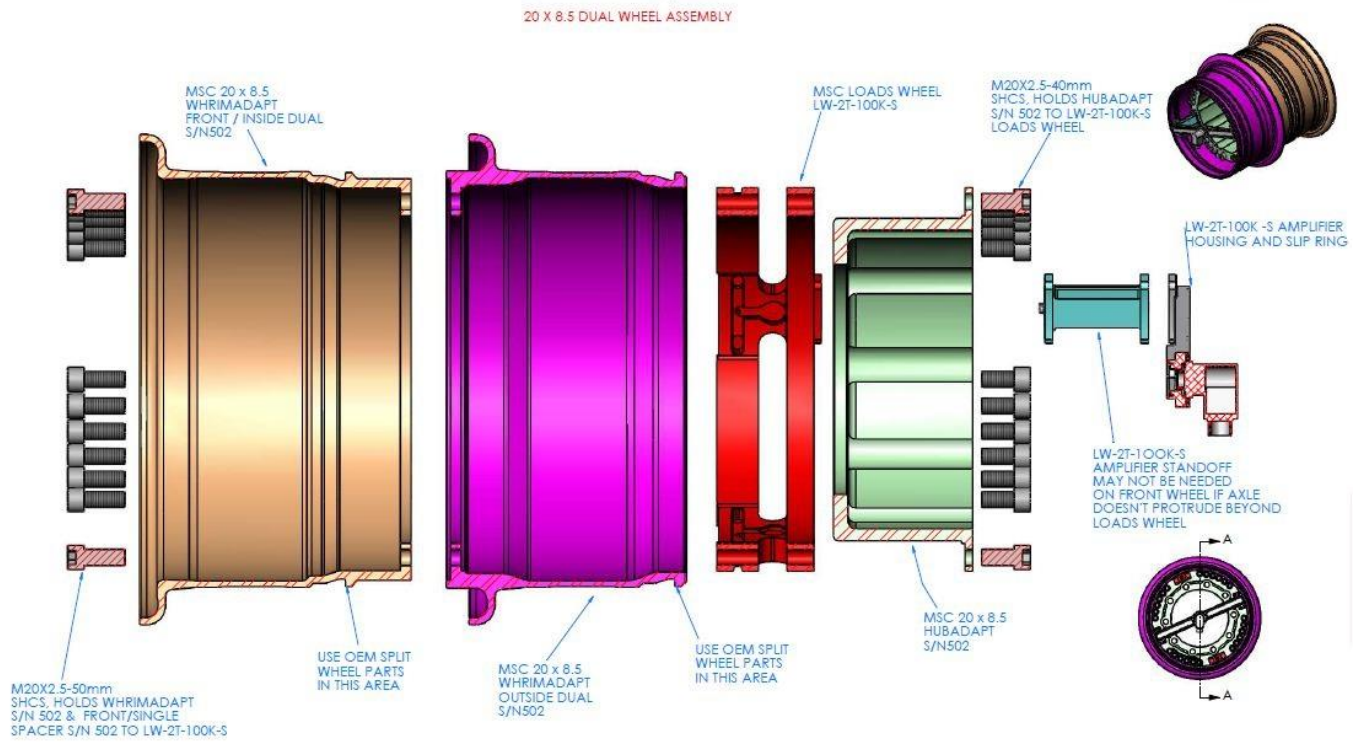
Tightening Inner Transducer Bolts with Torque Wrench and Torque multiplier
(note: picture does not show mounted tire. Normal Install will have tire already mounted to Rim)

- 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

- Stack the Outside Rim Adapter on top of the Inside Rim Adapter as shown. Carefully install the Transducer into the Outside Rim Adapter as shown. The Transducer will have to be carefully guided past the valve stem of the tire. Deflate the tire as need to get the Transducer past the value stem.



**Outside Rim Adapter stacked on top of Inside Rim Adapter.
(Tire not shown)**



Install Transducer into Outside Rim Adapter

- Install four M20x2.5x90 bolts, using anti-seize bolt lubricant. Be sure to install washer plates under the bolt heads when installing to 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.



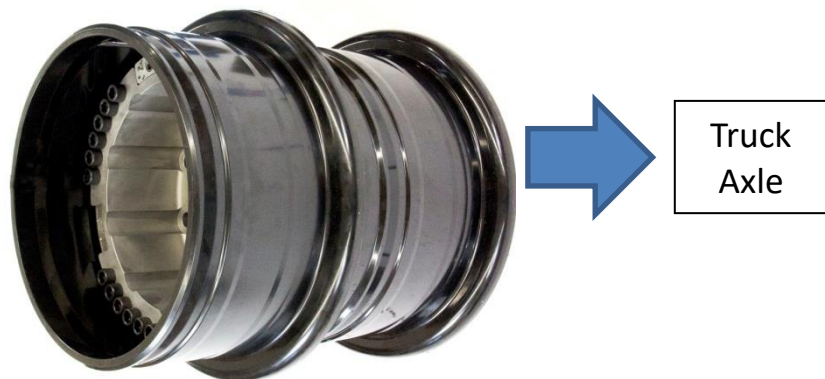
- Place the Hub Adapter onto the Transducer and install the twenty four M20x2.5x45 bolts, using anti-seize bolt lubricant, and tighten to 335 lb.ft (450 N.m) Torque.



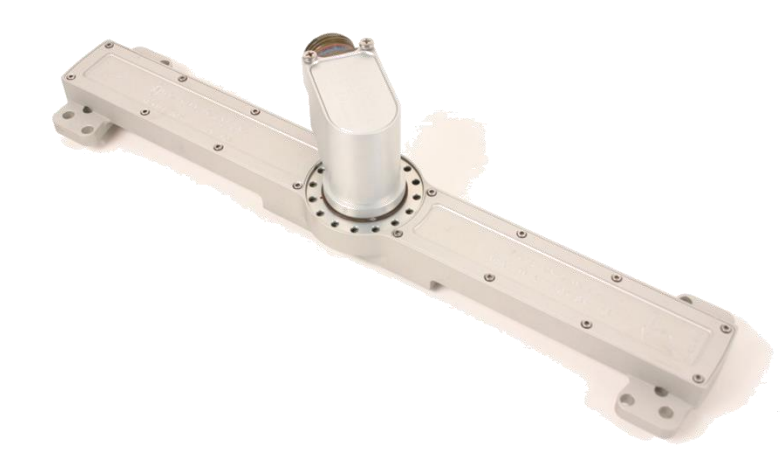
- Turn over the entire Wheel Assembly so that the Outside Rim Adapter is now touching the ground and install the remaining twenty M20x2.5x90 bolts, using anti-seize bolt lubricant. Be sure to install washer plates under the bolt heads when using aluminum rim adapters. Tighten all twenty four bolts to 335 lb.ft (450 N.m) Torque.



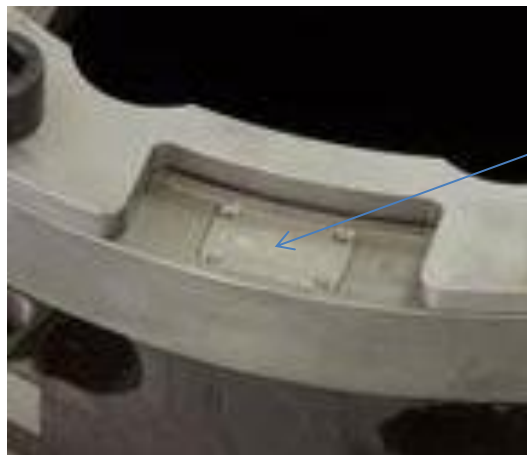
- Install the Dual Wheel transducer assembly to the axle using a tire jack. Install ten lug nuts, using anti-seize bolt lubricant, and tighten to customer specified torque. Then proceed to mount the Amplifier/Slip Ring.



Amplifier Installation

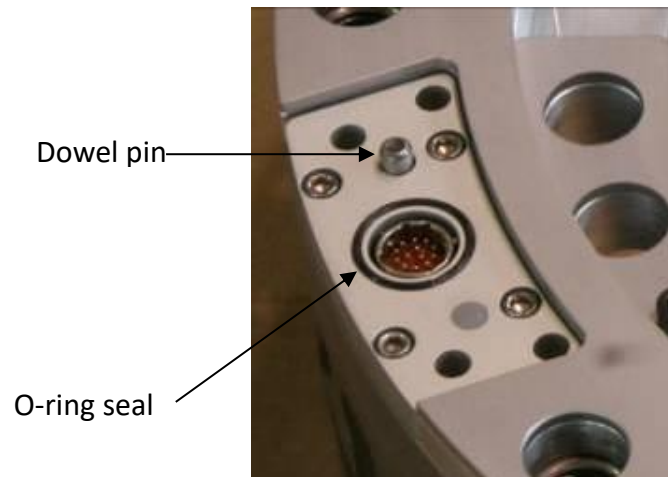


- The amplifier and slip ring assembly is installed after the lug nuts have been tightened. Note that each amplifier and transducer is a matched pair. This is important; data is stored in the amplifier package for each specific transducer. Also note that there are dowel pins on the transducer to insure proper orientation of the amplifier housing. A serial number is engraved on the transducer as shown below. The serial number is visible through a cut-out located on the hub adapter.

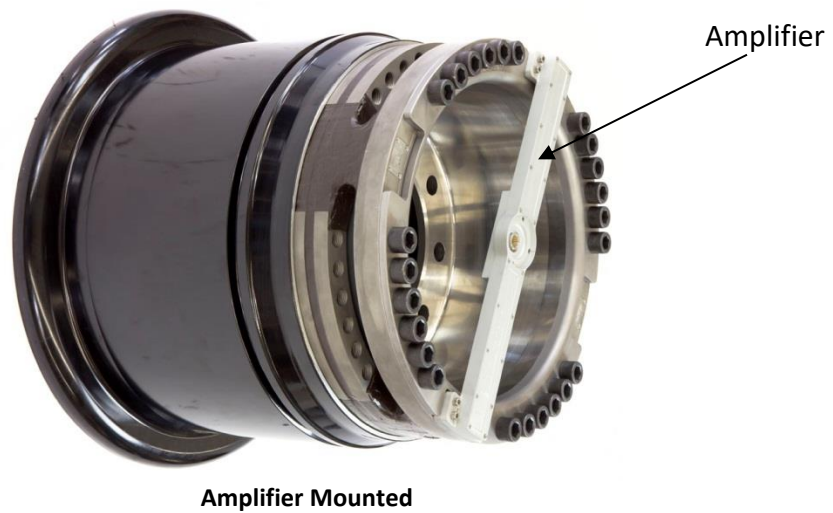


Engraved Transducer
serial #

- Make sure that the O-ring seal is in place as shown below.



- 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.



- Secure the amplifier with eight ¼-20 x 1-1/8 inch stainless steel socket-head screws and tighten to 5 lb.ft (7 N.m) torque. Temporary thread locker (eg. Blue Loctite) is recommended on these fasteners.

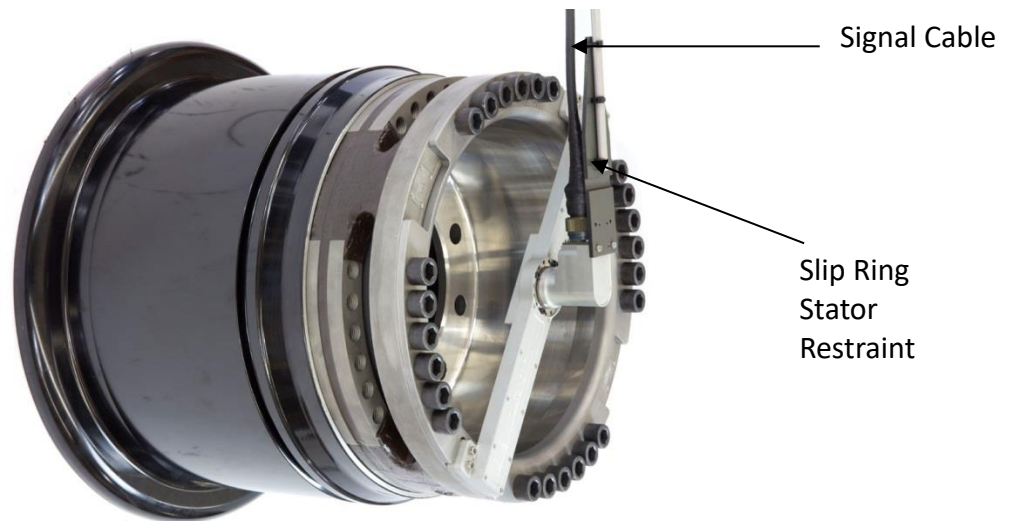
The slip ring is attached to the amplifier with 8-32 x 3/8 inch screws. Temporary thread locker (eg. Blue Loctite) is recommended on these fasteners. Once the slip ring is installed on the amplifier housing it is normally left attached when the measurement system is removed from the vehicle.



Slip Ring Mounted to Amplifier

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.

- There is a red dot on the slip ring rotor and a similar dot on the stator. When the dots are lined up, the encoder is aligned with its once-per-rev index pulse. At this point the Z-axis arrow on transducer points down. The positive Z direction is down in the SAE coordinate system (see “Understanding SAE Coordinates” later in this manual for a discussion on Coordinates.)
- It is necessary to provide a rotational restraint of the slip ring stator. Normally the customer supplies the rotational restraint. For best results the rotational restraint should be attached to the steering knuckle or backing plate on the backside of the tire on a steered wheel. In this way the measured data is always with respect to the spindle coordinates even when the wheel is steered.



Cable and Slip Ring Stator Restraint Attached

- A set of rotational restraints is included. Adjust the rotational restraints so that the top flat surface of the slip ring is level. This is necessary to ensure that when the measurements are converted to vehicle coordinates the Z-axis represents a true vertical force on the vehicle. If the slip ring cannot be mounted vertically, see “Slip Ring/Encoder Reference Angle” on page 46.
- Connect one end of the 30 ft long cable to the slip ring. Fusion tape should be placed over the cable to slip ring connector to ensure a weatherproof connection. The tape also 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 current draw from the vehicle is less about 0.75 amp per CT2 at 13.8 volts and reduces proportionately at higher supply voltages.
- 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.
- If using CAN Bus signal output, connect one end of the CAN Bus cable to each CT2 and the other end to the data acquisition.

- Connect the CT2 chassis ground to the vehicle chassis ground. This will reduce noise in the system. This can be done in one of the two following ways.
 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 vehicle chassis or data acquisition chassis ground.
 2. Connect the shield of the CT2 power cable to the vehicle chassis.
- Turn the power switch on. At this time, the force, moment, and position channels are held at zero until the CT2 receives an index pulse.

Amplifier Stand-offs

When using a dual wheel installation, amplifier stand-offs are necessary to prevent the Signal Cable from contacting the wheel or tire. The amplifier stand-offs are used to move the amplifier package, including the slip ring, signal cable, and slip ring stator restraint, outboard so that the cable can be routed around the wheel without having to make sharp bends in the cable.



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

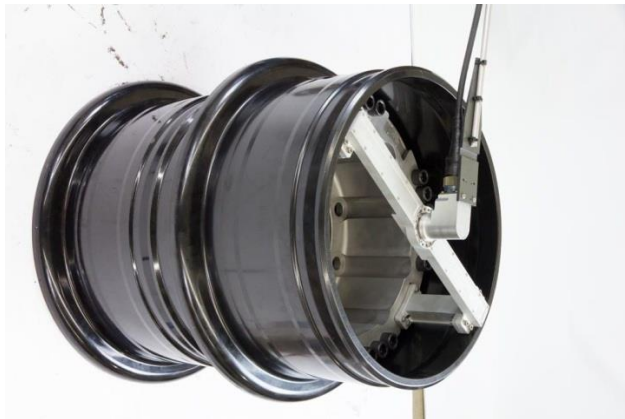
- O-rings are used to provide weatherproof sealing between the amplifier stand-offs and the transducer. There are also O-rings between the amplifier stand-offs and the amplifier package. Make sure the O-rings are in their proper place before installing the stand-offs and amplifier package.
- Secure the amplifier stand-offs with eight ¼-20 x 1-1/8 inch stainless steel socket-head screws and tighten to 5 lb.ft (7 N.m) torque. Temporary thread locker (eg. Blue Loctite) is recommended on these fasteners.



- Secure the amplifier to the stand-offs with eight ¼-20 x 1-1/8 inch stainless steel socket-head screws and tighten to 5 lb.ft (7 N.m) torque. Temporary thread locker (eg. Blue Loctite) is recommended on these fasteners.

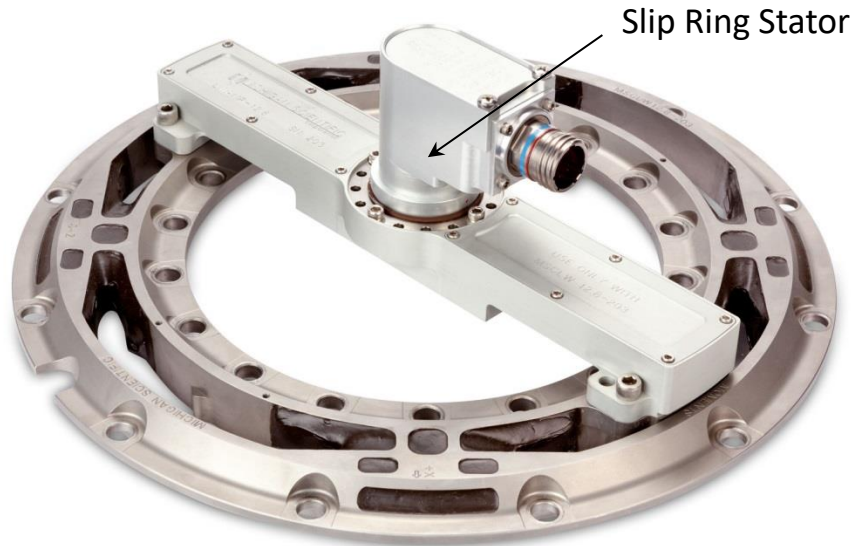


- Secure the slip ring, Signal cable, and Stator restraint as described in the Amplifier Installation section above.



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.



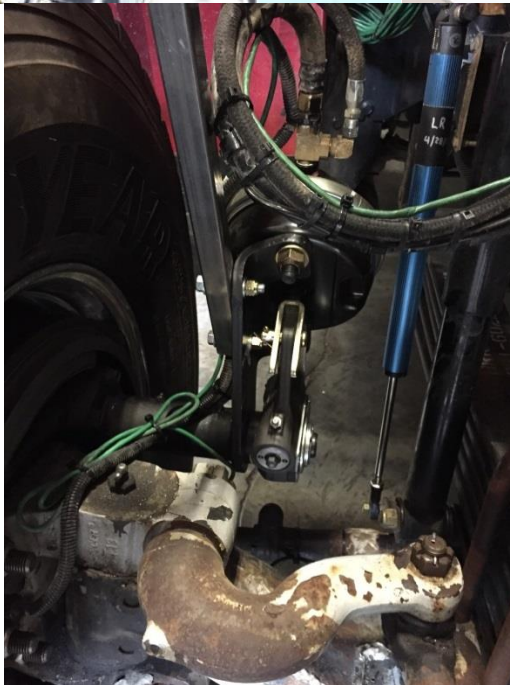
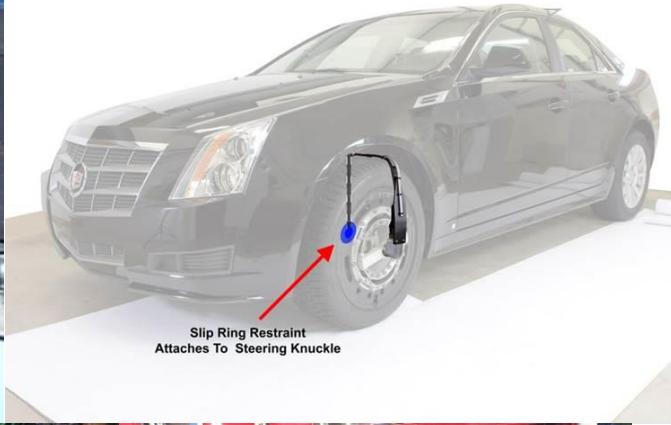
Use a digital protractor or level to check if the slip ring stator is vertical. As needed, make adjustment to the MVSR placement so that the slip ring is vertical. Once the MVSR is in the proper location, tape should be used to further secure the MVSR to the vehicle body. If the car body is non-ferrous, 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 two options for stator restraints. The first option is to make a rigid bracket that extends over the tire and connects to the knuckle or backing plate. This bracket will keep the slip ring stator near the vertical position while the wheels are steered. The second option is to restrain the stator in the rear (non-steering) wheel method and correct for the angle change of the slip ring stator with correction equations.

Over the Wheel Bracket

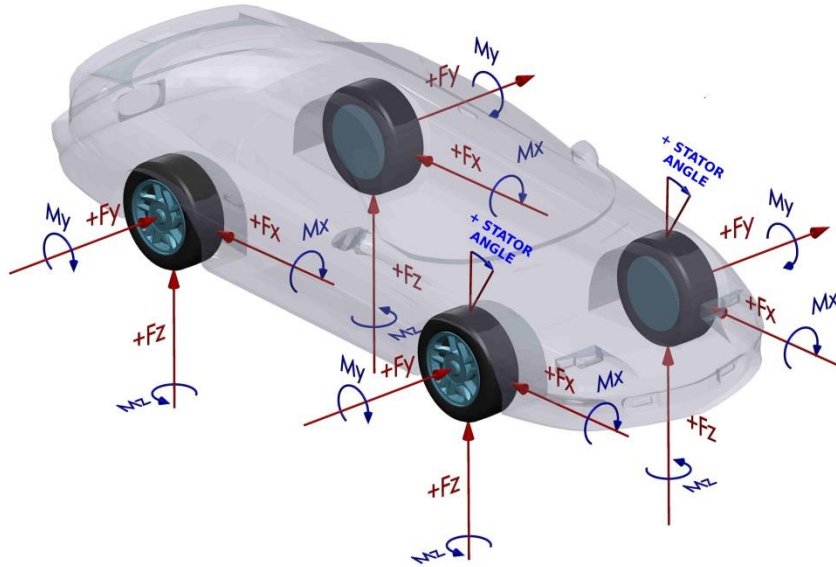
The over the wheel slip ring stator bracket will have to be custom made by the user. The reason for this is that the attachment points for every vehicle are unique, so there is no universal type over the wheel bracket. The over the wheel bracket should be stiff, yet lightweight. Below are a couple of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



Stator Angle Correction

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) sensor on the vehicle that changes output as the wheels steer. The sensor 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 sensor is operating, a calibration needs to be performed by the user to establish a relationship between the sensor output and the angle of the slip ring stator as the wheels are steered. Record both sensor 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 sensor 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.

$$\text{Stator Angle} = m (\text{sensor output}) + b$$

Next add the following correction equations into your data acquisition as calculated channels, where Fx, Fz, Mx, & Mz 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.

CT2



Introduction

One CT2 is used for each wheel force transducer. This handles coordinate transformation and the user interface. 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 which side of the vehicle the transducer is placed and corrections will be made to keep the output in SAE coordinates. Cross-axis sensitivity correction is performed. Error checking is in place to alert the user if the system is out of tolerance. Finally, a shunt procedure calculates output sensitivities and allows the user to record shunt values.

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.

Power Switch

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 transducer 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 memory chip located in the amplifier package so it is not lost when power is interrupted or a different CT2 is used. 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.

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 or to command the CT2 to invoke a positive shunt to allow the user to set up their data acquisition system. After a successful shunt sequence, the CT2 stores the serial number of the transducer internally. If a different transducer is connected, the Shunt light will flash slowly for 20 seconds at startup to indicate the difference. This will prompt the user to run a shunt sequence on the current CT2/WFT combination.

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.

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 may want to kill the bridge excitation to check for background noise. With bridge excitation interrupted, any signal activity is noise. It is best to perform this operation with the engine on and vehicle moving. The bridge power light goes off when the Bridge Power button on top of the enclosure is pressed. At this time, the module does not transform the data to vehicle coordinates and will perform no other function until the bridge power is turned back on.

Coordinates

The wheel and vehicle lights indicate whether the output data is in wheel or vehicle (spindle) 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 laboratory testing when the transducer is not spinning. Vehicle coordinates transform the data from the wheel coordinates to vehicle coordinates. This is used for on-vehicle tests where the wheel is spinning.

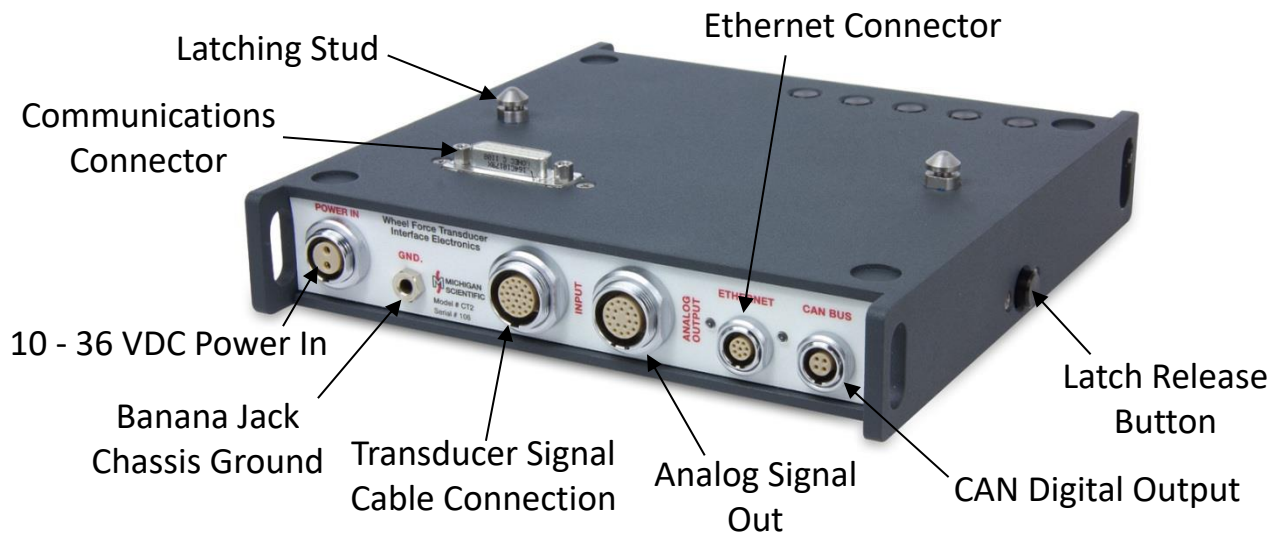
Fault

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.



Connectors

Connectors located on the back panel of the CT2 are for power, ground, transducer signal cable, analog output signal, Ethernet connection, and CAN digital Signal output. The connectors located on top and bottom of the enclosure are used communications between multiple CT2 electronics.

Output Channels

Ten analog outputs are available at the Analog Signal Break-out Box shown in the photograph above. The channels are for force and moments about the x, y, and z axes, and also wheel velocity, wheel position, and acceleration in the X & Z directions. All the analog outputs are single ended and isolated from power ground.

All of these channels are also available as digital signals using the CAN Bus signal output.

Output Channel Sensitivities

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 sensitives 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.

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)
Z Moment	9,000 N-m/V (6,638 lb-ft/V)
Accel X	10 G/Volt
Accel Z	10 G/Volt
Velocity	200 RPM/Volt (default setting)
Position	0-360 deg
SINE	\pm Full Scale
COSINE	\pm Full Scale

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 Power	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 Coordinate Transformation 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 Load Measurement 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.

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 10 to 36 VDC power. Power draw is about 0.75 amps at 13.8 volts for each WFT system.

One power cable is provided for two CT2s. If additional cables are required, contact Michigan Scientific.

Balancing - Zeroing

An electrical balance is critical to assure accuracy of wheel load measurements. Any electrical zero offset in the transducer or amplifier can introduce significant errors in the measurements. When measurements that are made on the rotating transducer are transformed to the stationary vehicle coordinate system, any zero offsets produce errors that are periodic at once-per-revolution. It is therefore important to reduce all zero offsets to a minimum.

The wheel load transducer is electrically balanced during fabrication. It is then temperature compensated to have minimum balance shift from 70°F up to 200°F. The amplifiers and CT2 are also designed to have minimal thermal offset over a wide temperature range.

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, simply drive the vehicle around a parking lot.

There are three zeroing procedures.

1. 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, it will cause an error if the direction of rotation is reversed during the zeroing sequence. 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 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.

2. 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.

3. Stationary Zero

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

- The CT2 electronics defaults to Vehicle Coordinates at startup.
- Press the Coordinates button.
- The blue wheel light will illuminate.
- 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 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.

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.

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-axis forces should have very little output. The z-axis force should read the negative weight of the wheel and tire. The y and z-axis moments should have little output. The x-axis 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.

Spin the wheel and observe the x and z-axis force outputs. There should be very little ripple in the outputs. Offset errors will cause once-per-rev variations. Scaling errors will cause twice-per-rev errors. If excessive once-per-rev errors are seen, repeat the zero process. If excessive twice-per-rev errors are seen, perform a shunt sequence and then repeat the zero procedure.

For this transducer, the allowable output variations are plus and minus 0.25% of rated load or 30 lbs. for x and z-axis force channels.

Factory Calibration

Calibration values and cross-axis sensitivity coefficients are programmed into the amplifier for each transducer. The wheel load transducer was statically calibrated in a load frame with a rigid outer ring in place of the modified rim.

An electrical shunt calibration was performed during physical calibration in the laboratory. During physical calibration, shunt resistor values are determined to establish equivalent physical load values. Shunt calibration resistor in the amplifiers were chosen to provide an electrical signal equal to approximately 25-50% of the rated capacity. Sensitivity calibration values in kilo-Newton/volt and pounds/volt are presented in the Appendix of this manual.

Radial forces were applied around the perimeter of the outer ring at 45° intervals. The forces were applied in each direction and data was recorded. The data were then fitted with least squares linear functions. Cross-axis sensitivity in each of the non-loaded axes were also recorded and fit with a linear approximation.

The calibration procedure was repeated with pure torque applied around each moment axis.

Shunt Calibration Sequence

Shunt Sequence - The CT2 calculates an internal gain, used to make output sensitivities match what is programmed into the Memory chip

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 memory chip. This calculated gain is recorded into the

memory chip 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% different than what is programmed into the memory chip, the shunt sequence does not pass.

Note: This sequence can be performed with the wheels on or off the ground with equal accuracy. However, if the wheels are on the ground, anything that causes force variations such as movement of the vehicle can cause errors in the shunt cal.

Positive/Negative Shunt - The CT2 can be commanded to invoke a positive and negative shunt to be used for data acquisition system setup.

To invoke the positive/negative shunt.

- 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.
- Press the Shunt button again to invoke the negative shunt or press the Mode button to end the positive shunt.
- If you invoked a negative shunt, the Shunt light will continue to flash rapidly and the outputs will hold a negative shunt until the Shunt or Mode button is pressed.

The calibration sheet lists sensitivity in lbs full scale and N full scale and a shunt values in pounds and Newton's for each channel. If desired, the user may check the sensitivity by recording the outputs during a shunt sequence and calculating the delta (magnitude of change from positive shunt to negative shunt). The shunt value listed in the calibration sheet is defined as half of this delta.

In-field checkout can be done by parking the vehicle on a scale and comparing the transducer outputs with scale values. The scale values will differ from the output of the transducer by a little more than the weight of the tire and rim adapter.

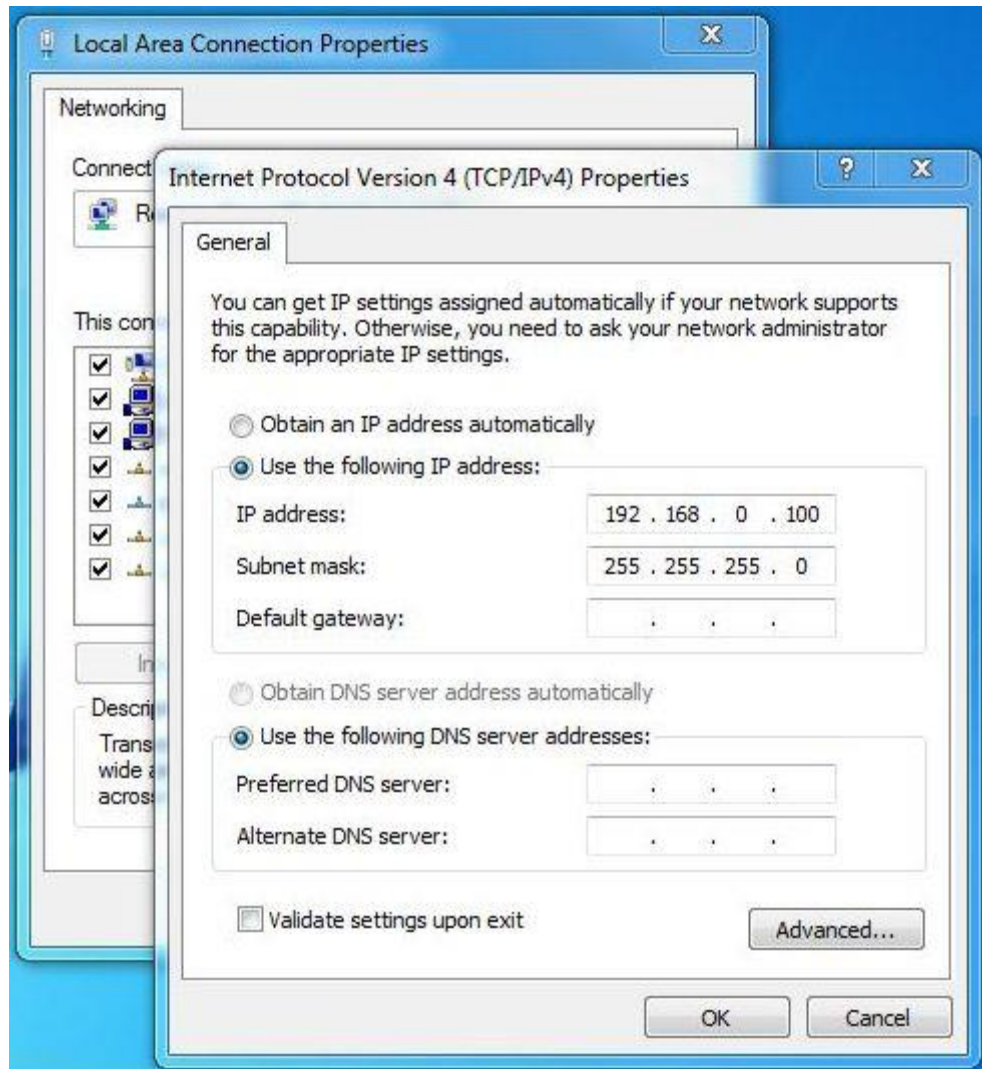
Physical re-calibration services are available from Michigan Scientific. Re-calibration is unnecessary if the zero balance remains consistent and the shunt calibration produces the voltages given on the calibration sheets.

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.



http://192.168.0.28/ CT2

CT2 Configuration



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

CT2 Serial Number:
276

Wheel Force Transducer Information

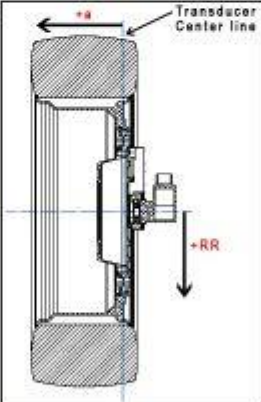
Model:	LW12.8
Serial Number:	355
Position:	RF
Calibration Date:	Thu Mar 26 2015

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

Full Scale Rotational Velocity:
 1000 RPM
 2000 RPM
 3000 RPM
 Replace Velocity/Position Output with Sine/Cosine

Analog Output Range:
 +/- 10V +/- 5V
 +/- 2.5V 0 to 5V

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

Measurement Origin	Definition of "a" & "RR"
<input type="radio"/> Center of WFT <input checked="" type="radio"/> User Defined with Respect to Center of WFT Units of Entered Values: <input checked="" type="radio"/> Inches <input type="radio"/> Millimeters Measurement Center Offset along Y-Axis (a): <input type="text" value="0.00"/> (-43 to 43 inches) Rolling Radius (RR): <input type="text" value="0.00"/> (0 to 157 inches)	

For Simulator Use Only

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

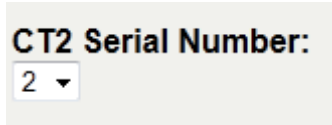
If the Transducer is not mounted such that the Z+ Axis is vertical pointing towards the ground, then determine the mounting angle and enter it below. To determine the mounting angle imagine that Z+ starts pointing towards the ground and the wheels rotate so that the vehicle starts to move forward. Enter 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.

Mounting Angle Degrees

Update All Active CT2 Boxes with these Settings

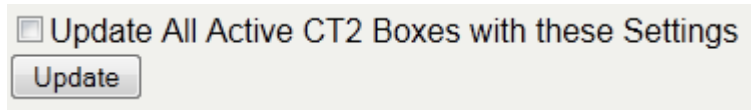
CT2 Serial Number

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 to 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

The CT2 defaults to Vehicle coordinates at start up, which for most on-the-road testing, is desired. However, when used on a simulator, the CT2 should be in wheel coordinates. (For an explanation of wheel and Vehicle coordinates, see page xx.) If the CT2 powers up in Vehicle coordinates when used on a simulator, the operator must remember to change the coordinates setting to Wheel coordinates each time power is cycled. This option allows the user to change the default to Wheel coordinates at startup so that it is not necessary to make this change each time the CT2 is powered up.



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 velocity and position signals with Sine and Cosine signals (applies to both Analog & CAN outputs).

Full Scale Rotational Velocity:

- 1000 RPM
- 2000 RPM
- 3000 RPM
- Replace CAN Velocity/Position Output with Sine/Cosine

Analog Output Ranges

For the Analog outputs, the full scale output voltage can be set as shown below to accommodate data acquisitions systems that cannot accept ± 10 volt signals. The CT2 changes the output sensitivity to use the full scale range.

Analog Output Range:

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

Note: The Analog outputs use a 16 bit DAC. When a different voltage range 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 contains the encoder and encoder electronics so it is the angle reference for

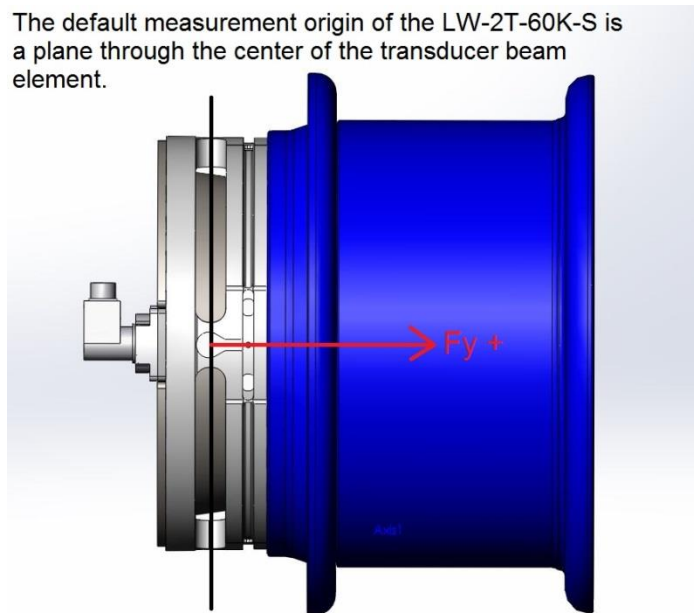
the coordinate transformation calculations. If the slip ring cannot be mounted vertically, measure the angle that the slip ring body is from vertical in the clockwise direction. Enter that number into the box shown below. The CT2 uses this information to correct the reference angle when performing the coordinate transformation.

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

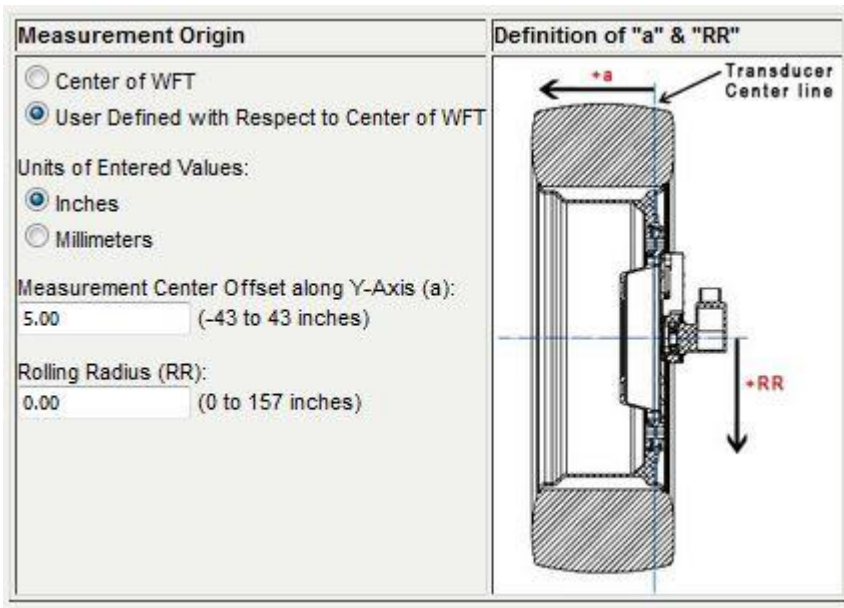
Caution! When using a stator restraint rod that connects to the vehicle fender (or some other part that does not move with the wheel) be sure that the slip ring body does not rotate in relation to the vehicle body during the entire suspension travel. If a stator restraint rod is connected to the fender, it must be vertical to prevent any angle change.

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).



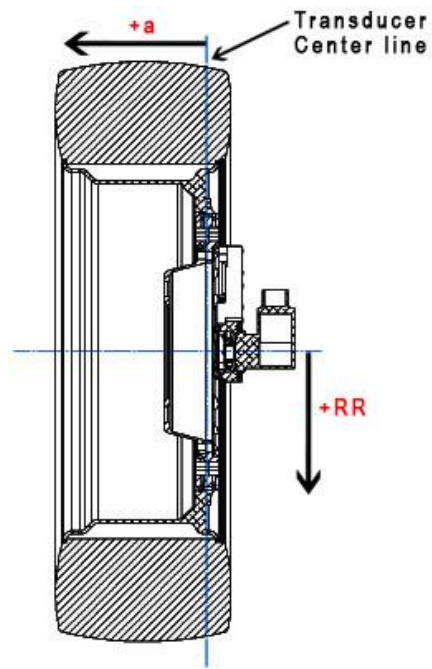
In some situations, the user may wish to change the location of the Measurement Origin (i.e.; resolve forces and moments to the vehicle hub). This option allows the user to input "a" (The length of the lever arm along the Y-axis from the transducer mid-plane to the desired location) and "RR" (The rolling radius or the length of lever arm along the Z-axis). Positive "a" is defined as the distance the measurement origin is to be moved towards the vehicle centerline. Positive "RR" is defined as the distance the measurement origin is to be moved down towards the ground, along the positive Z-axis in Vehicle Coordinates. "RR" can only be entered as a positive value. The default setting for the measurement origin is the WFT center.



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.



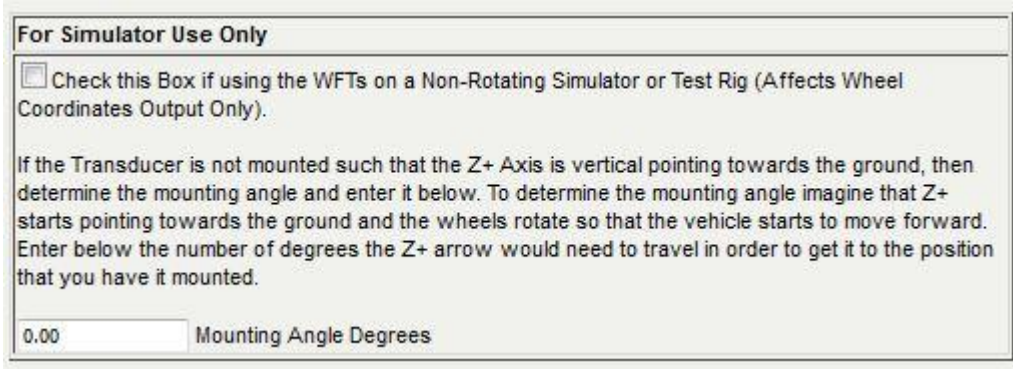
Note: Only the Mx and Mz channels are affected by these calculations. Ignoring force due to acceleration and mass of the WFT system, the forces do not change when the

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.

Using WFTs on a Simulator

When using the WFT on a simulator or Test Rig (e.g.. MTS329) the following should be done:

- Attempt to mount the Transducer so that the Z+ arrow points vertically towards the ground.
- In the CT2 webpage, check the box under the heading “For Simulator Use Only”.



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

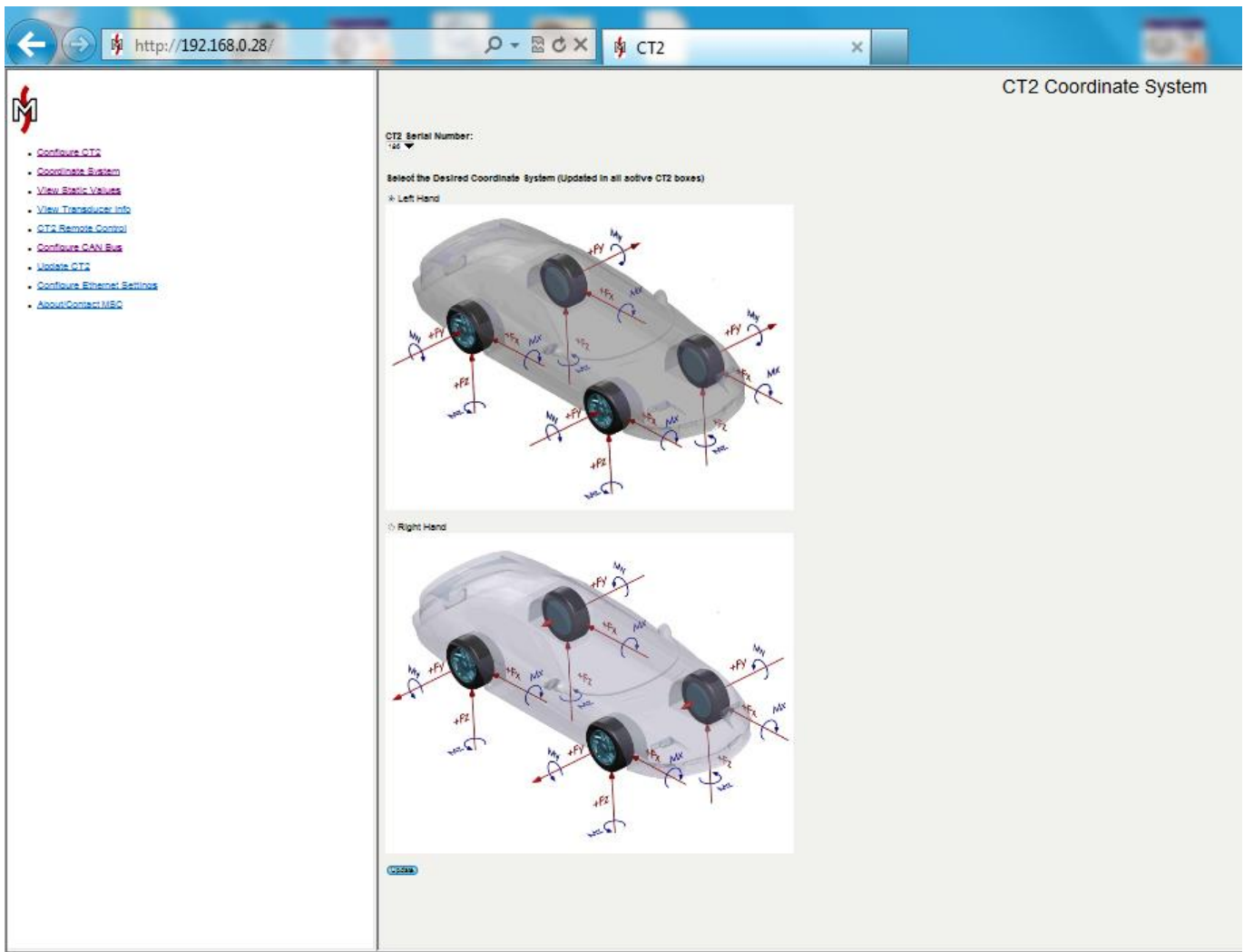
- If the Transducer cannot be mounted with the Z+ arrow pointing vertically towards the ground, enter the angle that the transducer is from vertical as defined in the following manner. "Imagine that the Z+ arrow starts pointing towards the ground and the wheels rotate so the vehicle starts to move forward. How many degrees would the Z+ arrow travel to get it to the position that you have it mounted “. Enter that angle.
- Operate CT2 in Wheel Coordinates.
- Replace Slip Ring and Slip Ring Cable with a Simulator Cable. This will preserve the life of the slip ring.
- A Zero in Wheel Coordinates will null out all the channels (zeroing out the static weight of the vehicle), so there are two 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 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.

2. 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 Analog signal outputs is negligible. (0.12 milliseconds)
- 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.

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 54.



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:
Network Mask:
Network Gateway:

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.

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.

CT2 192.168.0.28

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:
 2 ▾

Report Date: Tue Jul 05 2011
Report Time: 10:46:18 AM

Wheel Force Transducer Information:
 Model: LW12.8
 Serial Number: 48
 Position: RF
 Calibration Date: Sat Jun 18 2011

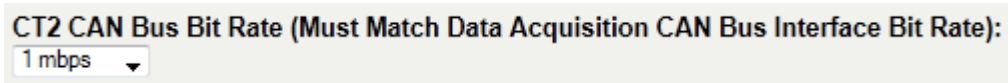
	X Force	Y Force	Z Force
Shunt Cal Value (N)	3174	2887	3159
Factory Scale Factor	0.974	0.924	0.976
Field Scale Factor	0.974	0.924	0.976
Scale Factor % Difference	0.000	0.000	0.000
Analog Full Scale Output (+/- N)	10000	10000	10000
Transducer Offset (Volts)	0.006	0.006	0.007
Transducer Offset (N)	6.4	5.8	6.7

	X Moment	Y Moment	Z Moment
Shunt Cal Value (Nm)	3032	2969	3139
Factory Scale Factor	0.935	0.945	0.971
Field Scale Factor	0.935	0.945	0.971
Scale Factor % Difference	0.000	0.000	0.000
Analog Full Scale Output (+/- Nm)	10000	10000	10000
Transducer Offset (Volts)	0.006	0.006	0.008
Transducer Offset (Nm)	6.4	6.4	7.6

Configuration Settings:
 Full Scale Rotational Velocity: 2000 RPM
 Slip Ring/Encoder Stator Offset Angle: 0.00 Degrees Clockwise from Vertical

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. The CT2 CAN bus interface bit rate must be set to match the CAN bus interface bit rate of your data acquisition system. If they do not match then CT2 data will not be recognized by the data acquisition system. The CAN bus bit rate directly affects the number of samples per second that the CT2 can place on the CAN bus as well as the number of possible error retransmissions if an error occurs with a CAN message. Clicking update will update this setting for all active CT2 boxes that are stacked together.



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.

Another factor that affects the number of samples per second that can be output on the CAN bus is the number of CT2 boxes per CAN bus interface on your data acquisition system. The charts below gives some recommended guidelines as to the maximum CT2 CAN output rates that you should use based on how many CT2 boxes are connected to each CAN bus interface on your data acquisition and if you are outputting the accelerometer outputs on the CAN Bus. The chart assumes a CAN bit rate of 1 Mbps and that no other devices are on the CAN bus. The chart on the left shows the maximum output rates when not outputting accelerometer signals and the chart in the right shows the maximum output rates when outputting accelerometer signals.

	Recommended Maximum CT2 CAN Output Rates		With Accelerometers		
	Sample Output Rate (Samples/Sec)	# of Possible Error Retrans.	# of CT2 Boxes per CAN Bus @ 1 Mbps	Sample Output Rate (Samples / Sec)	# of Possible Error Retrans.
1	2,048	1	1	1,750	1
2	1,250	1	2	1,024	1
4	650	2	4	550	2

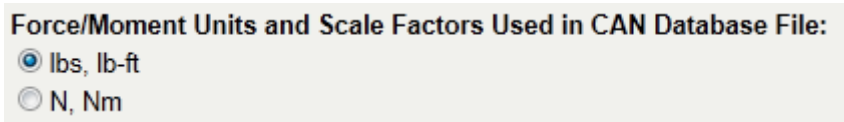
Selecting the check box below will add accelerometer outputs to the CAN Bus. Outputting of the accelerometers is optional because it reduces the Maximum Output rates. Clicking update will update this setting for all active CT2 boxes that are stacked together.



The CAN Bus data output rate can be adjusted between 250 to 2500 samples per second. A decimal place is allowed (e.g. 409.6 samples/second). Note: You should verify that your data acquisition is capable of sampling CAN data at your desired CT2 digital data output rate. Clicking update will update this setting for all active CT2 boxes that are stacked together. The approximate through delay from the analog input to the start of frame bit of the 1st message on the CAN bus is displayed in milliseconds for the entered data output rate.



A CAN database (.dbc) file that can be imported by many data acquisition systems is dynamically created for all active CT2 boxes that are stacked together. This file describes which CAN message id and corresponding data bytes go with each data channel/wheel position. It also describes each channel's name, units and scale factors. The engineering units and scale factors used in the .dbc file can be selected as Newtons, Newton-Meters (N,Nm) or Pounds, Pound-Feet (lbs, lb-ft).



Note: If alternate unit text is desired it can easily be edited by changing the unit text between quotes in the .dbc file.

There are 2 CAN messages output per sample for each CT2 box. These messages must have a unique 11-bit message id to be recognized by the data acquisition system. Here you can change these CAN message ids for each active CT2 box that are stacked together. In the table you will find the CT2 box sn, pos and data channels that correspond with each CAN message id.

CAN Bus Termination

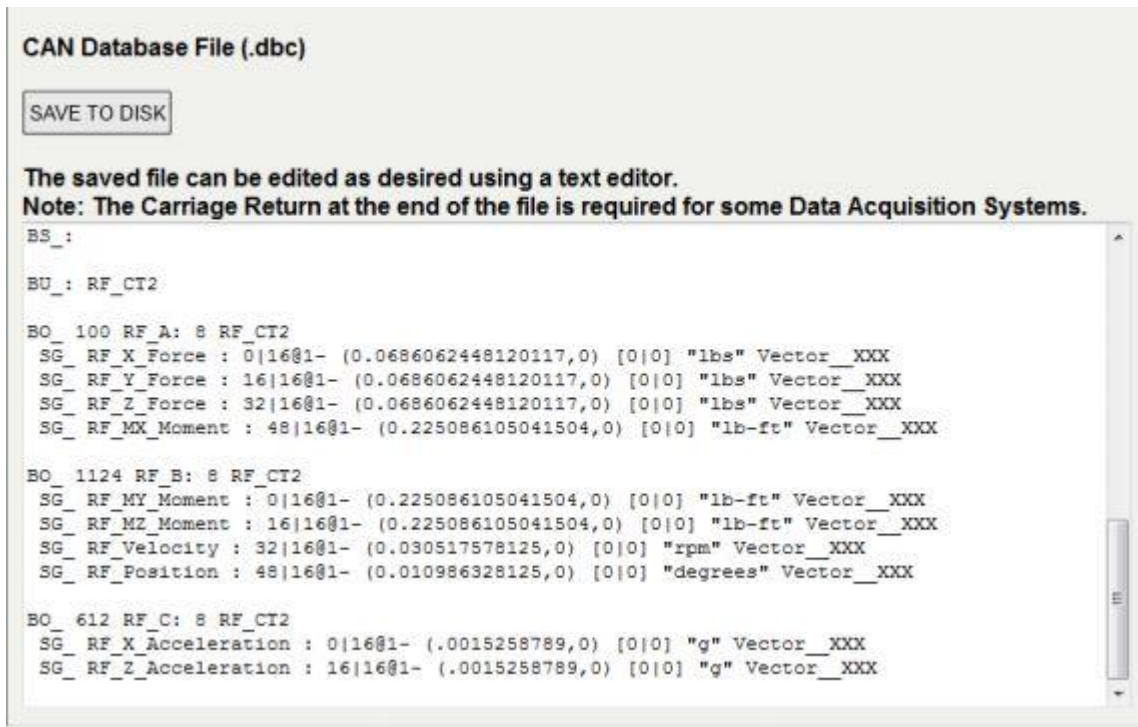
Also in the table, you can set whether 120 ohm CAN bus termination is supplied per each active CT2 box by checking the CAN Bus Termination Box. Every CAN bus must have 120 ohm end-to-end termination. For 1 CT2 box connected to 1 data acquisition CAN interface, both the CT2 box and the data acquisition 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
0xNA	NA	LF	FX, FY, FZ, MX	NA
0xNA	NA	LF	MY, MZ, Velocity, Position	
0x 30	2	RF	FX, FY, FZ, MX	<input checked="" type="checkbox"/>
0x 40	2	RF	MY, MZ, Velocity, Position	
0xNA	NA	LM	FX, FY, FZ, MX	NA
0xNA	NA	LM	MY, MZ, Velocity, Position	
0xNA	NA	RM	FX, FY, FZ, MX	NA
0xNA	NA	RM	MY, MZ, Velocity, Position	
0xNA	NA	LR	FX, FY, FZ, MX	NA
0xNA	NA	LR	MY, MZ, Velocity, Position	
0xNA	NA	RR	FX, FY, FZ, MX	NA
0xNA	NA	RR	MY, MZ, Velocity, Position	

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

The .dbc file is located in the text box at the bottom of the “CT2 CAN Bus Configuration” page. To use the file click the SAVE TO DISK icon, then select the desired file location and file name. Make sure that the file extension is .dbc before you save.



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 calibration	hold positive shunt	mode	bridge	coords	

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.

Transducer Offset Check

It is recommended that the customer keep track of the transducer offset over time. If the offsets for each channel remain consistent with the factory offset listed on the calibration sheet, re-calibration is not necessary.

- Remove hub and wheel adapters. Hub and Wheel adapters can cause a small shift in transducer offset when they are bolted up. This is normal and the transducer will return to its original offset once they are removed.
- 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.

Cross-Axis Sensitivity

The cross-axis sensitivity for each wheel force transducer was measured in a rigid laboratory test fixture. These numbers are recorded in the smart transducer where the CT2 uses them to correct any errors due to linear cross-axis sensitivity.

Insulation Check

Insulation resistance of the wheel load transducer bridge circuits to the metal should be checked occasionally or if malfunction is suspected. The insulation resistance should be greater than 1000 M-ohms. Lower insulation resistance values may result from contamination of the connectors or breakdown of the strain gage insulation. If care is taken to clean the connector area and low values persist the transducer should be returned to Michigan Scientific for correction and re-calibration. The pin-out is listed below.

Wheel Force Transducer-to-Amplifier Connector Pin-Out	
13 pin military	
Pin Numbers	Function
1	X Power +
2	X Signal +
3	X Signal -
4	X Power -
5	Y Power +
6	Y Signal +
7	Y Signal -
8	Y Power -
9	Z Power +
10	Z Signal +
11	Z Signal -
12	Z Power -
13	Shield

There are two transducer-to-amplifier connectors. One is used for the force channels and the other for moments. These are labeled on the front of the transducer.

Weatherproofing

All connectors should be covered with fusion tape to keep water and dust out of the connectors. The connectors are designed to be weatherproof but the tape provides some extra protection against dirt and dust.

Wheel Offset Considerations

Wheel offset from the centerline of the tire to the centerline of the transducer produces a moment about the vehicle X-axis due to the vertical load. When considering the load rating of the transducer, this moment is added to the moment produced by side loading at the tire patch.

Rotational Restraints

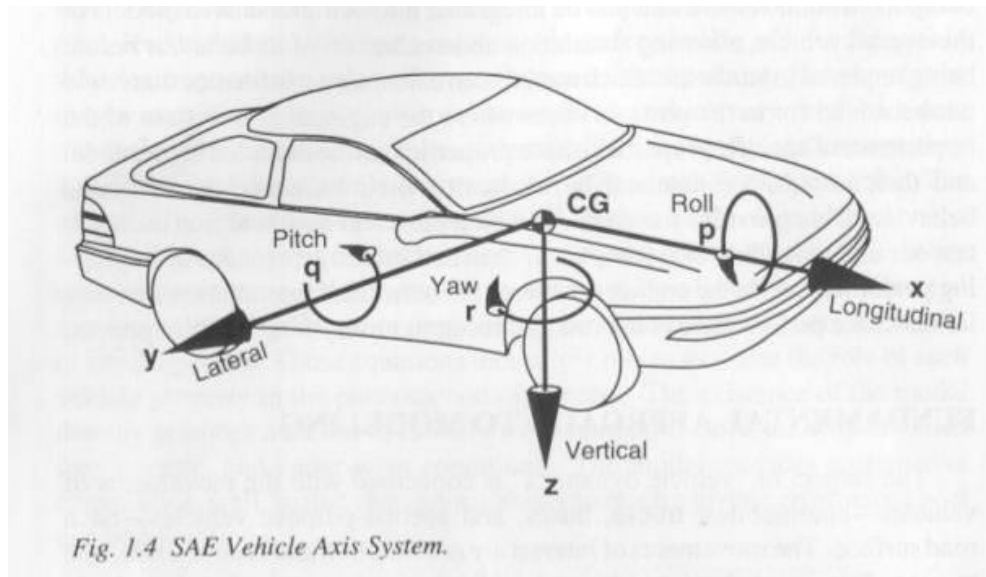
The preferred method of providing a rotational restraint of the slip ring on a front wheel is by means of a strap that goes up and over the tire to the knuckle or backing plate. A simple rod from the slip ring to a loop on the body is usually sufficient for a rear wheel or straight line testing. Simple rotational restraints with magnetic body brackets are provided by Michigan Scientific.

Sampling Frequency

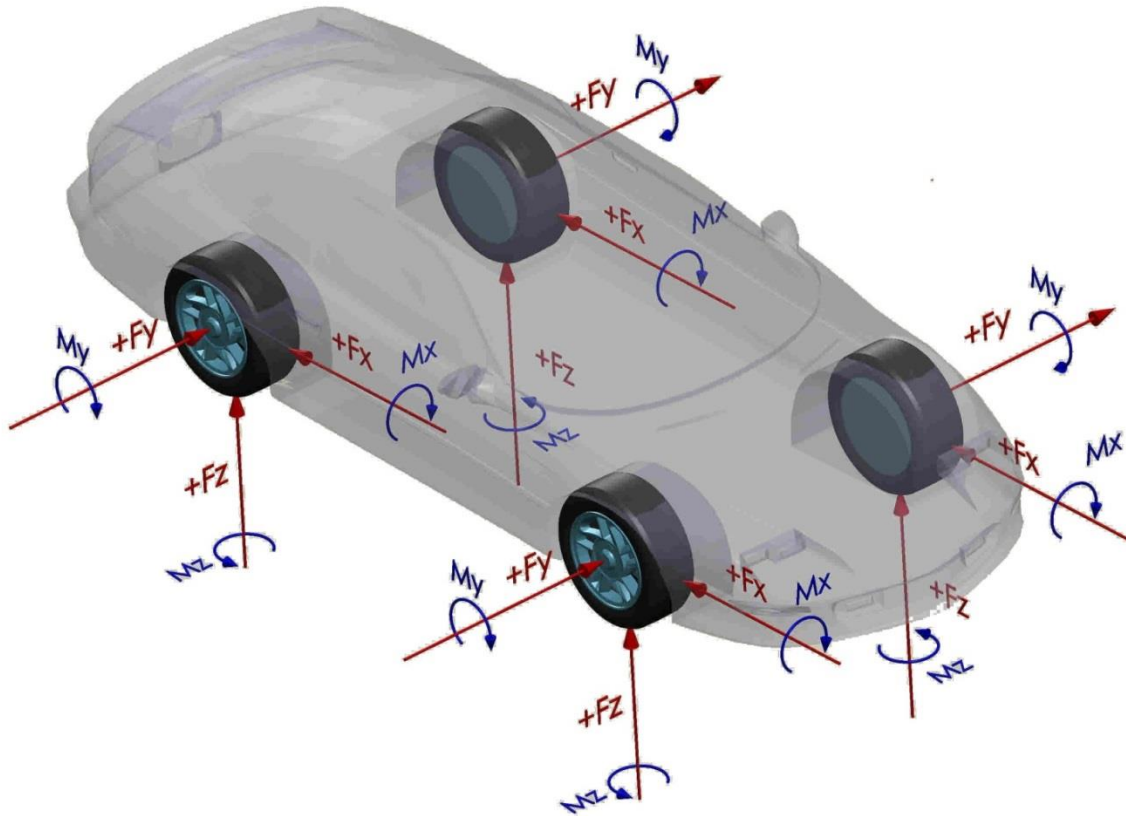
Much of the work done with WFTs is for wheel or chassis load measurement with a frequency of interest below 100 Hz. A sampling rate of 1,000 samples/second and pre-sample filter of 400 Hz. are usually adequate. This gives a sample approximately every 6 inches (15 centimeters) of a wheel traveling at 150 mi/hr (240 km/hr). For impulsive loads such as that encountered when striking a pothole, a sampling rate of up to 4000 samples/second may be necessary to define the peak loads to within a few percent.

Understanding SAE Coordinates (default WFT 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.



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 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:

Fx = Longitudinal Force

Fy = Lateral Force

Fz = Vertical Force

Mx = Roll Moment (Wheel Camber)

My = Pitch Moment (Wheel Torque)

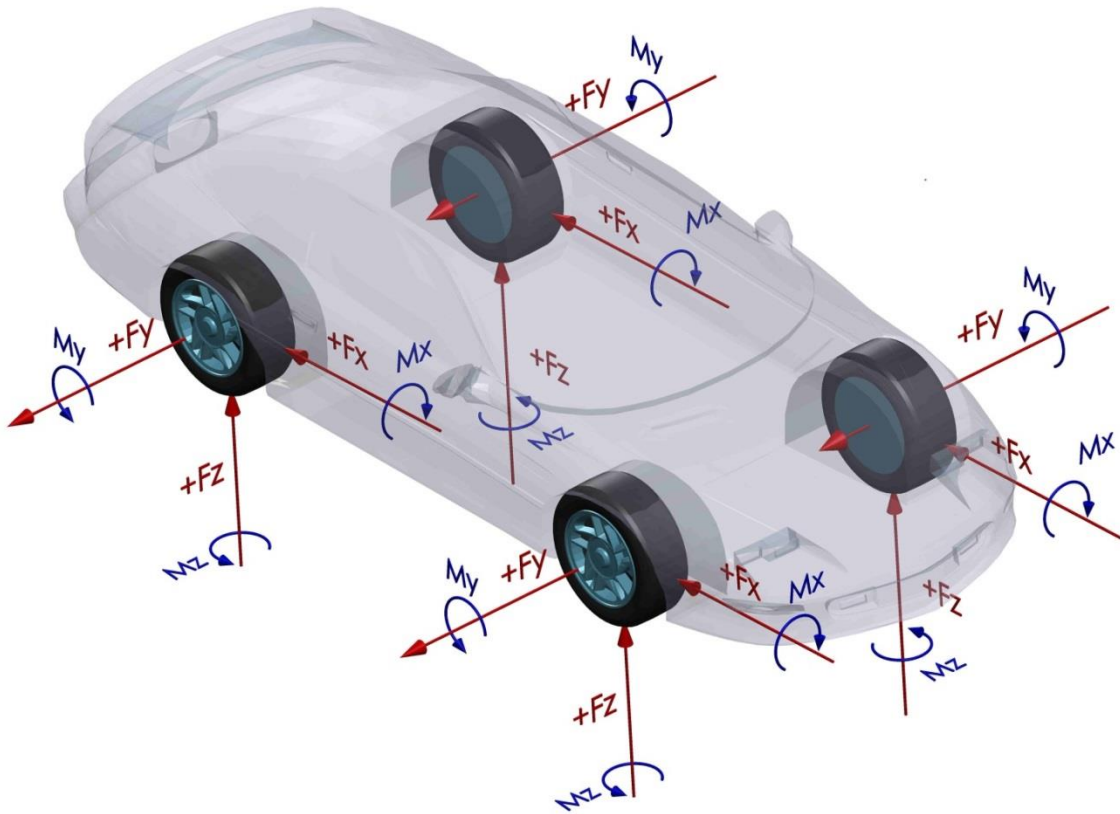
Mz = Yaw Moment (Wheel Steer)

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. 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).



Troubleshooting

Symptom	Possible Causes	Solution
CT2 Does not power up when the power switch is turned on.	Internal overload circuit is tripped. Power cord not connected to power. Power supply polarity is incorrect.	Cycle the power on the CT2. Check that power cord has power supplied to it and try to power up the CT2 again. Check polarity. See appendix. If incorrect, reverse power supply leads and try to power up the CT2 again.
Fault light illuminates at startup	Signal cable not connected properly. Memory chip communication failure.	Check signal cable connections. Cycle power, leave box off for 5 seconds before turning back on. Cycle power, leave box off for 5 seconds before turning back on. Check for grounding loops and ensure proper CT2 grounding.
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.
After zero sequence, Zero light goes out but Fault light illuminates.	Transducer offset greater than 4 volts. The electronics will still zero the channel that has greater than 4 V offset but it alerts the user. This condition can cause the system output to saturate before it reaches full scale. The Fault light will go out next time the power is cycled.	With wheel off of the ground, change CT2 to Setup mode and check output voltages. Confirm which channel has an offset greater than 4 V. Unbolt the wheel & hub adapter. If offset goes away, check adapters for damage. If offset does not go away, send transducer in to Michigan Scientific for Checkout and repair.

Symptom	Possible Causes	Solution
Shunt light does not go out and fault light illuminates after a shunt sequence.	Force input to the transducer during shunt sequence causes out of tolerance shunt. CT2 failed to record data in memory chip. Transducer is out of tolerance.	Jack up vehicle, cycle power, and repeat the shunt sequence. Check the cable connections, cycle power, and repeat the shunt sequence. Send the transducer in for checkout and calibration.
Data has once-per-revolution wave form.	The zero is not correct. The tire can have stiffness variations, which will appear as once-per-revolution variations. This is a real force. Wheel adapter can be bent or out of tolerance. The force is real.	Perform zero procedure. If force variation is not acceptable, replace the tire. If force variations are not acceptable, replace the wheel adapter.
Data has twice-per-revolution waveform.	The sensitivities are out of tolerance due to incorrect or corrupted sensitivity values. One of the strain gage bridges has failed.	Perform the shunt sequence. It is important that no dynamic forces are imposed on the transducer at this time. These forces can come from movement in the vehicle. For best accuracy, lift the wheel off the ground. Check the outputs during the shunt sequence and check the zero data when the CT2 is in setup mode. If the shunt value is not correct or the zero has shifted, send transducer in for checkout and repair.
Fx, Fz, Mx, and Mz channels look like a sin waves when wheel is turning	CT2 is set to wheel coordinates. CT2 is in setup mode.	Check status of lights on front panel. If the Wheel Coordinates light is illuminated, press the Coordinates button on top to change back to vehicle coordinates. Check outputs. If the Setup Mode Light is illuminated, press the Mode button on top to change back to run mode.

Symptom	Possible Causes	Solution
Channels, which should have no load, have an offset even after the zero procedure is performed.	<p>CT2 is in Set-up mode</p> <p>Data channels have error due to rolling zero procedure</p> <p>Slip Ring is not oriented properly.</p> <p>Incorrect zero, direction of wheel rotation was changed during the zero procedure.</p> <p>External forces were imposed during the zero procedure on the hoist.</p> <p>Incorrect zero, on-the-road zero was performed on a rough surface.</p> <p>Data acquisition system has some offset.</p> <p>CT2 electronics are damaged.</p> <p>Offsets are too large for the CT2 to zero them. Damage to transducer.</p>	<p>Switch CT2 to RUN mode</p> <p>If the rolling zero procedure was performed on the road, there will be real forces that will be zeroed out. For best accuracy, perform the zero on the hoist. Further discussion is in the zeroing section of this manual</p> <p>See “Angle reference incorrect” below</p> <p>Be sure that the wheel is turned only in one direction during the zero procedure.</p> <p>When turning the wheels, be sure to apply force only on the amplifier package. This insures that no forces are imposed through the transducer.</p> <p>Redo the zero procedure. For best accuracy, perform the zero on the hoist.</p> <p>Using a volt meter, check the outputs from the CT2. If the outputs are indeed zero, null the offsets in the data acquisition system.</p> <p>Swap the CT2 with another unit, if available, and try to zero it. If the problem goes away, send the CT2 electronics in for checkout and repair</p> <p>The wheel may have been damaged. Remove from the wheel and hub adapters and place on the bench. Change the CT2 to setup mode. Check the offset. If it is out of range, send in for checkout and repair.</p>

Symptom	Possible Causes	Solution
Outputs from CT2 stay zero for all channels even when force is present.	<p>CT2 is not turned on.</p> <p>Encoder has not found an index pulse.</p> <p>The bridge power kill feature is invoked.</p> <p>Signal cable from transducer has been disconnected.</p> <p>Signal Cable from transducer has been damaged.</p> <p>Output cable from the CT2 is disconnected or damaged.</p> <p>The data acquisition cabling is not connected improperly.</p>	<p>Check to see if the CT2 is turned on.</p> <p>The output channels stay at zero until the encoder sees an index pulse. Turn tire at least one complete revolution. Check outputs.</p> <p>Check to see if the bridge power light is on. If it is not, press the Bridge Power button. The light should illuminate.</p> <p>Turn off the CT2 electronics, reconnect the cable and turn the CT2 electronics back on.</p> <p>Inspect cable for damage. A cable diagram is located in the appendix.</p> <p>Check connection and inspect cable for damage</p> <p>Check the output from the CT2 with a volt meter. If the output is correct, check the cabling or data acquisition setup.</p>
The channel offsets change during use.	<p>If off-set is only present in Fy channel, transducer may not have been exercised.</p> <p>A severe event caused some shifting in the bolted joints between the transducer and adapters.</p> <p>A severe event overloaded the transducer.</p>	<p>Exercise transducer by driving car. Perform figure 8 maneuver in both directions and perform two hard brake stops, then re-zero.</p> <p>While it is not common, a severe event could cause some offset in channels. Perform the zero sequence.</p> <p>Check the transducer offsets. Remove the wheel and hub adapters. Change the CT2 to Setup Mode Check the offsets for each channel with a voltmeter. If the offsets have changed, send the transducer in for checkout and possible repair.</p>

Symptom	Possible Causes	Solution
Higher or lower than expected output from one or more channels	<p>The data acquisition system sensitivities are incorrect.</p> <p>Incorrect amplifier package</p> <p>Transducer is damaged.</p> <p>Amplifier package is damaged.</p>	<p>Check data acquisition system. The correct sensitivities are listed on the calibration sheet in the back of this manual.</p> <p>Check that the correct amplifier package is being used with the transducer.</p> <p>Check the transducer offsets and shunt values. Send in for checkout and repair if needed.</p> <p>Send in for checkout and repair if needed</p>
One or more output channels output incorrect polarity.	<p>Right/Left Switch is not in the correct position.</p> <p>Cable to data acquisition is improperly connected.</p> <p>Sensitivity is incorrect in the data acquisition system.</p> <p>Slip Ring is not oriented properly</p> <p>Coordinate System is not as expected</p>	<p>Check to see if switch is correct. Change if needed.</p> <p>Check the voltage from the CT2. If correct, check pin-out for signal cable to the data acquisition system.</p> <p>Check the voltage from the CT2. If correct, check the sensitivities in the data acquisition system.</p> <p>See “Angle reference incorrect” below</p> <p>Check the selected Coordinate System in CT2 webpage</p>
Angle reference incorrect	<p>Slip Ring is not oriented properly</p> <p>Encoder Stator Offset Angle entered incorrectly</p>	<p>Orient the slip ring so that the connector is pointed vertical. The side surfaces of the slip ring should be vertical.</p> <p>Using the CT2 Smart Transducer Config Tool, first confirm that the angle stored in the memory chip is incorrect and then update with the appropriate angle.</p>
Data appears noisy	<p>CT2 chassis ground not connected to vehicle chassis</p>	<p>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.</p> <p>Or</p> <p>Connect the shield of the CT2 power cable to the vehicle chassis.</p>

Appendix 1

Wiring and Shielding

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

FUNCTION	PINOUT	COLOR		PINOUT
+12VDC	1	Blue		A
-12VDC	3	Red		B
CAL Control	4	Yellow		C
Smart Sensor	5	Green		D
ENC +12VDC	18	Pink		E
Ground	19	Gray		F
Data_P	23	White		G
Data_N	24	Brown		H
Overall Shld	Collet/Shell			K


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/Sine Low
14	Velocity/Sine High
15	Position/Cosine Low
16	Position/Cosine High
17	Acceleration X Low
18	Acceleration X High
19	Acceleration Z Low
20	Acceleration Z High

CT2 Power Connector Pin-Out

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

Transducer Calibration Quick Reference Sheet

	MICHIGAN SCIENTIFIC corporation	8500 Ance Road Charlevoix, MI 49720 Phone: (231) 547-5511 Fax: (231) 547-7070 www.michsci.com																																
QUICK REFERENCE SHEET TRANSDUCER CALIBRATION																																		
TRANSDUCER SERIAL NUMBER: <p style="text-align: center; margin: 0;">LW-2T-60K-S- 681</p>	CALIBRATION DATE: <p style="text-align: center; margin: 0;">November 10, 2018</p>																																	
Load Wheel Interface Electronics: Gain and offset adjustments are handled in the Load Wheel Interface Electronics. The interface uses a shunt calibration to calculate an appropriate gain so that the following sensitivities are correct. It is good practice to use the shunt feature to check the sensitivities internally in the Load Wheel Interface.																																		
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QUICK REFERENCE SHEET
TRANSDUCER CALIBRATION

TRANSDUCER SERIAL NUMBER:

LW-2T-60K-S- 682

CALIBRATION DATE:

November 10, 2018

Load Wheel Interface Electronics:

Gain and offset adjustments are handled in the Load Wheel Interface Electronics. The Interface uses a shunt calibration to calculate an appropriate gain so that the following sensitivities are correct. It is good practice to use the shunt feature to check the sensitivities internally in the Load Wheel Interface.

SENSITIVITY:

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SHUNT CALIBRATION (FOR BEST ACCURACY):

Fx: Shunt=	4.716 V*	31,806 lb	141,473 N
Fy: Shunt=	4.085 V*	13,775 lb	61,270 N
Fz: Shunt=	4.704 V*	31,730 lb	141,135 N
Mx: Shunt=	4.317 V*	28,660 lb ft	38,855 N m
My: Shunt=	4.732 V*	31,410 lb ft	42,584 N m
Mz: Shunt=	4.273 V*	28,363 lb ft	38,453 N m

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Speed is updated at each encoder pulse. Speed in mph, or kph, can be calculated if the rolling radius is known.

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