Michigan Scientific Corporation

Wheel Force Transducer System

Model: LW-2T-20K

For Heavy Pickup Trucks, SUVs, & Commercial vehicles

MICHIGAN SCIENTIFIC corporation

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Revision 2.4

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 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-20K
6-Axis Wheel Force Transducer
Stainless Steel

Capacities

Maximum Force Capacity	[Fx, Fz]	20,000 lb	90 kN
	[Fy]	10,000 lb	45 kN
Maximum Torque Capacity	[Mx, Mz]	11,000 lb-ft	15 kN-m
	[My,]	15,000 lb-ft	20 kN-m
Acceleration	[Accel X, Accel Z]	100g	
Maximum Recommended Static		4000 lb.	1800 kg

Full Scale Output (before amplifier)	1mV/V nominal
Transducer	4 arm strain gage bridges
Nonlinearity	Less than 0.5% of full-scale output
Hysteresis	Less than 0.5% of full-scale output
Zero Balance prior to installation	Less than 2% of rated output
Cross Axis Sensitivity after correction	<1% of full-scale
Radial Sensitivity Variation	<1% of radial load
Bridge Resistance	233 to 1400 ohm, axis dependent
Compensated Temperature Range	-40 to 125 C (-40 to 257 F)
Insulation Resistance from Bridge to Case	Exceeds 1000 Mohm
Vehicle Power Input Voltage	10 to 36 VDC

Mass of Components, Typical

Component	lbs	Kg
Wheel Load Transducer	23.4	10.6
Amplifier Package	1.3	0.6
Slip Ring and Encoder	0.5	0.2
CT2 Electronics	2.5	1.1

System Components

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

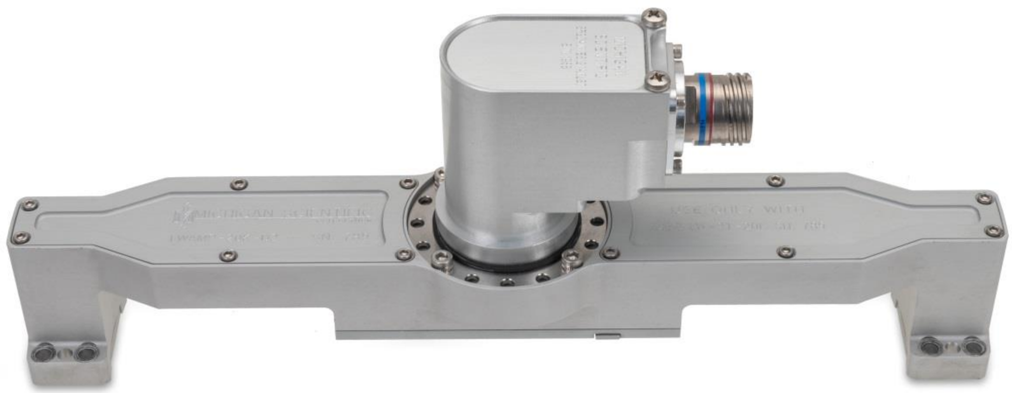
Transducer

Six Axes Wheel Force Transducer

CT2 Electronics

CT2 Electronics. This is the User Interface for WFT System. See page 32 for operating instructions.

Amplifier and Slip Ring



The amplifier provides excitation and amplification for the 6 transducer strain gage bridges. The amplifier package contains internal ±55g (D1 amplifiers) or ±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.

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.

Hub Adapter

The hub adapter mates to the smaller bolt circle of the transducer and is designed to match the offset of the production wheel. If used in conjunction with rim adapter, proper wheel off-set and brake clearance is maintained. Standard hub adapters are machined from solid high strength stainless steel or aluminum.

If you intend to design and manufacture WFT adapters yourselves or have a 3rd party company manufacture them, please follow the Adapter Design Guides in Appendix 2, so boundary conditions are consistent and the WFT provides the most accurate results.

Rim Adapter

Solid Aluminum Rim Adapter from Forging.
Load Rating matches WFT.

Michigan Scientific (MSC) makes three types of rim adapters for the LW-2T-20K WFT. First type is made from solid aluminum forging. These are the strongest adapters and will carry the same recommended static load rating as the Wheel Force Transducer.

The second type is a 2-piece Rim Adapter. This consists of an off the shelf wheel barrel paired with an MSC made adapter flange. This will have a recommended load rating below the WFT maximum, but which is sufficient for many vehicles. While there are many wheel barrel sizes offered, some wheel sizes are not available in this type of adapter.

The third type is a welded steel rim adapter. Because of the welding the recommended static load rating is undetermined.

If you intend to design and manufacture WFT adapters yourselves or have a 3rd party company manufacture them, please follow the Adapter Design Guides in Appendix 2, so boundary conditions are consistent and the WFT provides the most accurate results.

Simulator Adapter

The simulator adapter mates with the outer bolt pattern of the transducer. It mates the transducer to the simulator or test rig loading ring.

If you intend to design and manufacture Simulator adapters yourselves or have a 3rd party company manufacture them, please follow the Adapter Design Guides in Appendix 2, so boundary conditions are consistent and the WFT provides the most accurate results.

Signal Cable

Signal Cable connects from the slip ring to the CT2 Electronics (20ft/6m length).

Simulator Cable

Signal Cable connects from the amplifier to the CT2 Electronics.

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.

Analog Signal Breakout Box

Signal Breakout Box cable (5ft/1.5m length)

Ethernet Cable

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

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 (4ft/1.2m length).

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.
- 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.

- **Note: First install the tire onto the rim adapter. This can be done on a standard tire changer machine.**

Assembly

- Place the hub adapter as shown.

- Set the transducer on the hub adapter as shown.

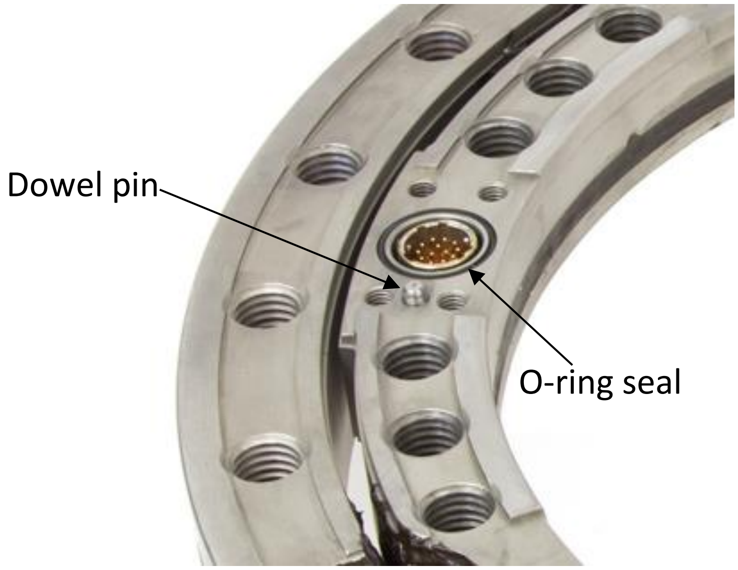
- Install eighteen M14 bolts hand tight with a small amount of anti-seize on the thread as shown above.

- Place the transducer and hub adapter assembly into the wheel adapter as shown below. Be sure to align the valve stem with the notch provided in the transducer.

- Install twelve M14 socket head cap screws with a small amount of anti-seize on the thread. Torque all of the M14 socket head cap screws to 136 N-m (100 lb-ft) using a crisscross pattern.
- Install the assembly on the vehicle. Tighten the lug nuts to the vehicle manufacturer’s specified torque.

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.



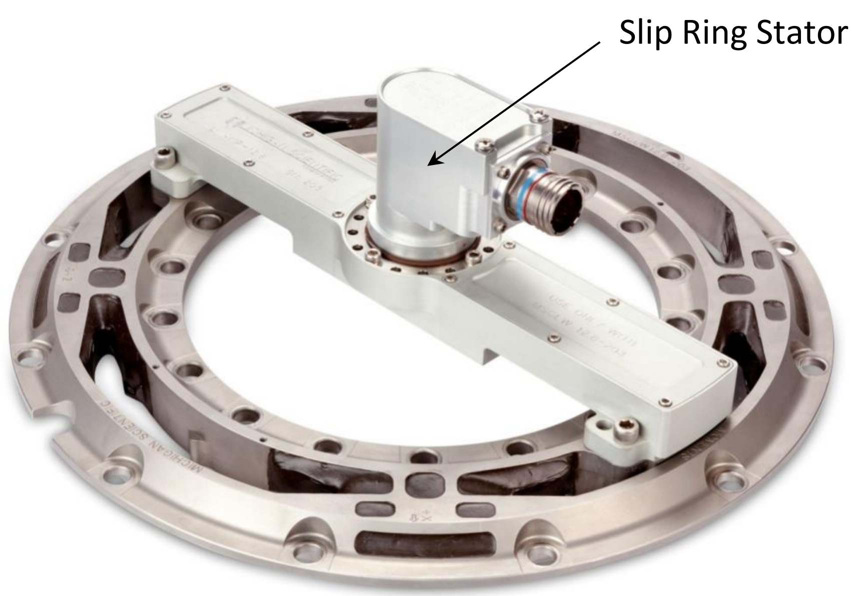
- O-rings are used to provide weatherproof sealing between the amplifier housing and the transducer. Make sure the O-rings are in their proper place before installing the amplifier package.
- Secure the amplifier with M5 stainless steel socket-head screws and tighten to 8 N-m (70 in-lb) torque. Temporary thread locker (e.g. 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 (e.g. Blue Loctite) is recommended on these fasteners. 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 Positon 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 49.

Stator Restraints for Front (Steering) Wheels

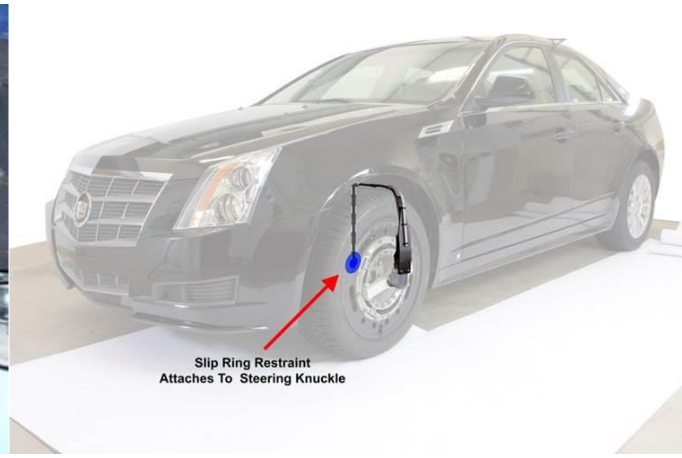
For wheels that will be steered during a test, there are three options for stator restraints. (1) MSC Stator Angle Correction Device (SAC), (2) make a custom over the wheel bracket, or (3) use the post-processing stator angle correction method. One of these methods should be used to prevent an error 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

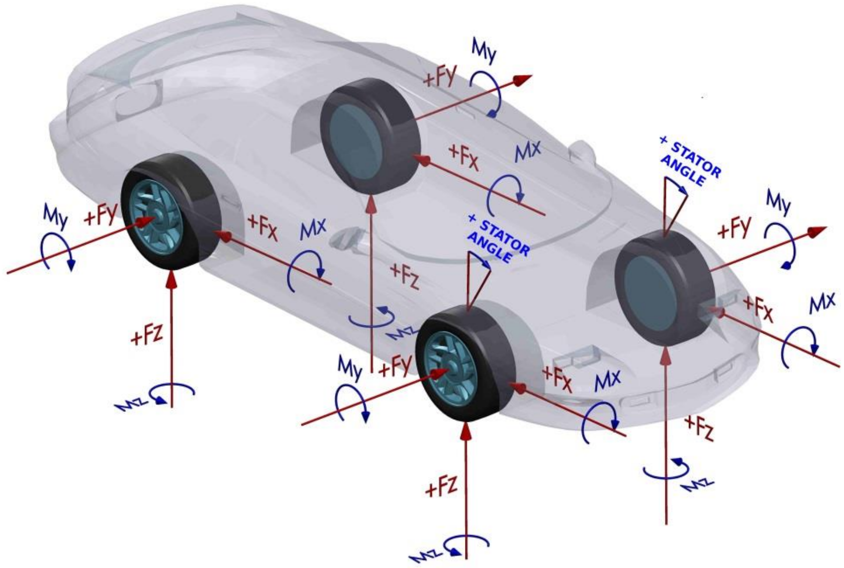
The over the wheel slip ring stator bracket will have to be custom made by the user. The reason for this is that the attachment points for every vehicle are unique, so there is no universal type over the wheel bracket. The over the wheel bracket should be stiff, yet lightweight. Below are a couple of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



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 Fx, Fz, Mx, &Mz are the outputs from the Wheel Force Transducer.

FXcorrected = Fx*cos(stator angle) – Fz*sin(stator angle)

FZcorrected =Fx*sin (stator angle) +Fz*cos(stator angle)

MXcorrected = Mx*cos(stator angle) – Mz*sin(stator angle)

MZcorrected = Mx*sin(stator angle) + Mz*cos(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

- 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.
- If using analog outputs, connect the Analog Signal Break-out Box to the CT2. Then use 8 BNC cables to connect to the data acquisition
- 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.
- Connect the CT2 chassis ground to the vehicle chassis ground. This will prevent 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 (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.

Non-Spinning Assembly Instructions

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

Attempt to mount the Transducer into the Simulator Loading Ring so that the Z+ arrow points vertically towards the ground.

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.

Assembly

- Place the hub adapter as shown.

- Set the transducer on the hub adapter as shown.

- Install eighteen M10-1.5 x 25mm bolts hand tight with a small amount of anti-seize on the thread and under the bolt head as shown above.

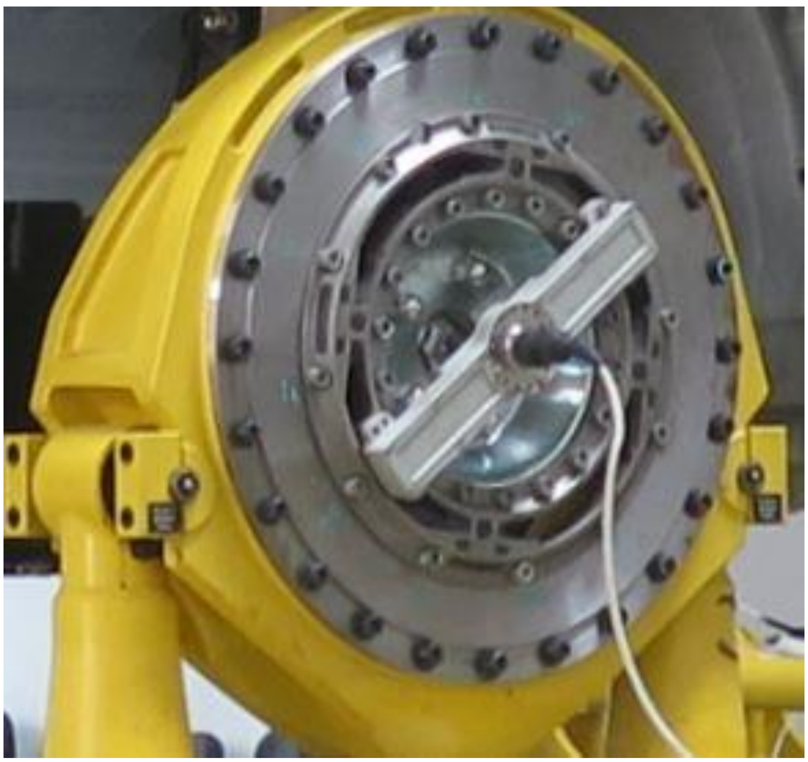
- Place the transducer and hub adapter assembly into the simulator adapter.

- Torque all of the M10 bolts to the following torque using a crisscross pattern using Anti-seize as shown above:

Transducer to Simulator adapter bolts, if solid aluminum or steel/stainless steel: 60 lb-ft (81 N.m)

Transducer to Stainless Steel or Titanium Hub adapter bolts: 60 lb-ft (81 N.m)

- Install twelve M10 x 1.5 x 25mm.
- Install the assembly on Simulator Loading ring as shown below with the **Z+ arrow pointing vertically towards the ground**.



Amplifier Installation

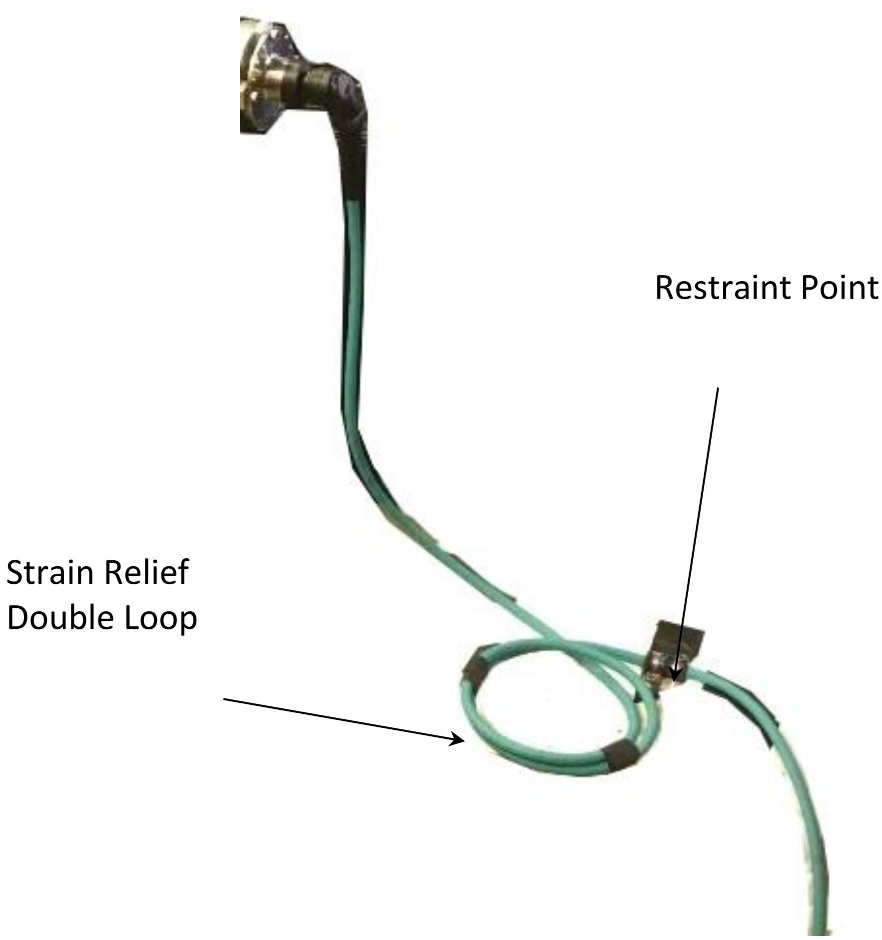
- The amplifier and slip ring assembly is installed after the lug nuts have been tightened.   Note that each amplifier and transducer is a matched pair. This is important; data is stored in the amplifier package for each specific transducer. Also note that there are dowel pins on the transducer to insure proper orientation of the amplifier housing.

- 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 four 1/4-20 inch stainless steel socket-head screws and tighten to 7 N-m (60 lb.in) torque. Temporary thread locker (e.g. Blue Loctite) is recommended on these fasteners.

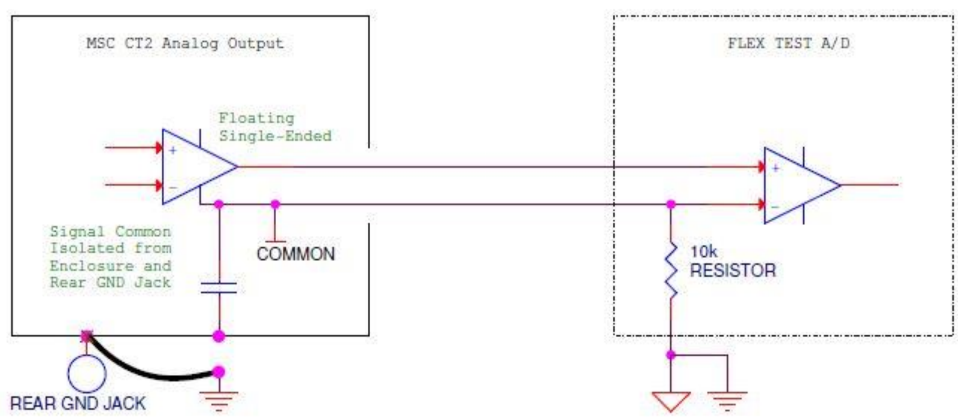
Non Spinning Application - Cable Installation and Strain Relief

- The Simulator cable is attached to the amplifier with 8-32 x 3/8-inch screws. Temporary thread locker (e.g. Blue Loctite) is recommended on these fasteners.
- The Simulator cable 90 degree connector should point down towards the ground. Before the restraint point, the cable should have a double loop strain relief. The two cable loops should be taped together as shown in the picture below. This method has been designed to minimize large movement of the cable and to ensure the long cable life in the Simulator environment.



- Connect the other end of the simulator cable or extension 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 10 to 36 volts. The current draw from the vehicle is less than 1 amp per CT2 at 12 volts and reduces proportionately at higher supply voltages.
- 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.
- If using analog outputs, connect the Analog Signal Break-out Box to the CT2. Then use 8 BNC cables to connect to the data acquisition/controller. CT2 Analog outputs are Floating Single-Ended Output, so one BNC ground should be connected to data acquisition/controller ground to prevent common mode drift. All BNC shells are common in CT2. See diagram below.



- Connect the CT2 chassis ground to lab power ground. 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 lab power ground.
  2. Connect the shield of the CT2 power cable to the lab power ground.
- Turn the power switch on.

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.

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.

When the CT2 is first powered up (in Vehicle Coordinates, Run Mode), all signals will be held at zero until the slip ring rotates and passes the index pulse. 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 should be 180 degrees from the slip ring stator.

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.

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, Sine, and Cosine. 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 ±10V, ±5V, ±2.5V, and 0-5V. Because of that, the number shown is the full scale value for each channel. This number needs to be divided by the full scale voltage to calculate the sensitivity in units/volt. Example - If the full scale analog outputs are set to ±10 Volt, the X Force sensitivity will be 10,000 N/V (100,000 N /10 volts). If the analog outputs are set to 0-5 Volt, X Force the sensitivity will be 40,000 N/Volt with a 2.5 volt offset.

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		
X Force	100,000N	22,480lb
Y Force	50,000N	11,240lb
Z Force	100,000N	22,480lb
X Moment	16,000 N-m	11,801lb-ft
Y Moment	22,000 N-m	16,226lb-ft
Z Moment	16,000 N-m	11,801lb-ft
Velocity	2000 rpm (default)	
Position	0 - 360deg	
Accel X	± 100g	
Accel Z	± 100g	

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 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 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)

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 –40 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, 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 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-axes forces should have very little output. The z-axis force should read the negative weight of the wheel and tire. The y and z-axes 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-axes 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 50 lbs. for x and z-axes 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 resistors 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^{o} 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.

Shunt Hold - 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 lb/lb-ft full scale and N/N-m 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.

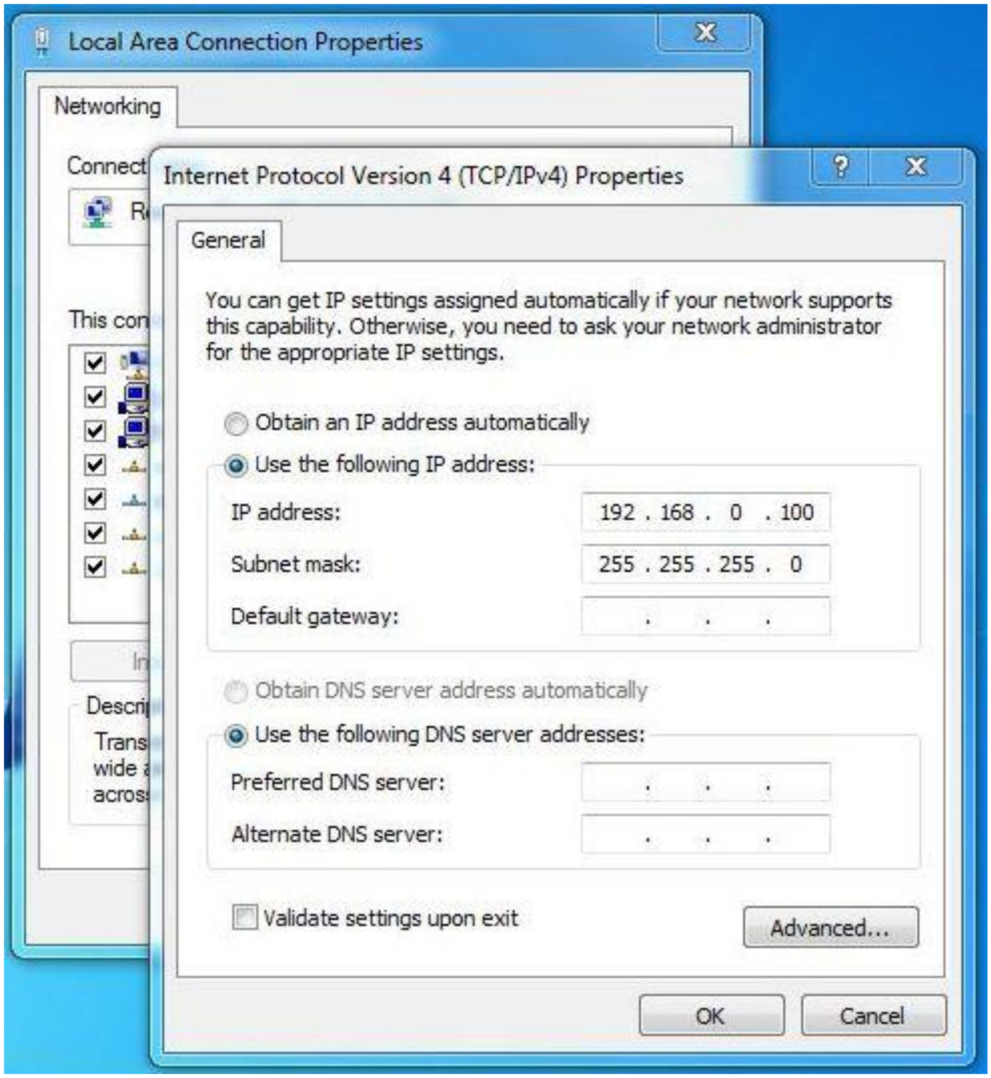
Physical re-calibration services are available from Michigan Scientific. Re-calibration is unnecessary if the zero balance remains consistent and the shunt calibration produces the voltages given on the calibration sheets.

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.

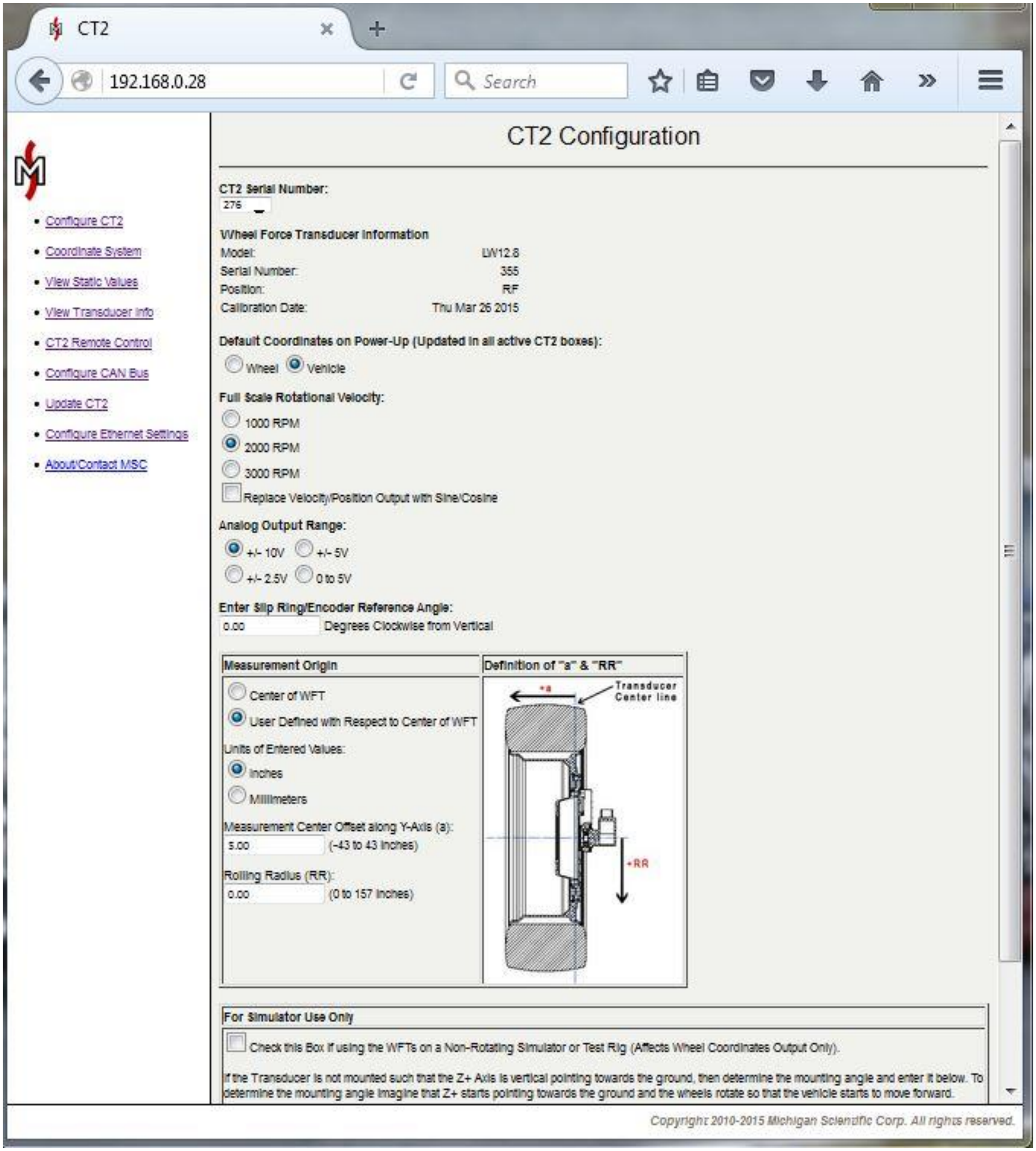
To access the web page.

- 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.



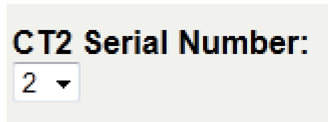
- Pull up a web browser
- Enter the IP address of the CT2 into the browser bar (see below for more information on IP addresses)
- The web page, shown on the following page, will appear in the web browser

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

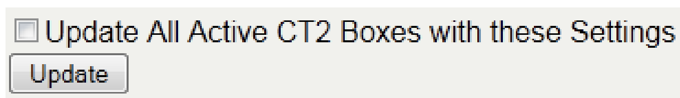

CT2
192.168.0.28
Search
CT2 Configuration
Configure CT2
Coordinate System
View Static Values
View Transducer Info
CT2 Remote Control
Configure CAN Bus
Update CT2
Configure Ethernet Settings
About/Contact MSC
CT2 Serial Number:
276
Wheel Force Transducer Information
Model: LW12.8
Serial Number: 355
Position: 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:
0.00 Degrees Clockwise from Vertical
Measurement Origin
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)
Definition of "a" & "RR"
+a
Transducer Center line
+RR
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.
Copyright 2010-2015 Michigan Scientific Corp. All rights reserved.

CT2 Serial Number

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



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.

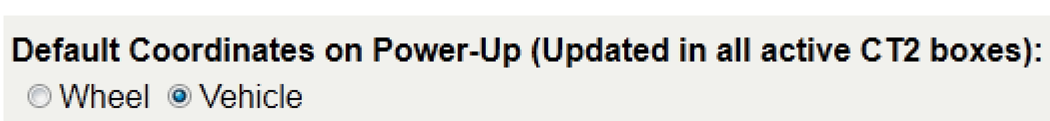


If settings for all the CT2 units are to be the same, the "Update All Active CT2 Boxes with these Settings" button can to be pressed before the "Update" button is pressed. Updating all units at once avoids the need for the user to go through the settings for each serial number individually if settings 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

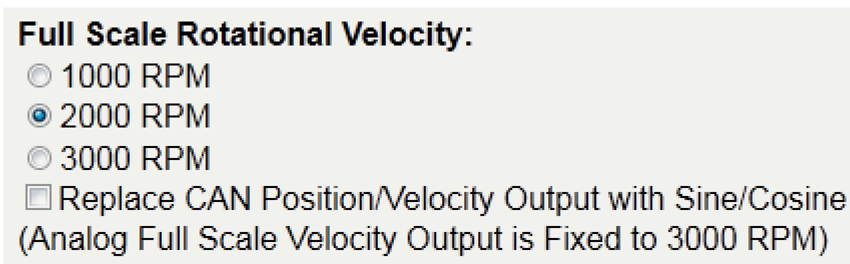
The CT2 defaults to Vehicle coordinates at start up, which for most on-the-road testing, is desired. However, when used on a simulator, the CT2 should be in wheel coordinates. (For an explanation of wheel and Vehicle coordinates, see page xx.) If the CT2 powers up in Vehicle coordinates when used on 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



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.

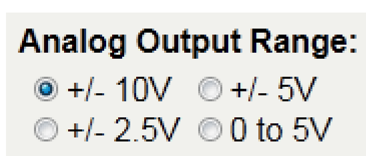
Full Scale Velocity

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 (on the CAN outputs only) with Sine and Cosine signals. If this option is checked, the full scale velocity on the analog channels will be 3,000 rpm.



Analog Output Ranges

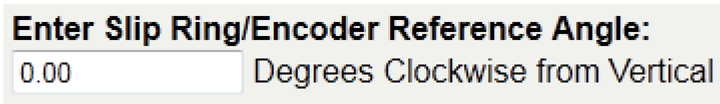
For the Analog outputs, the full scale output voltage can be set as shown below to accommodate data acquisitions systems that cannot accept ±10 volt signals. The CT2 changes the output sensitivity to use the full scale range.



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.

Encoder 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.

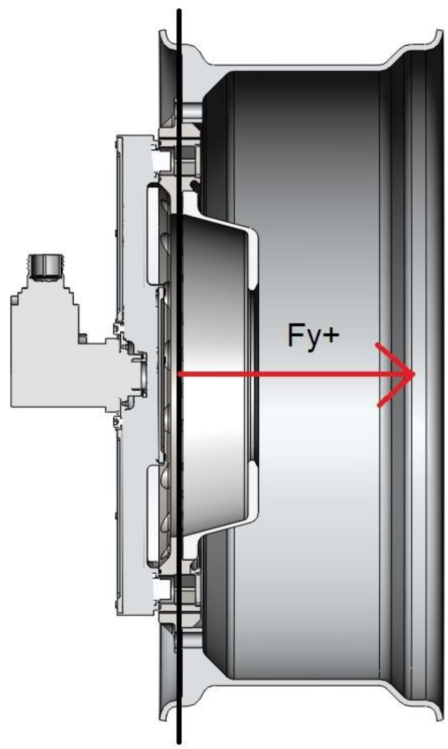


Caution! *When using a stator restraint rod that connects to the vehicle fender (or some other part that does not move with the wheel) be sure that the slip ring body does not rotate in relation to the vehicle body during the entire suspension travel. If a stator restraint rod is connected to the fender,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

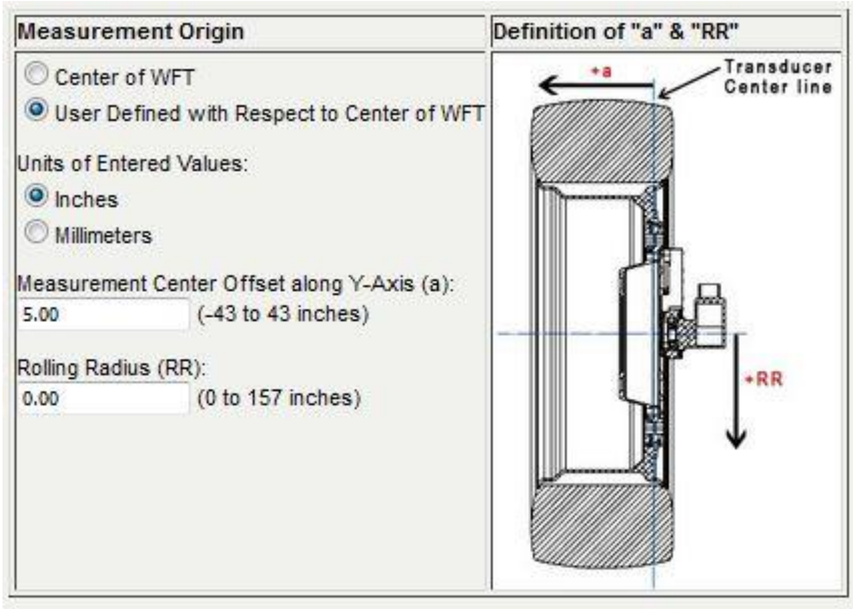
Measurement Origin

The default measurement origin of the LW-2T-20K is the center of rotation and a plane that runs through the center of the transducer. The distance to the measurement origin plane to either edge surface of the transducer is 0.75” (19.05 mm).

Plane through the center of the transducer



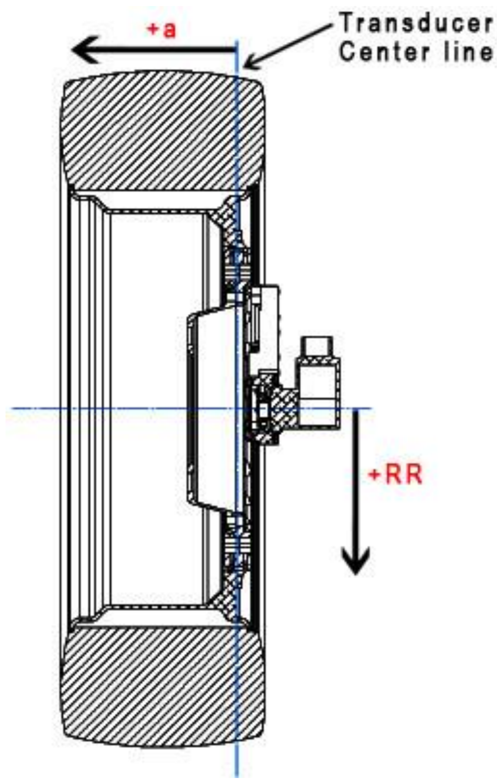
In some situations, the user may wish to change the location of the Measurement Origin (i.e.; resolve forces and moments to the vehicle hub). This option allows the user to input “a” (The length of the lever arm along the Y-axis from the transducer mid-plane to the desired location) and “RR” (The rolling 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.

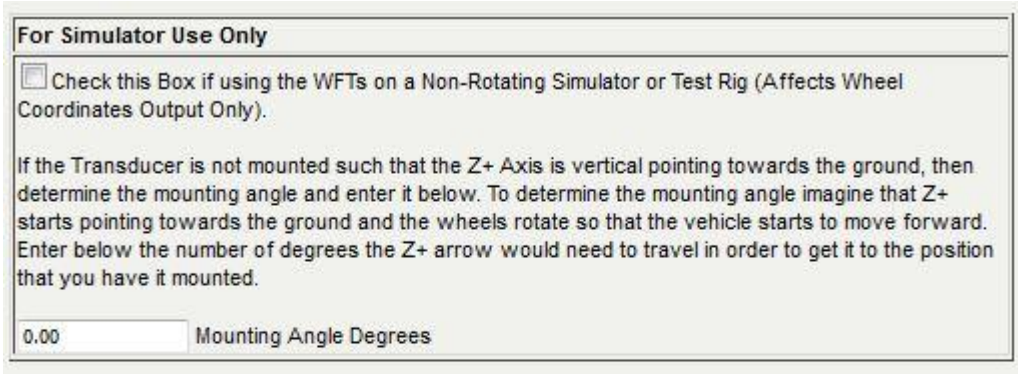


Note: Only the Mx and Mz channels are affected by these calculations. Ignoring force due to acceleration and mass of the WFT system, the forces do not change when the measurement origin is moved. My is not changed because the location of the tire patch can vary enough to introduce large errors into the 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".



- 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:

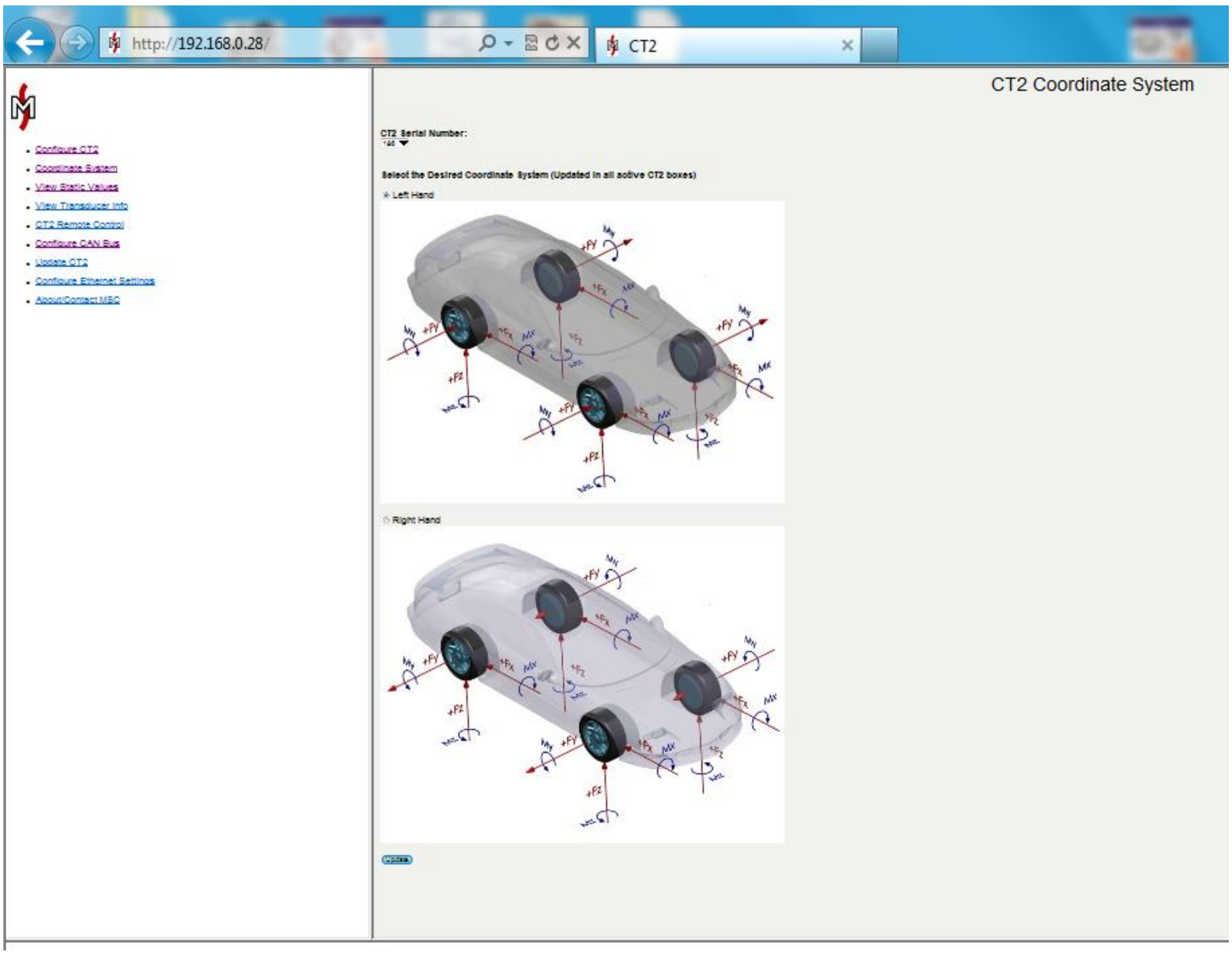
1. Zero the WFTs once car has been attached to the WFTs and simulator. Then add the static weight of the vehicle to WFT data through a calculated channel. The road data would not have to be modified.

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.

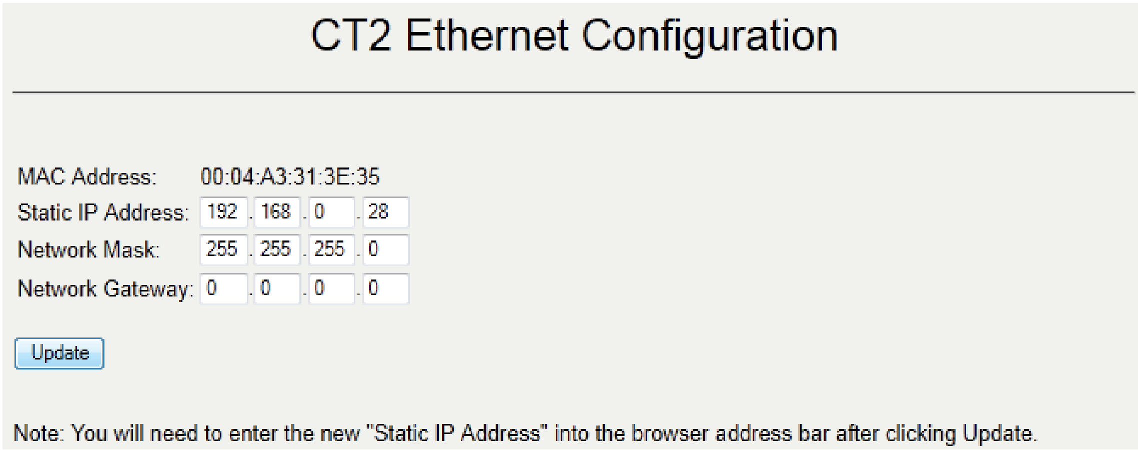
Changing WFT Coordinate System

- 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 in explained further on page 59.

- 

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.



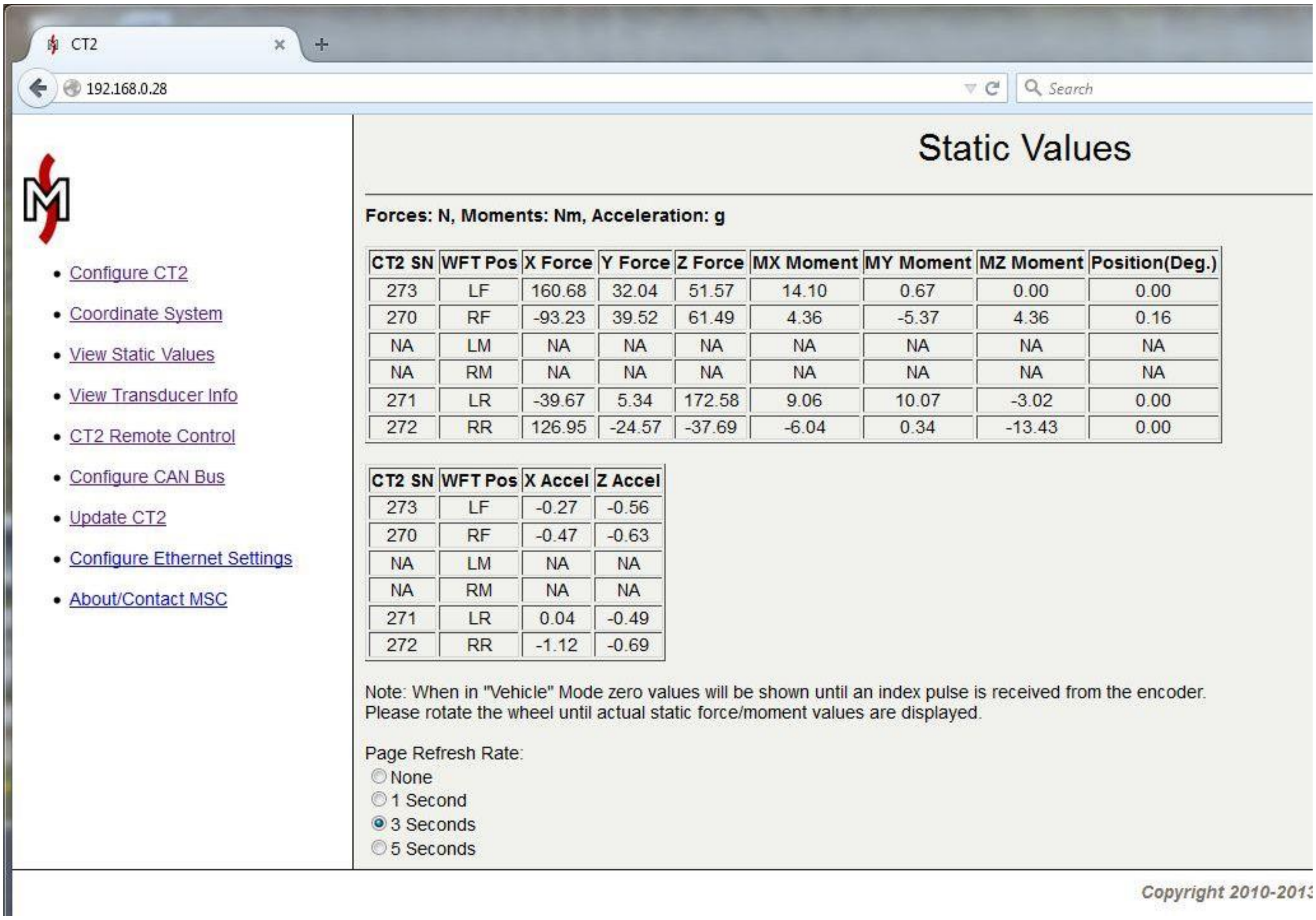
In the event that the Ethernet Configuration was changed away from the default setting and not recorded, it can be reset to the defaults shown above.

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 he static values for all active WFT systems, shown below.



CT2

192.168.0.28

Search

Static Values

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

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

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

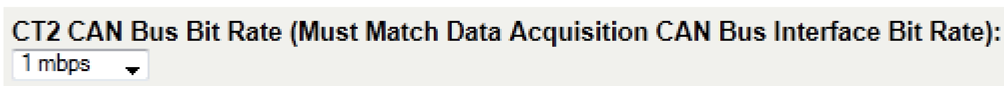
Configuration Settings:

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.

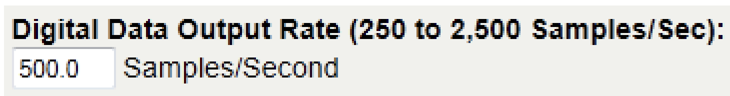


Note: It is necessary that the CT2 box receive a CAN acknowledge bit from the connected data acquisition system. Do not use passive (listen-only) mode on your data acquisition.

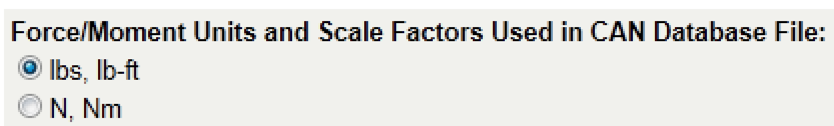
Another factor that affects the number of samples per second that can be output on the CAN bus is the number of CT2 boxes per CAN bus interface on your data acquisition system. The chart below gives some recommended guidelines as to the maximum CT2 CAN output rates that you should use based on how many CT2 boxes are connected to each CAN bus interface on your data acquisition. The chart assumes a CAN bit rate of 1 Mbps and that no other devices are on the CAN bus.

	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

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.

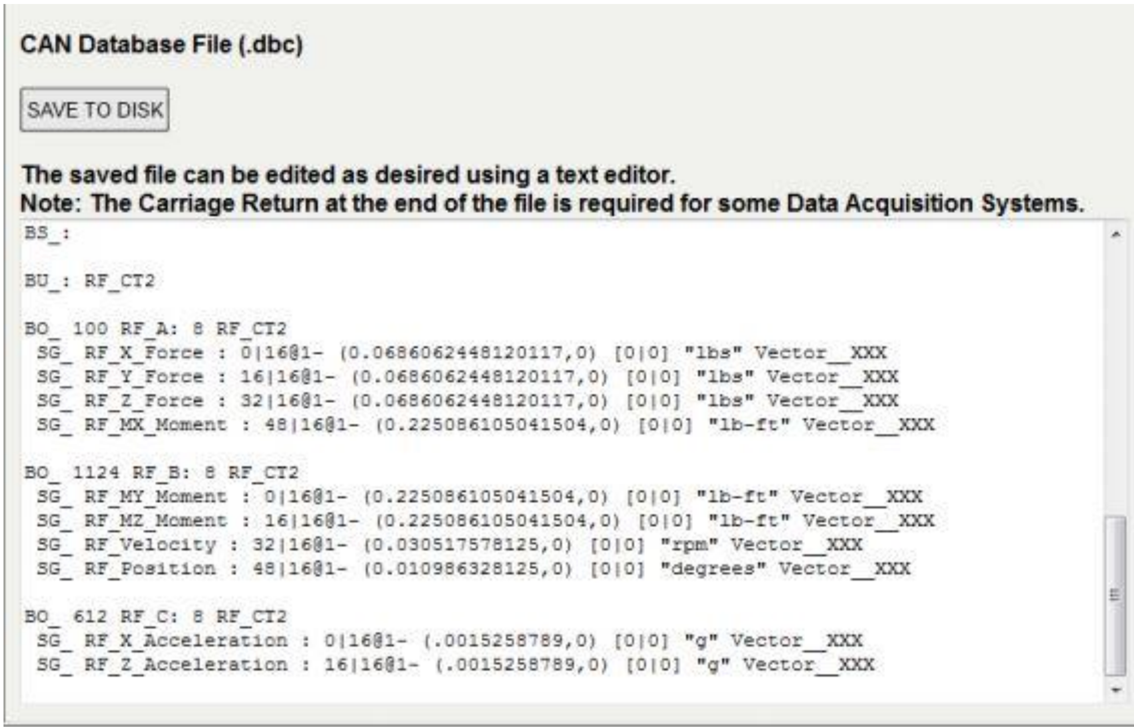
Set 11-bit Message Ids: 0x001 to 0x7FF and CAN Bus Termination:

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	☑
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.

Update

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.



CAN Database File (.dbc)

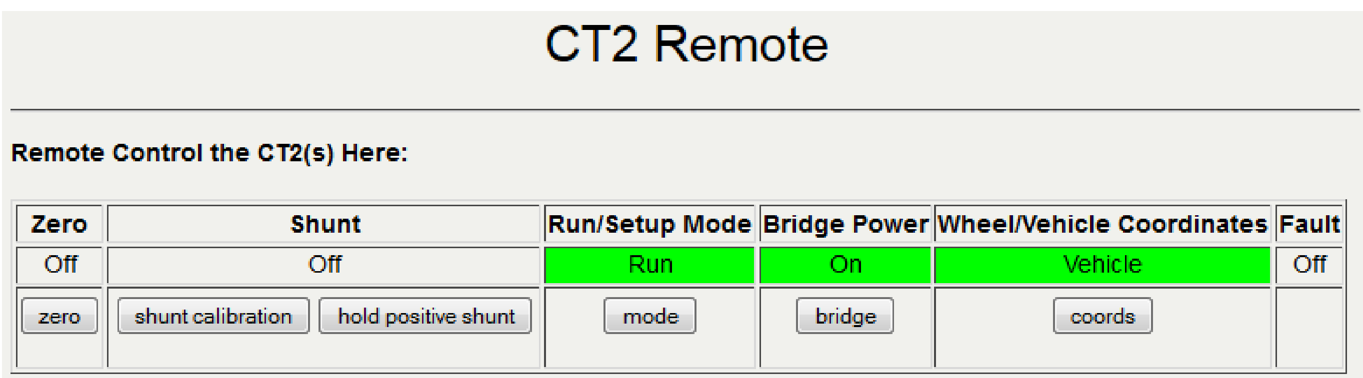
SAVE TO DISK

The saved file can be edited as desired using a text editor.
Note: The Carriage Return at the end of the file is required for some Data Acquisition Systems.

```
BS_:

BU_: RF_CT2

BO_ 100 RF_A: 8 RF_CT2
 SG_ RF_X_Force : 0|16@1- (0.0686062448120117,0) [0|0] "lbs" Vector__XXX
 SG_ RF_Y_Force : 16|16@1- (0.0686062448120117,0) [0|0] "lbs" Vector__XXX
 SG_ RF_Z_Force : 32|16@1- (0.0686062448120117,0) [0|0] "lbs" Vector__XXX
 SG_ RF_MX_Moment : 48|16@1- (0.225086105041504,0) [0|0] "lb-ft" Vector__XXX

BO_ 1124 RF_B: 8 RF_CT2
 SG_ RF_MY_Moment : 0|16@1- (0.225086105041504,0) [0|0] "lb-ft" Vector__XXX
 SG_ RF_MZ_Moment : 16|16@1- (0.225086105041504,0) [0|0] "lb-ft" Vector__XXX
 SG_ RF_Velocity : 32|16@1- (0.030517578125,0) [0|0] "rpm" Vector__XXX
 SG_ RF_Position : 48|16@1- (0.010986328125,0) [0|0] "degrees" Vector__XXX

BO_ 612 RF_C: 8 RF_CT2
 SG_ RF_X_Acceleration : 0|16@1- (.0015258789,0) [0|0] "g" Vector__XXX
 SG_ RF_Z_Acceleration : 16|16@1- (.0015258789,0) [0|0] "g" Vector__XXX
```

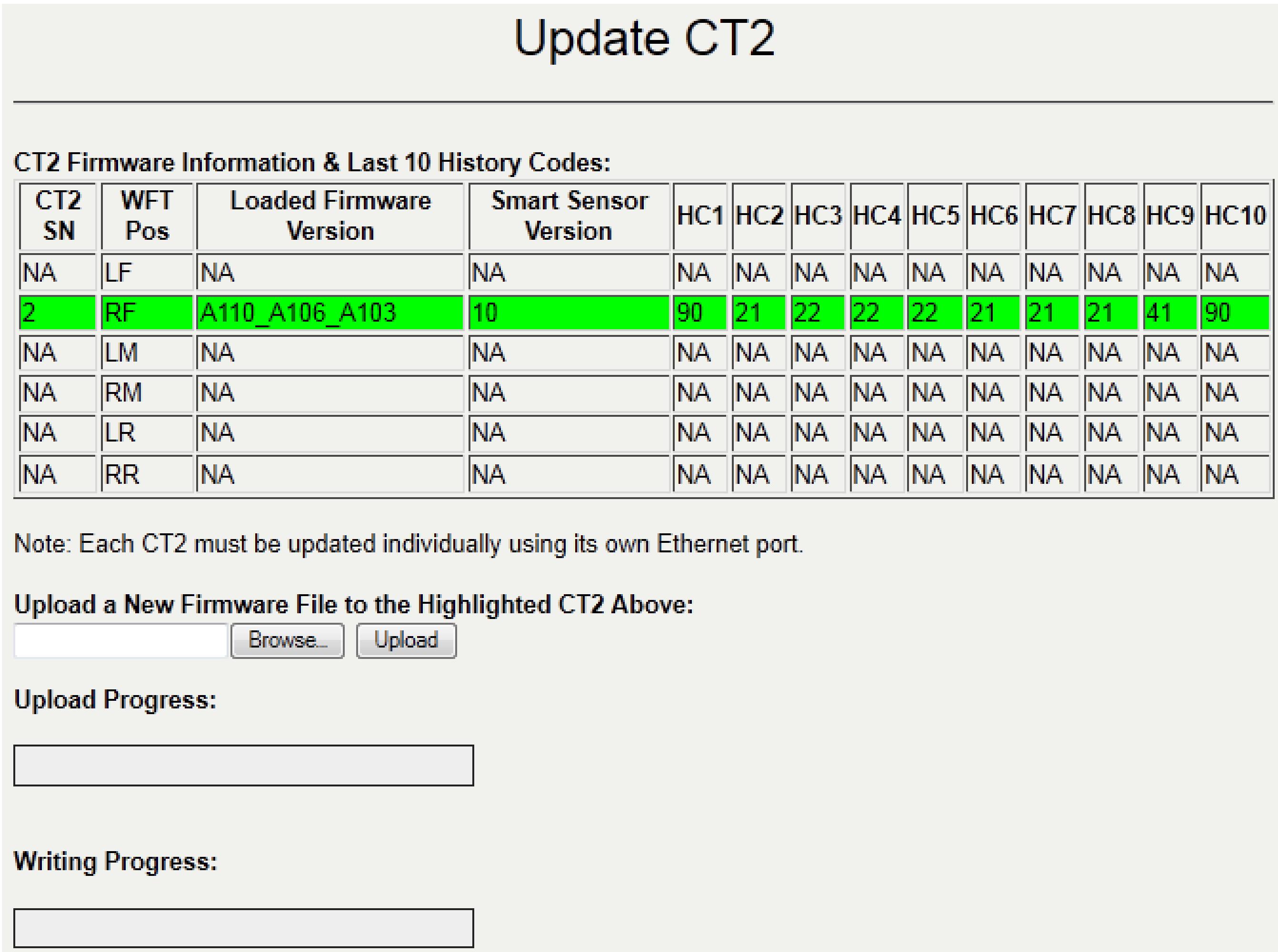
CT2 Remote Control

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.



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:

Browse... Upload

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 sensor 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.

13 pin WFT-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.

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.

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.

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.

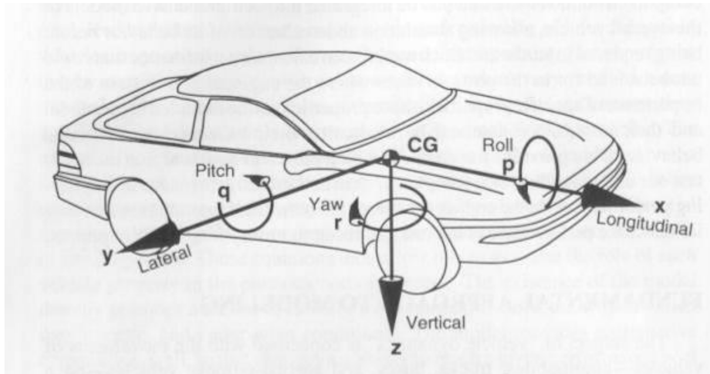
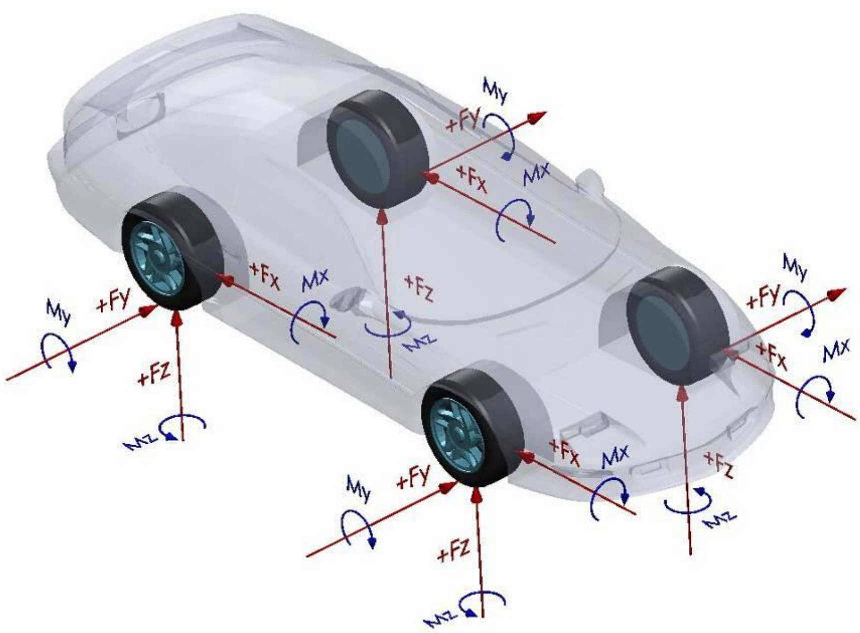


Fig. 1.4 SAE Vehicle Axis System.

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).



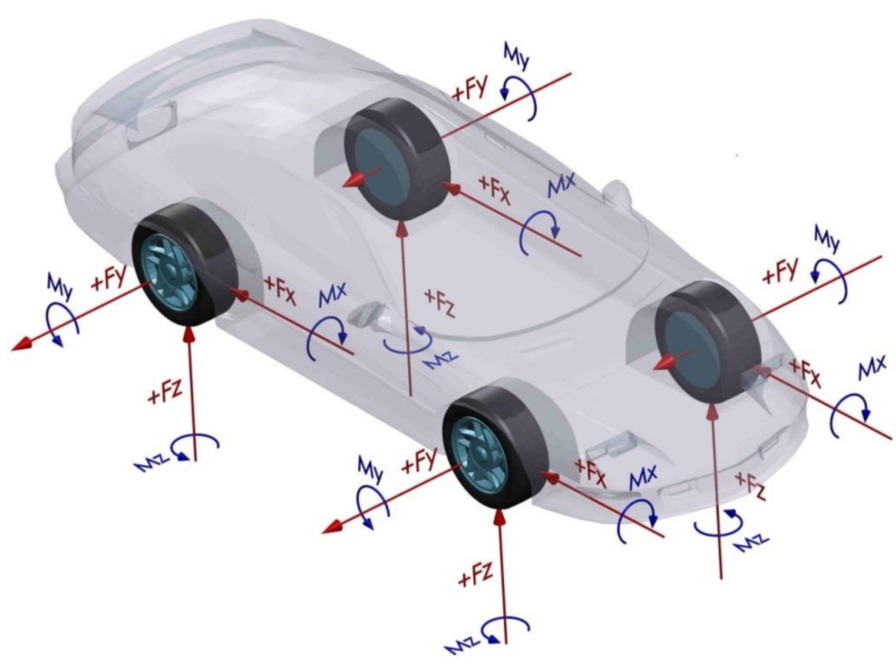
With regards to the WFT measurement system, the origin of the SAE coordinate system is placed at the perpendicular intersection of the axis of wheel rotation and an imaginary plane that passes through the centerline of the transducer's spokes.

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 Fy and My 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).



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 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. 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. Swap components.
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. Encoder Issue	Continue rotating wheels. 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 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 or amplifier is out of tolerance by 2.5% or more.	Jack up vehicle, cycle power, and repeat the shunt sequence. Check the cable connections, cycle power, and repeat the shunt sequence. Swap amplifiers and move smart sensor (See appendix 4) 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.
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.	CT2 is in Set-up mode	Switch CT2 to RUN mode
	Data channels have error due to rolling zero procedure	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
	Slip Ring is not oriented properly.	See “Angle reference incorrect” below
	Incorrect zero, direction of wheel rotation was changed during the zero procedure.	Be sure that the wheel is turned only in one direction during the zero procedure.
	External forces were imposed during the zero procedure on the hoist.	When turning the wheels, be sure to apply force only on the amplifier package. This insures that no forces are imposed through the transducer.
	Incorrect zero, on-the-road zero was performed on a rough surface.	Redo the zero procedure. For best accuracy, perform the zero on the hoist.
	Data acquisition system has some offset.	Using a volt meter, check the outputs from the CT2. If the outputs are indeed zero, null the offsets in the data acquisition system.
	CT2 electronics are damaged.	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
	Offsets are too large for the CT2 to zero them. Damage to transducer.	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.

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

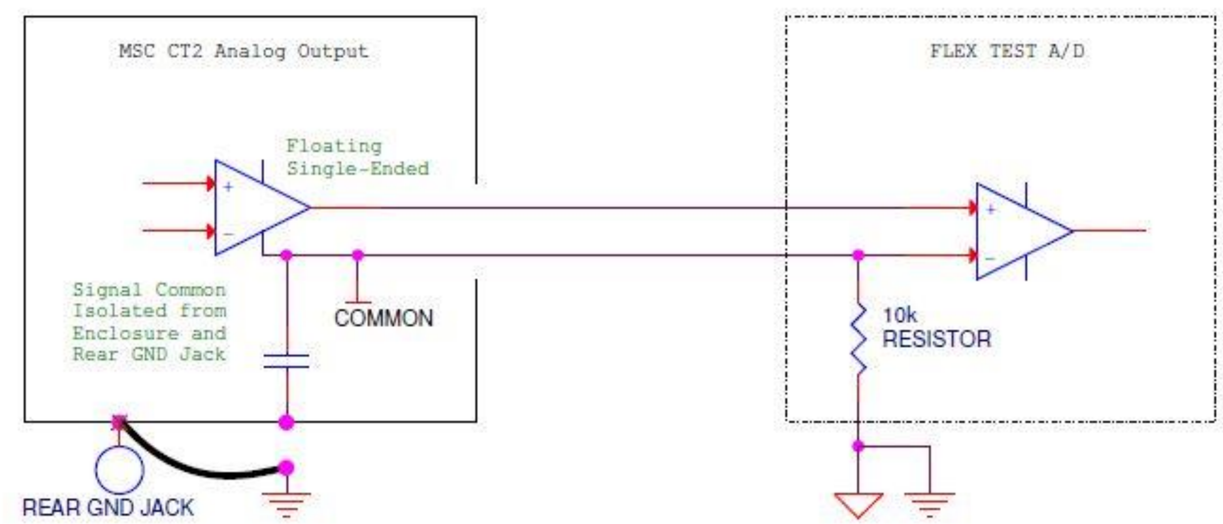
Symptom	Possible Causes	Solution
Higher or lower than expected output from one or more channels	The data acquisition system sensitivities are incorrect. Incorrect amplifier package Transducer is damaged. Amplifier package is damaged.	Check data acquisition system. The correct sensitivities are listed on the calibration sheet in the back of this manual. Check that the correct amplifier package is being used with the transducer. Check the transducer offsets and shunt values. Send in for checkout and repair if needed. Send in for checkout and repair if needed
One or more output channels output incorrect polarity.	Right/Left Switch is not in the correct position. Cable to data acquisition is improperly connected. Sensitivity is incorrect in the data acquisition system. Slip Ring is not oriented properly Coordinate System is not as expected	Check to see if switch is correct. Change if needed. Check the voltage from the CT2. If correct, check pin-out for signal cable to the data acquisition system. Check the voltage from the CT2. If correct, check the sensitivities in the data acquisition system. See "Angle reference incorrect" below Check the selected Coordinate System in the CT2 webpage
Angle reference incorrect	Slip Ring is not oriented properly Encoder Stator Offset Angle entered incorrectly	Orient the slip ring so that the connector is pointed vertical. The side surfaces of the slip ring should be vertical. Using the CT2webpage, first confirm that the slip ring/encoder reference angle stored in the webpage is incorrect and then update with the appropriate angle.
Data appears noisy	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.

Appendix 1- Wiring and Shielding

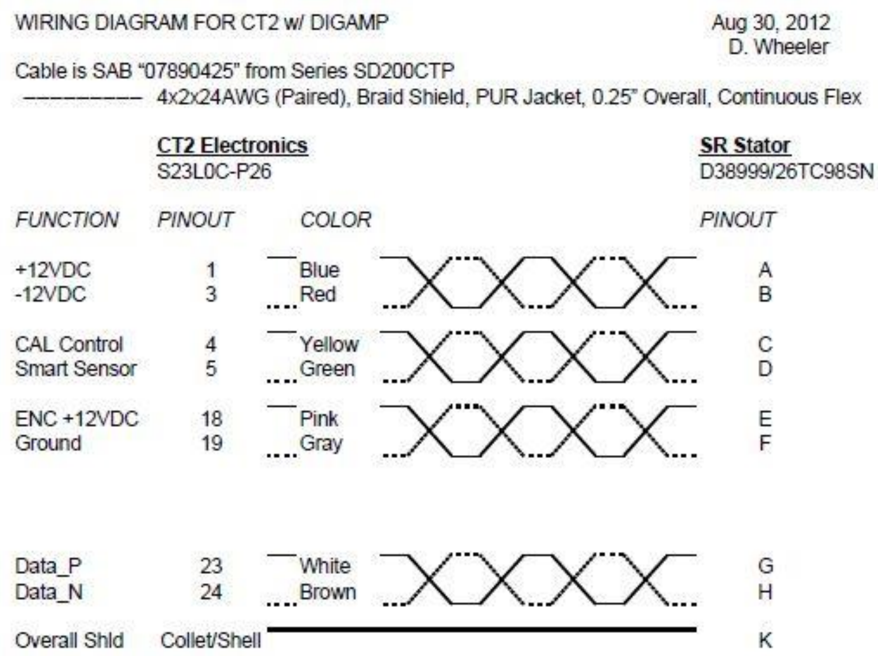
CT2 *Power* Connector Pin-Out

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



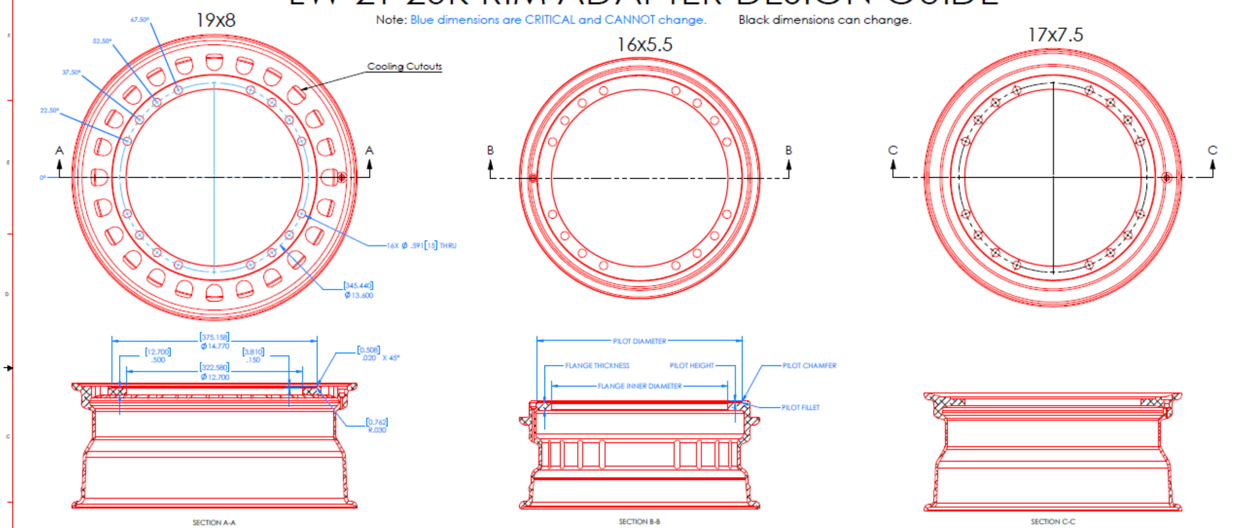
CT2 *Signal Out* Connector Pin-Out

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- Adapter Design Guidelines

LW-2T-20K RIM ADAPTER DESIGN GUIDE

Note: Blue dimensions are CRITICAL and CANNOT change. Black dimensions can change.



It is essential that the adapters match the recommended guidelines. This will ensure the system can withstand the rated loads and provide the most accurate results.

Michigan Scientific Corporation (MSC) prefers to use the test vehicle's Original Equipment Manufacturer (OEM) wheel design as the basis of the rim adapter design. If 3D wheel models or drawings of the OEM wheel are not available, MSC recommends using The Tire and Rim Association or ISO standards as a design basis for the tire mounting profile.

MSC machines rim adapters from 6061-T6 aluminum forgings. These forgings have consistent yield strength and hardness throughout. If 'bar stock' or 'billet' is used, the heat treatment may not be consistent through the section, resulting in a lower yield strength and hardness than published. The material must have a yield strength of at least 40 ksi (275 MPa) if the examples above are followed. If a weaker material is used, the thickness of the rim adapter sections will need to increase.

The "COOLING CUTOUTS" allow for airflow to the brakes and reduce the weight of the adapter system. MSC refines the size and shape of the cutouts for each adapter design. Typical cutouts are shown. The pattern of the cutouts should be a multiple of 24, and they should be aligned away from the Wheel Force Transducer (WFT) mounting holes as shown.

The "FLANGE THICKNESS" must be 0.500 in (12.700 mm). The M14x2.0 fasteners should thread all the way through the transducer to ensure complete thread engagement.

Rims that are 16 inches could need cutouts from the wheel drop to allow the WFT fasteners to thread in. For rims that are smaller than 16 inches, consult MSC for how to design the rim adapter.

MSC verifies all rim and hub adapter assemblies using FEA to simulate the SAE J328 wheel durability standard. This should be done with all adapters to verify the load ratings and fatigue life of the adapters. A LW-2T-20K transducer has a SAE J328 static load rating of 4000 lb (1815 kg). This should not be exceeded. MSC can check your adapter design at no cost. Contact MSC online at michsci.com/contact-us or via phone at 1-231-547-5511.

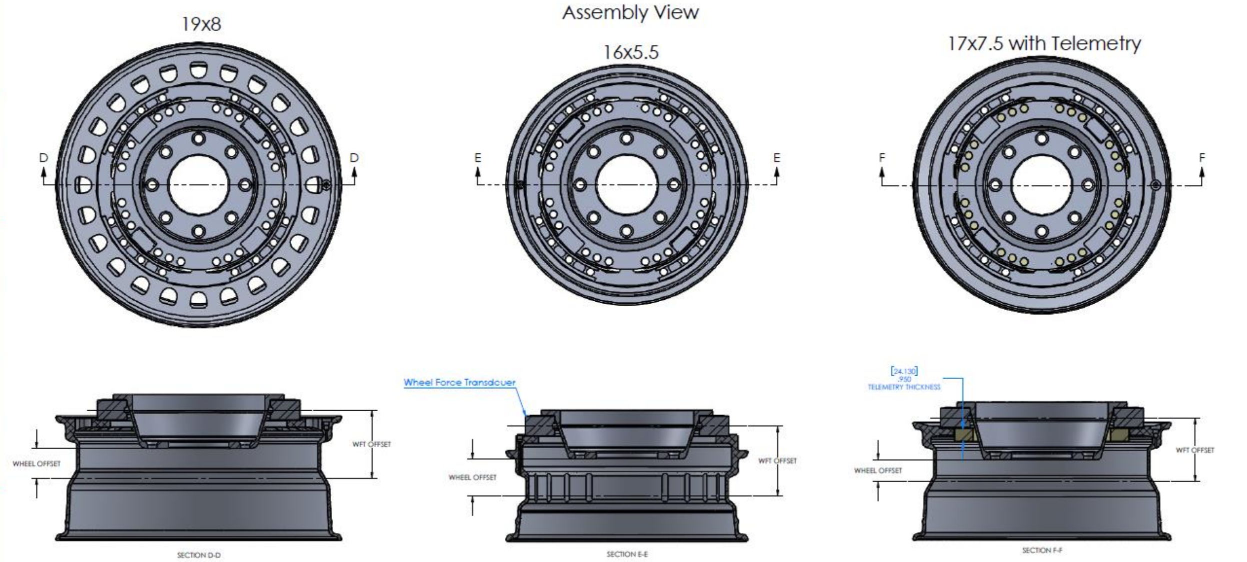
Details and specifications provided in this document are purely for informational purposes and are subject to alterations. No liability is accepted for errors or omissions.

MICHIGAN SCIENTIFIC CORPORATION 8500 ANCE ROAD CHARLEVOIX, MICHIGAN 49720

Rim Adapter Design Guide | SIZE D | DWG. NO. LW-2T-20K Rim Adapter Design Guide | SCALE 1:2.75 | SHEET 1 OF 2

LW-2T-20K RIM ADAPTER DESIGN GUIDE

Assembly View



It is essential that the adapters match the recommended guidelines. This will ensure the system can withstand the rated loads and provide the most accurate results.

The "WFT OFFSET" is the distance from the centerline of the rim to the centerline of the transducer. The "WFT OFFSET" should be as small as possible to reduce the moment load on the WFT. The WFT and adapters need at least 0.15 in (3.8 mm) of clearance to the brake and suspension components to prevent interference. See the drawing for additional clearance required for telemetry WFT systems.

3D models and 2D drawings of the LW-2T-20K are available for download on MSC's website. (michsci.com)

Note: Blue dimensions are CRITICAL and CANNOT be changed.
Black dimensions can be changed

MSC verifies all rim and hub adapter assemblies using FEA to simulate the SAE J328 wheel durability standard. This should be done with all adapters to verify the load ratings and fatigue life of the adapters. A LW-2T-20K transducer has a SAE J328 static load rating of 4000 lb (1815 kg). This should not be exceeded. MSC can check your adapter design at no cost. Contact MSC online at michsci.com/contact-us or via phone at 1-231-547-5511.

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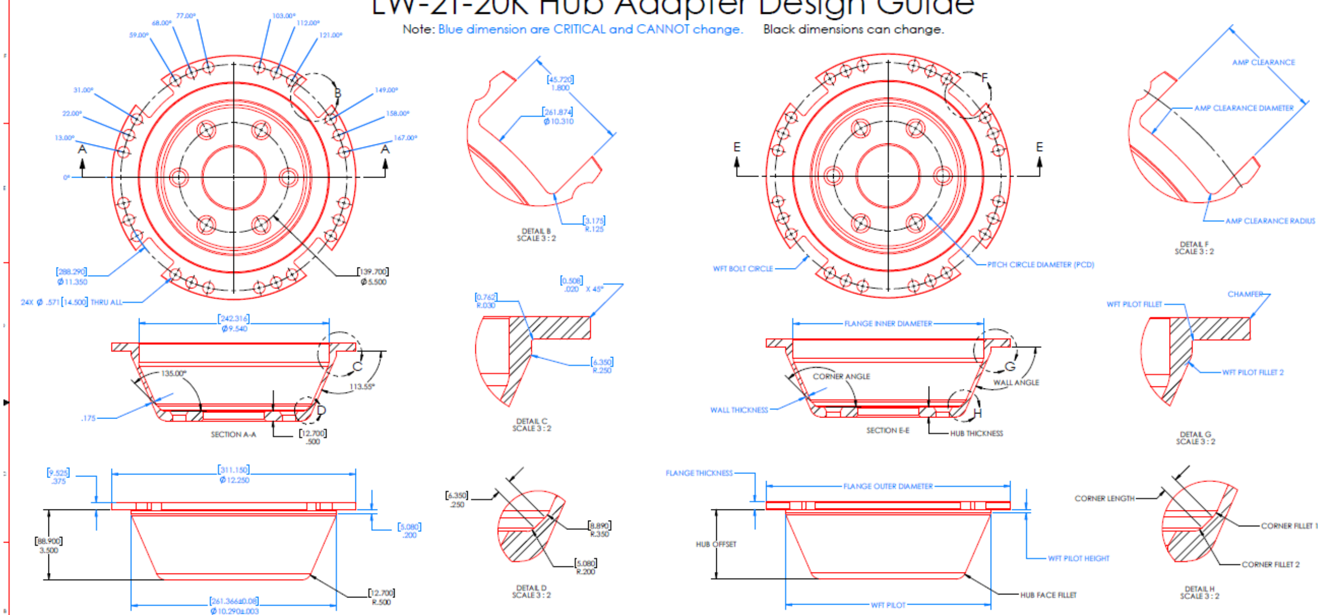
MICHIGAN SCIENTIFIC CORPORATION 8500 ANCE ROAD CHARLEVOIX, MICHIGAN 49720

Rim Adapter Design Guide | SIZE D | DWG. NO. LW-2T-20K Rim Adapter Design Guide | SCALE 1:2.75 | SHEET 2 OF 2

LW-2T-20K Hub Adapter Design Guide

Note: Blue dimension are CRITICAL and CANNOT change. Black dimensions can change.



It is essential that the adapters match the recommended guidelines. This will ensure the system can withstand the rated loads and provide the most accurate results. The critical features are shown in blue. Customers may change all other geometry. Examples of permitted changes are shown on the second sheet.

The "HUB THICKNESS" should not be less than 0.500 in (12.700 mm).

Detail D shows geometry that reduces the material stresses to increase the adapter fatigue life. The "CORNER ANGLE" should be between 115-145 degrees.

Michigan Scientific Corporation (MSC) machines hub adapters from 17-4 H1100 stainless steel. This material provides good insulation from brake heat. Alloy steels can be used but they will conduct brake heat more than the stainless steel. The material should have a yield strength of at least 890 MPa (130 ksi) and a hardness between 32 and 45 HRC.

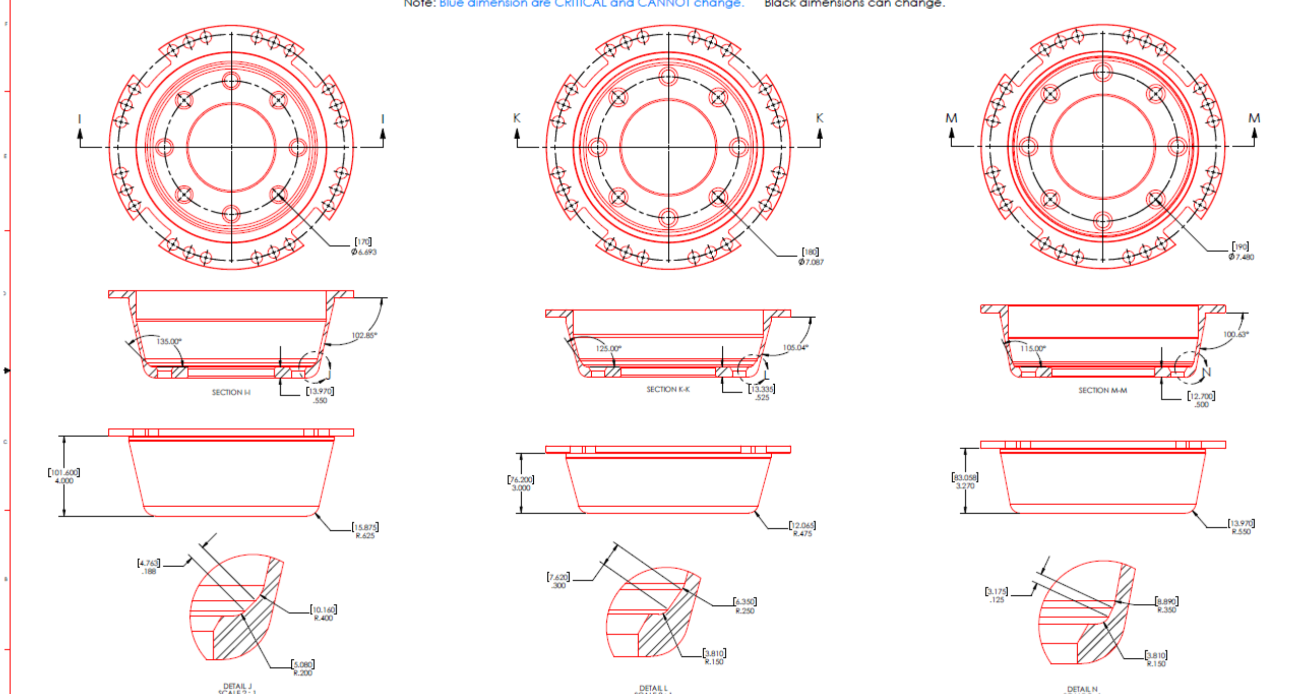
MSC verifies all rim and hub adapter assemblies using FEA to simulate the SAE J328 wheel durability standard. This should be done with all adapter systems to verify the load ratings and fatigue life of the adapters. A LW-2T-20K transducer has a SAE J328 static load rating of 4000 lb (1815 kg). This should never be exceeded.

MSC can check your adapter designs at no cost. Contact MSC online at michsci.com/contact-us or via phone at 1-231-547-5511.

IMPORTANT: If your system uses Telemetry, make sure to check that the Hub Adapter and Telemetry fit together.

LW-2T-20K Hub Adapter Design Guide

Note: Blue dimension are CRITICAL and CANNOT change. Black dimensions can change.

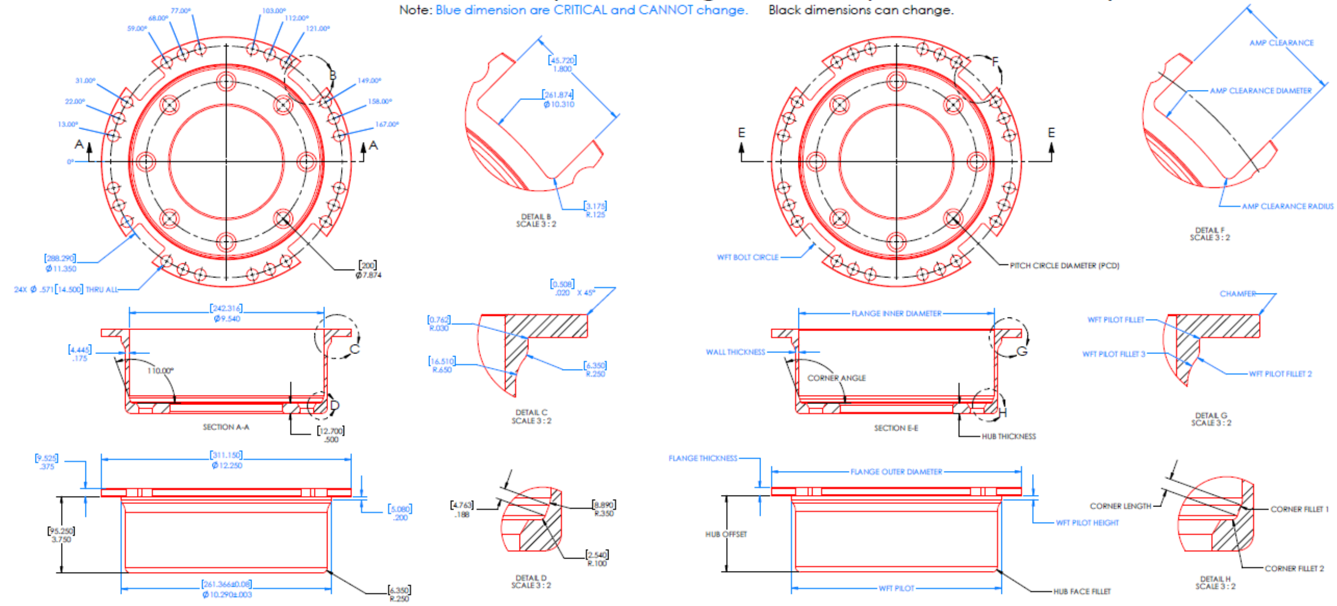


It is essential that the adapters match the recommended guidelines. This will ensure the system can withstand the rated loads and provide the most accurate results. The critical features are shown in blue. Customers may change all other geometry. Examples of permitted changes are shown above.

Details and specifications provided in this document are purely for informational purposes and are subject to alterations. No liability is accepted for errors or omissions. ©2020 Michigan Scientific Corporation

LW-2T-20K Hub Adapter Design Guide (PCD 200+ mm)

Note: Blue dimension are CRITICAL and CANNOT change. Black dimensions can change.



It is essential that the adapters match the recommended guidelines. This will ensure the system can withstand the rated loads and provide the most accurate results. The critical features are shown in blue. Customers may change all other geometry. Examples of permitted changes are shown on the second sheet. This design guide is for vehicles with a PCD greater than or equal to 200 mm.

The "HUB THICKNESS" should not be less than 0.500 in (12.700 mm).

Detail D shows geometry that reduces the material stresses to increase the adapter fatigue life. The "CORNER ANGLE" should be between 105-115 degrees.

Michigan Scientific Corporation (MSC) machines hub adapters from 17-4 H1100 stainless steel. This material provides good insulation from brake heat. Alloy steels can be used but they will conduct brake heat more than the stainless steel. The material should have a yield strength of at least 890 MPa (130 ksi) and a hardness between 32 and 45 HRC.

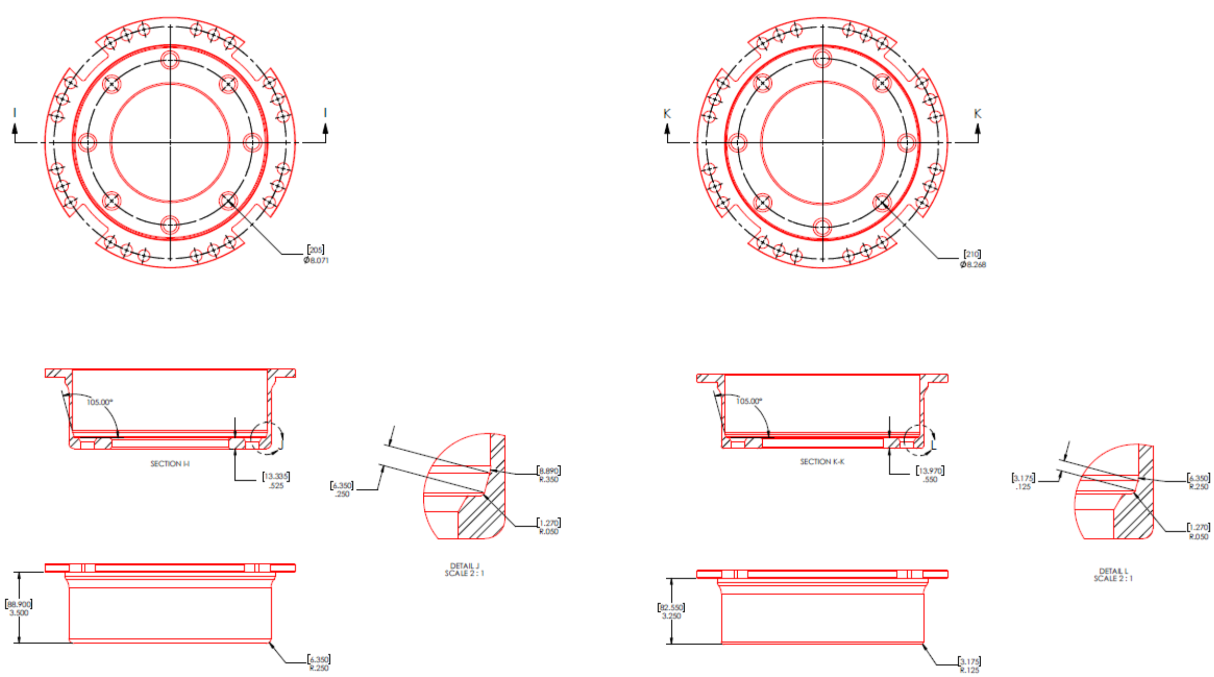
MSC verifies all rim and hub adapter assemblies using FEA to simulate the SAE J328 wheel durability standard. This should be done with all adapter systems to verify the load ratings and fatigue life of the adapters. A LW-2T-20K transducer has a SAE J328 static load rating of 4000 lb (1815 kg). This should never be exceeded.

MSC can check your adapter designs at no cost. Contact MSC online at michsci.com/contact-us or via phone at 1-231-547-5511.

IMPORTANT: Consult MSC if your system uses telemetry.

LW-2T-20K Hub Adapter Design Guide

Note: Blue dimension are CRITICAL and CANNOT change. Black dimensions can change.



It is essential that the adapters match the recommended guidelines. This will ensure the system can withstand the rated loads and provide the most accurate results. The critical features are shown in blue. Customers may change all other geometry. Examples of permitted changes are shown above.

Appendix 3 - Example Quick Reference Calibration Sheet

MICHIGAN SCIENTIFIC corporation

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Phone: (231) 547-5511
Fax: (231) 547-7070
www.michsci.com

QUICK REFERENCE SHEET
TRANSDUCER CALIBRATION

TRANSDUCER SERIAL NUMBER:	CALIBRATION DATE:
LW-2T-20K- **791**	August 21, 2019

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:

Fx: Sensitivity :	1 Volt =	**2,248** lb	**10,000** N
Fy: Sensitivity :	1 Volt =	**1,124** lb	**5,000** N
Fz: Sensitivity :	1 Volt =	**2,248** lb	**10,000** N
Mx: Sensitivity :	1 Volt =	**1,180** lb ft	**1,600** N m
My: Sensitivity :	1 Volt =	**1,623** lb ft	**2,200** N m
Mz: Sensitivity :	1 Volt =	**1,180** lb ft	**1,600** N m
Accel X: Sensitivity :	1 Volt =	**10** g	**98** m/s^2
Accel Z: Sensitivity :	1 Volt =	**10** g	**98** m/s^2

With the supplied Michigan Scientific amplifiers this transducer would give an output of one volt, if the above load were applied. Two volts would mean that the applied load is twice the above value; minus one volt would mean the load is the value shown above, in the opposite direction, etc.

SHUNT CALIBRATION (FOR BEST ACCURACY):

Fx: Shunt= 4.136 V*	**9,297** lb	**41,353** N
Fy: Shunt= 4.578 V*	**5,145** lb	**22,887** N
Fz: Shunt= 4.149 V*	**9,328** lb	**41,489** N
Mx: Shunt= 4.451 V*	**5,252** lb ft	**7,121** N m
My: Shunt= 4.374 V*	**7,098** lb ft	**9,624** N m
Mz: Shunt= 4.413 V*	**5,208** lb ft	**7,061** N m

Although using transducer sensitivity to setup data-acquisition systems, is convenient, the accuracy of the values measured can be off by one percent or more due to normal variations in the data collection electronics. In order to correct for these variations, and get the most accurate data, Michigan Scientific recommends using a shunt calibration to check the sensitivities. To do this, perform a shunt sequence on the Load Wheel Interface Electronics. Record the outputs. Calculate the delta voltage (value from positive shunt to negative shunt) and divide by 2. Compare this number to the number listed above. The Load Wheel Interface makes adjustment so that the output is correct but variations may occur in the data collection system. You may find it necessary to adjust the recording equipment sensitivity for best accuracy.
* Shunt voltage listed is nominal, the actual voltage may vary.

SPEED AND POSITION

Speed Sensitivity :	10 Volts =	**2,000** RPM
Position Sensitivity :	10 Volts =	**360** Degrees

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

Appendix 4 – 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.

Notes: