

Michigan Scientific Corporation

Wheel Force Transducer System



Model: LW65, for Telemetry set-up

For Cars, SUV, and Light Truck



MICHIGAN SCIENTIFIC
corporation

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Introduction

The Michigan Scientific Telemetry Wheel Force Transducer system is a 6-axes transducer that measures forces and moments on a vehicle wheel. It offers accurate measurement of force and moment inputs on a vehicle hub, convenient Transducer interface box, and wireless data transmission.

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 sensor 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.

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. A magnetic ring is mounted to the back the transducer and several precisely located Hall Effect sensors are mounted close to the magnet ring inside the Telemetry Stator. An Encoder Zero procedure needs to be done each time the system is moved to a new vehicle so the Encoder has an angle position reference. The encoder provides angular position information needed for both the coordinate transformation and velocity calculations.

Coordinate transformation, supply power to the induction and the user interface is handled by the CT2-TEL 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 sensor and corrections will be made to keep the output in SAE coordinates. Error checking is in place to alert the user if the system is out of tolerance. Corrections are made for cross axis sensitivity. Finally, a shunt procedure calculates output sensitivities and allows the user to record shunt values. Signal outputs can be ± 10 volt analog, via CAN bus, or Ethernet. Communication to the CT2 for setup is done through an Ethernet connection and an embedded web page.

Specifications

MSC LW65
6-Axis Wheel Force Transducer
Stainless Steel

Capacities

Maximum Force Capacity	[Fx, Fz]	14,500 lb	65 kN
	[Fy]	7,850 lb	35 kN
Maximum Torque Capacity	[Mx, My, Mz]	7,700 lb-ft	10.5 kN-m
Acceleration	[Accel X, Accel Z]	100g	
Maximum Recommended Static Corner Weight		2900 lb.	1320 kg

Other

Transducer	6 independent, full strain gage bridges
Nonlinearity	Less than 0.20% of full-scale output
Hysteresis	Less than 0.25% of full-scale output
Cross Axis Sensitivity after correction	<0.4% of full-scale
Radial Sensitivity Variation	<0.3% of radial load
Transducer Temperature Range	-40 to 125 C (-40 to 257 F)
Insulation Resistance from Bridge to Case	Exceeds 1000 Mohm
Vehicle Power Input Voltage	9 to 36 VDC
Telemetry Frequency Range	2.4 GHZ

Mass of Components, Typical

Component	lbs	Kg
Wheel Force Transducer	17.5	7.95
Telemetry Ring	1.8	0.8
Telemetry Stator with Cable	1.8	0.8
CT2-TEL Electronics	4.0	1.8

System Components

The Wheel Force Transducer Measurement System is made up of multiple components.

Transducer



Six Axes Wheel Force Transducer. All Michigan Scientific Wheel Force Transducer (MSC WFTs) use Six independent Full Strain Gage bridges which measure the three forces and three moments. MSC WFTs have high accuracy and low cross-talk.

Telemetry & Encoder Ring



The Telemetry & Encoder Ring, TEL-ENC-65 has built-in RF Telemetry Transmitter, induction regulator, encoder magnet ring, & secondary induction coil. The telemetry transmitter provides excitation and amplification to the strain gage bridges. It also contains the precision shunt calibration resistors with low temperature coefficients which insure good performance over all temperature ranges.

The Telemetry Transmitter frequency is set in the factory and must be used with a Telemetry Stator set at the same frequency.

The TEL-ENC-65 is bolted to the LW65 transducer at the factory and should remain mated with the transducer that shares its serial number, as they were calibrated as a mated pair.

CT2-TEL Electronics



CT2-TEL Electronics. The CT2-TEL contains the Induction Power Supply. The dimensions are 19 cm x 3.5 cm x 30 cm. See page 28 for operating instructions.

Telemetry Stator



The Telemetry Stator, TEL-STATOR-65, contains the RF Telemetry Receiver, Primary induction coil, and Hall Effect sensors. The RF Telemetry Receiver detects and processes the signals from the Telemetry Transmitter. These signals along with the encoder pulse signals are digitized and sent the CT2-TEL for signal processing. The frequency of each Telemetry Stator is programmed in the factory to match the RF frequency of the transmitter built-in to a particular WFT. The frequency of each Telemetry Stator can be changed with the CT2-TEL webpage, see page 58.

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. Michigan Scientific also offers lightweight titanium hub adapters.

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



2-Piece Rim Adapter. Limited Load Rating



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

Michigan Scientific (MSC) makes two types of rim adapters for the LW65 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.

In some cases MSC can also provide welded aluminum or welded steel rim adapters. These carry lower load rating and can only be used in certain tests. Consult MSC for recommendations on your application.

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.

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



Analog Signal Breakout Box with BNC connectors

Ethernet Cable



Ethernet Communications Cable; Connects CT2-TEL to a computer for access to the CT2-TEL webpage.

CAN Bus Cable



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

CT2 Grounding Cable



CT2 Chassis Grounding cable

Transducer ID Dongle



Transducer ID Dongle stores Transducer Calibration, Offset, and Shunt Calibration Information.

Telemetry Alignment Tool

This alignment tool is used to properly align the Telemetry Stator to the Telemetry Ring. The alignment tool sets both the concentricity and gap. One curved surface should be in contact with the outside of the Telemetry Ring and the other curved surface should be in contact with the outer surface of the Telemetry Stator.



Telemetry Stator Bracket



Adjustable bracket used to secure the Telemetry Stator to the Carrier bolt on the brake caliper.

WFT and Telemetry Stator Frequencies

The telemetry used in Michigan Scientific WFT-TELS broadcasts in the 2.407 to 2.487 GHz range. Each Transducer is set to a distinct frequency channel within that range so that each set of transducers do not interfere with each other. Each Telemetry Stator is programmed to a certain channel matching only one of the WFT-TELS in that set. Together they form a matched pair. If a Telemetry Stator gets damaged, a spare can be reprogrammed by the customer to the needed channel to replace the damaged Telemetry Stator. Information on reprogramming the Telemetry Stator can be found on page 58.

Telemetry Spinning Assembly Instructions

This section of the manual describes the assembly of the transducer, wheel and hub adapters, telemetry ring, and telemetry stator.

Before Assembly

- Be sure that all mating surfaces are free of dirt.
- 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.

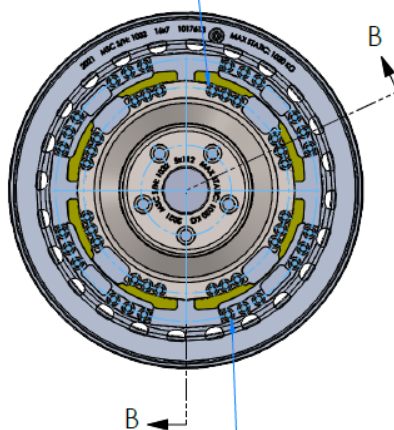
Note: First install the tire onto the rim adapter. This can be done on a standard tire change machine.

Assembly Diagram

1017612

LW65 - Telemetry - Right Side

(24) Titanium M10x1.5-18 mm
Torque to 60 lb.ft (81 N.m)
Use anti-seize on threads
and under head



Hub Adapter
S/N 1032

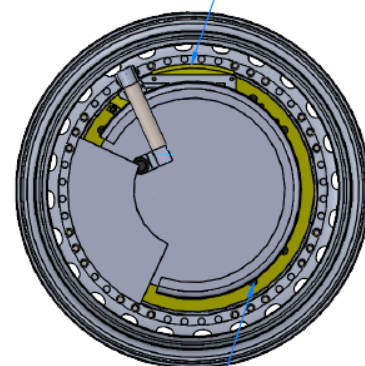
LW65

LW65 Telemetry Ring

SECTION B-B

Rim Adapter
S/N 1032

LW65 Telemetry
Alignment Tool



(8) M8x0.8-20mm Torx Screws
Torque to 50 in.lb
Use anti-seize on threads

(24) Titanium M10x1.5-55 mm
Torque to 60 lb.ft (81 N.m)
Use anti-seize on threads
and under head

UNLESS OTHERWISE SPECIFIED:		DATE	NAME	MICHIGAN SCIENTIFIC CORPORATION	
TOLERANCES ARE IN INCHES		DRAWN	05/26/21	JPS	8500 AVICE ROAD
FRACTIONAL		CHECKED	-	-	CHARLEVILLE, MICHIGAN 49720
DECIMAL		ENG APPR	-	-	WWW.MICHSCI.COM
ANGULAR		MFG APPR	-	-	PROJECT CODE
HOLE					2012 VW Golf Mk7 LW65 Assembly
WEIGHT					SIZE DWG. NO.
GENERAL					B 1017612
FINISH					REV
					SCALE: 1:4
					SHEET 2 OF 2

Assembly

- Place the Transducer with Telemetry on end, insert the hub adapter, and install two M10-1.5 x18mm bolts with anti-seize through the hub adapter and into the transducer.



- Set the hub adapter on a flat surface and install the remaining M10-1.5 x18mm bolts with anti-seize. The bolt can remain hand tight for now.



Installing the Telemetry Stator Bracket

Michigan Scientific can provide an adjustable Telemetry Stator Bracket. The provided Bracket may not fit all vehicles. If the provided bracket cannot mount in your vehicle a custom bracket must be fabricated by the customer. Any custom brackets must be rigid enough to prevent Telemetry Stator movement and prevent contact with any rotating components. Custom bracket should also include a heat shield.

The adjustable telemetry stator bracket is made up of the following components:



1. Caliper bolt attachment 1 -left



2. Caliper bolt attachment 2 – right



3. Bracket elbow



4. M10 bolts & sleeves



5. TEL-STATOR backing Plate - left

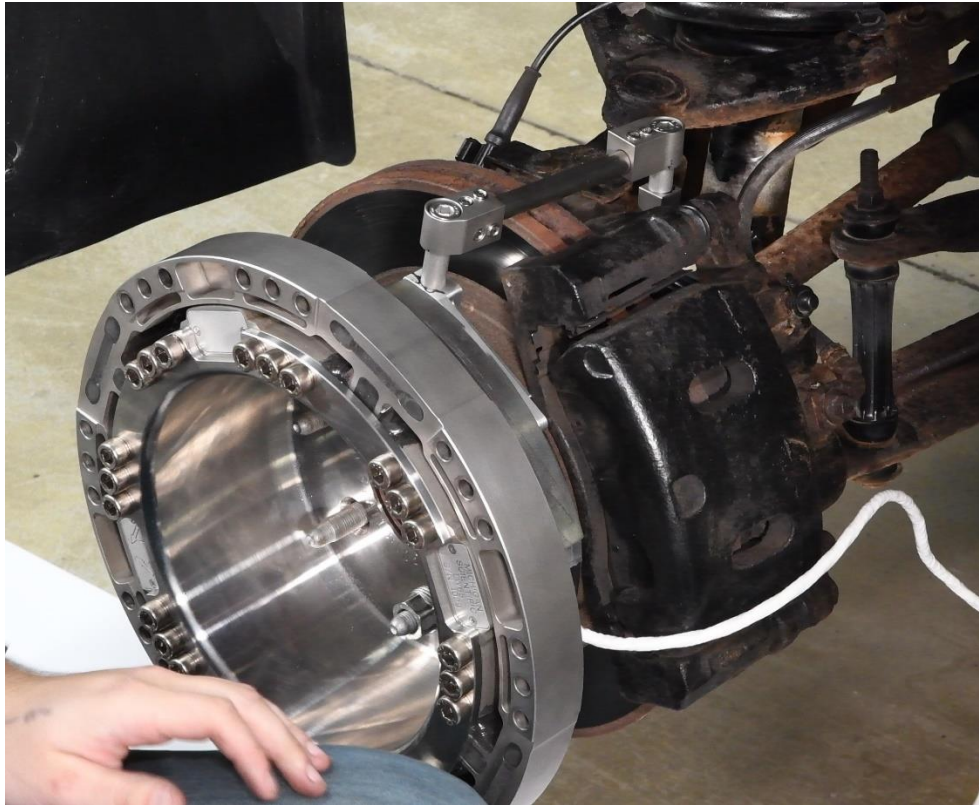


6. TEL-STATOR backing Plate - right



7. 0.500" low carbon steel rod; Cut to length, as needed.

Here is an example of the Telemetry Stator Bracket fully installed.



Below are the installation instructions for the adjustable Telemetry Stator Bracket. All Telemetry Stator Bracket bolts should be installed with a small amount of anti-seize.

1. Remove wheel from vehicle.



2. Remove the carrier bolt/Caliper bolt which holds the brake caliper to the knuckle.



3. Depending on vehicle specifics, install the **Caliper bolt attachment #1** or **Caliper bolt attachment #2** between the Caliper bolt and the brake caliper bracket.



4. Find the appropriate length **M10 bolt and sleeve** to connect the **Caliper bolt attachment part** and **Bracket Elbow** while just having clearance past the brake rotor. In some applications there is little clearance between the brake rotor and Wheel inner diameter.





5. Install the appropriate **TEL-STATOR Backing plate** to the **Telemetry Stator** with 3 M4x20mm bolts. Then install a **Bracket Elbow** to the **TEL-STATOR Backing plate** with an **M10 Bolt and sleeve**.

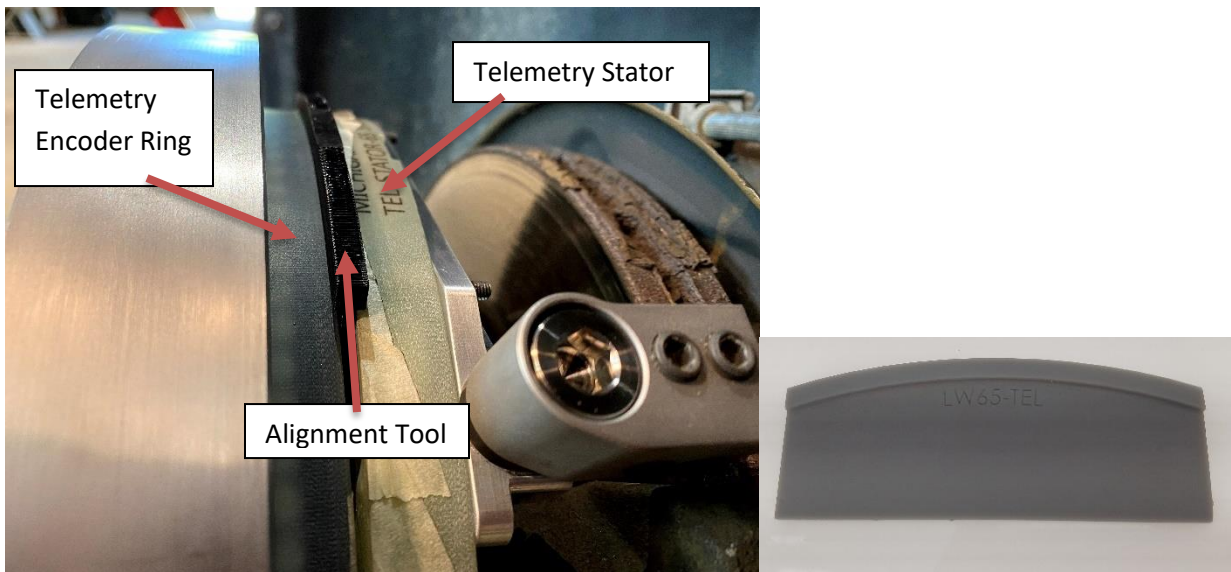




6. Install the WFT and hub adapter assembly to the vehicle hub.



7. Bring the Telemetry Stator near the WFT and use the **Alignment Tool** to locate the Telemetry Stator into its exact location. **The Telemetry Stator concentricity to the Telemetry Encoder Ring is critical.** Find out the length of steel rod that is required to join the two **Bracket Elbows** and cut the 0.50" provided steel rod to the correct length.



8. Install the entire Telemetry Stator Bracket. Use the M8 set screws to tighten the Bracket Elbows to the 0.50" steel rod. The set screws should make a small indent into the rod. Check alignment. At this time you may need to adjust the **M10 Bolt & Sleeve** length or the **0.50" Steel rod length** to improve the alignment.
9. Once proper alignment is achieved, all bolts must be tightened to proper specification. A small amount of anti-seize should be used on all bolts.

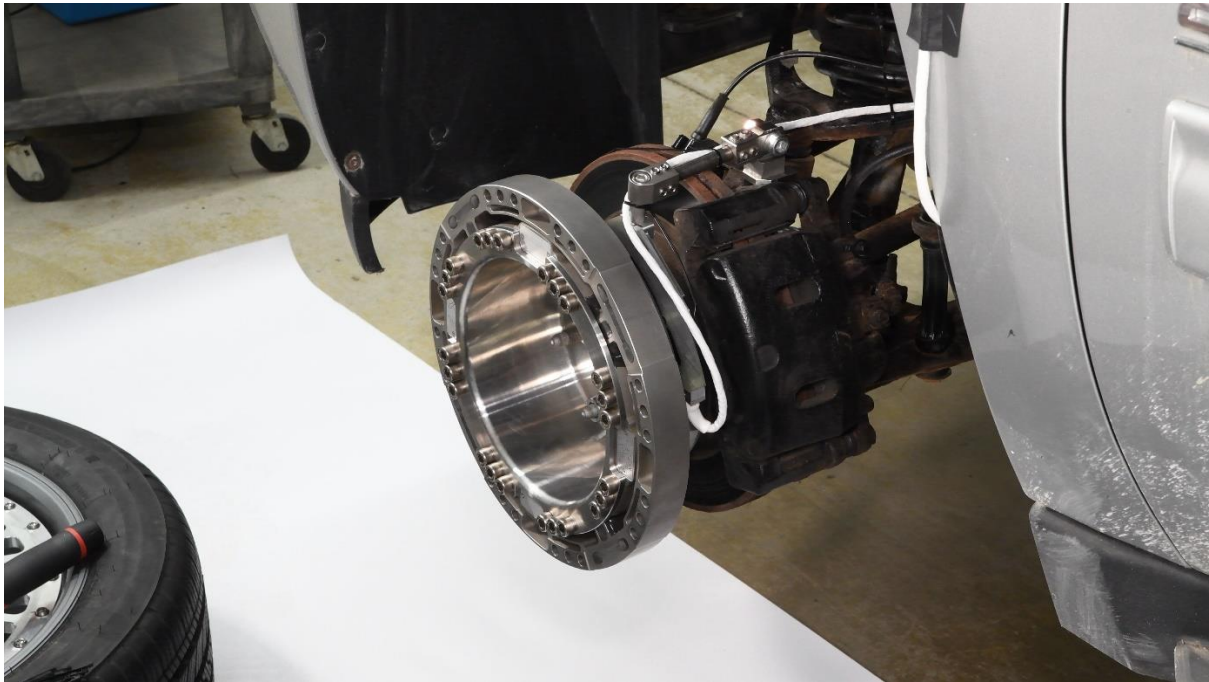
Bolt Size	Tightening Torque	Bolt location
M4 x 20mm SHCS	2.25 N.m	Telemetry Stator to Backing plate
M10 SHCS, varying lengths	54 N.m	Bracket elbow to backing plate/caliper bolt attachment
M8 set screw	10 N.m	Bracket elbow to steel rod
M14 Caliper bolt	190 N.m or manufacturer's spec.	Caliper bolt attachment to Brake Caliper



10. After tightening re-check alignment with Alignment Tool. If Alignment is still proper then proceed to Cable Routing.

Cable Routing.

11. Secure the Telemetry Stator Bracket cable to the brake caliper or steering knuckle being sure to clear the brake rotor with an air gap between the cable and brake rotor. The cable must also clear the ID of the wheel adapter. Routing the cable towards the center of the wheel is recommended and minimizes movement while steering.



12. Turn the wheel its full range of motion to ensure that the cable will at no point contact the wheel adapter or brake rotor.
13. Route Telemetry Stator cable back into the cab of vehicle where the CT2-TEL will be located. Typically the cable is either routed under the vehicle and then into the cab or behind the wheel well lining and then through the window of the vehicle. Be sure to properly secure cable to the vehicle, avoid any moving parts, and leave slack in the cable so that the wheel can fully steer and suspension can fully compress/extend without damaging the cable.
14. Once the Telemetry Stator Bracket is properly aligned and all the bolts are properly tightened, and cable has been routed, remove the WFT/Hub Adapter Assembly
15. Place the WFT/Hub Adapter assembly onto the Rim adapter, install twenty four M10-1.5 x 55mm bolts though the transducer and into the rim adapter with a small amount of anti-seize on the thread as shown.
16. Install twenty four M10-1.5 x 55mm bolts though the transducer and into the rim adapter with a small amount of anti-seize on the thread as shown.

Place the hub adapter onto the Transducer as shown below.



17. Torque all of the M10 bolts to the following torque using a crisscross pattern:

Transducer to Rim adapter bolts, if solid aluminum rim adapter: 60 lb-ft (81 N.m)

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

Transducer to Rim adapter bolts, if welded aluminum rim adapter: 27 lb-ft (37 N.m).

Note: if using welded aluminum rim adapter max recommended static corner load is reduced to 500 kg. Welded aluminum rim adapters over 17" are not recommended.

18. Install the WFT assembly on the vehicle being careful not to contact the Telemetry Stator or its cable. Check clearance between the Telemetry Stator bracket and the ID of the rim adapter. Make adjustments to the bracket, as needed, if there is contact. Again check the cable clearance to the rim adapter. Be sure to turn the wheel full left and right to check cable clearance. Tighten the lug nuts to the vehicle manufacturer's specified torque.



WFT Set-up

- 19 Connect the loose end of the Telemetry Stator cable to the CT2-TEL electronics.
- 20 Connect the power cable to the CT2-TEL electronics.
- 21 Plug in the correct Transducer ID dongle. Make sure that the Transducer ID dongle has the same serial number as the transducer at the other end of the Telemetry Stator cable plugged into this CT2-TEL.
- 22 Connect other end of the power cable to a DC voltage source in the range of 9 to 36 volts. The current draw from the vehicle varies but should not exceed 1.5 amps at 13.8 volts and reduces proportionately at higher supply voltages.
- 23 If using analog outputs, connect the Analog Signal Break-out Box to the CT2. Then use eight BNC cables to connect to the data acquisition.
- 24 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. One connector of the CAN cable should be plugged into each CT2-TEL.

25 Turn the power switch on.

26 When the DATA VALID led on the front panel is lit (green), it means that the Telemetry Stator is receiving Valid data from the telemetry transmitter in the WFT. If the DATA VALID led is not lit, the Induction Error led will be lit. In this case 1; try to Autotune the induction (see page 29), 2; check TEL-STATOR to TEL-ENC RING alignment, then, if needed, 3; try to reprogram the Telemetry Stator frequency (see page 58).

27 At power-up the WFT will automatically start a Shunt sequence which will last approximately 30 seconds, while this is happening the Zero and Shunt will stay lit. Wait until these lights turn off before proceeding. Also at this time when in vehicle coordinates, the force, moment, and position channels are held at zero until the CT2-TEL receives an index pulse.

28 Perform Autotune, Shunt, Zero and Zero Angle functions to properly set-up the WFT. Details of these functions are described in the CT2-TEL section below.

CT2-TEL



Introduction

One CT2-TEL box is used for each wheel force transducer. This box provides power to the primary induction coil, performs coordinate transformation, and serves as the user interface. The CT2-TEL also has an Auto tune button which finds the proper frequency for the induction to optimize power transfer of the induction system. 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 alerts the user if the system is out of tolerance. Finally, a shunt procedure calculates output sensitivities and allows the user to record shunt values.

Main CT2-TEL Set-up functions

The main CT2-TEL set-up functions are Autotune, Shunt, Zero Angle, and Zero. The Autotune should be performed first.

Induction Autotune & Data Valid

Whenever the transducer or Telemetry Stator has been moved to a different vehicle the induction power needs to be re-tuned. This can be done with the Autotune feature.

Before pressing the Autotune button, ensure that :

1. The WFT Telemetry and Telemetry Stator are set to the same frequency, see page 58, to re-program a Telemetry Stator frequency, if needed.
2. The spacing between the two has been set with the Telemetry Alignment Tool. The concentric alignment is the most important, but the gap should also be set as well as possible.

Press the button for 2-3 seconds and wait about one minute for the Autotune process to complete. The blue Induction Tuning LED should be on during this process.



Once the process has finished either the green Data Valid LED will come on or the red Induction Error light will come on.

If the green Data Valid LED comes on the transmitter is getting sufficient power and the Telemetry Stator is properly matched. You are getting valid data.

If the red Induction Error LED comes on re-check the Telemetry Stator alignment. If the alignment is good, try to reprogram the Telemetry Stator to the frequency of the WFT it is being used with, see page 58.

Shunt Calibration Sequence

Shunt Sequence - The CT2-TEL calculates an internal gain, used to make output sensitivities match what is programmed into the Transducer ID dongle

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 35 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. Pressing the Shunt button will briefly cycle power to the telemetry transmitter, which invokes a shunt calibration resistor at each strain gage bridge in the transducer. The CT2-TEL reads the voltage change, caused by the shunt, and adjusts the gain of each channel to match the sensitivity programmed into the Transducer ID Dongle. This calculated gain is recorded into the memory chip located in the dongle so this information is not lost when power is interrupted or a different CT2-TEL is used. If the

calculated gain is more than 2.5% different than what is programmed into the memory chip, the shunt sequence does not pass, and the FAULT light will be lit.

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.

The calibration sheet lists system sensitivities in engineering units/volt and a shunt calibration equivalent values in engineering units.

These N / volt sensitivities on the calibration sheet are only valid if the analog outputs are left as +/- 10 Volts Full Scale.

As good practice, the user should 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 sensor by a little more than the weight of the tire and rim adapter.

Physical re-calibration services are available from Michigan Scientific.

Zero Angle

The Zero Angle button is used to set the vertical position reference of the encoder. This is very important because this position reference is used for coordinates transformation.

1. Raise the vehicle on a hoist and make sure that it is level.
2. Press the Zero Angle Button
3. Rotate the Wheel until the LED under the Zero Angle Button begin to flash. If the LED does not start to flash, the Telemetry Stator is not aligned properly.
4. The rotate the Transducer & Wheel so that the Z+ arrow on the Transducer points vertically down. Use an inclinometer or precise level to ensure that the Z+ arrow is exactly vertical.



5. Press the Zero Angle Button again
6. The reference angle for the encoder is now set.

Zeroing the WFT

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

There are two zeroing procedures for Spinning Applications.

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: *It does not matter which direction you rotate the wheel during the zero sequence, however changing the direction of rotation during the zero procedure will cause errors. Remember when rotating 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.*

1. Turn on the CT2-TEL.
2. While in *Run Mode* make sure the CT2-TEL is in *Vehicle Coordinates*
3. Lift the tires clear of the ground.

4. Press the *Setup Mode* button.
 - The blue Setup Mode light will illuminate.
5. 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 rotated at a steady rate, do not impart excessive acceleration or deceleration to the wheel while rotating it. This may cause calculation errors. To reduce errors, the CT2-TEL uses position-based sampling for this procedure.

6. Rotate the transducer. When rotating the transducer, never apply force to the tire. This can cause an error in the zero calculations. Always apply force to the hub bolts if possible. Rotate in one direction until the amber *Zero* light goes out, this should take 2 revolutions.

Using more than one sensor with stacked CT2s

7. You may rotate each transducer independently.
8. To zero only one wheel, you will need to turn off the CT2-TEL electronics, on the wheels that you do not want to zero, or un-stack them.
9. When the CT2-TEL completes the zero procedure, it will write the calculated offset value to the memory chip located in the Transducer ID dongle. This feature avoids the need to rezero the transducer when the power is interrupted or if a different CT2-TEL is used.

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.

1. While in *Vehicle Coordinates*, press the *Setup Mode* button.
2. The blue *Setup Mode* light will illuminate.

3. Coast the vehicle along a smooth and level section of road or parking lot.
4. Press the *Zero* button.
5. The amber *Zero* light will illuminate.
6. The CT2-TEL detects that the tires are turning and will use the average of the next 8 revolutions to compute the offset.
7. Once the procedure is complete, the light will go out.
8. When the CT2-TEL completes the zero procedure, it will write the calculated offset value to the memory chip located in the Transducer ID dongle. This feature avoids the need to rezero the transducer when the power is interrupted or if a different CT2-TEL is used.

Verifying the Zero Procedure

To check the quality of the zero, set the CT2-TEL 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 sensor 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 errors. Scaling errors will cause twice-per-rev variation errors. If excessive once-per-rev errors are seen, repeat the zero process. If excessive twice-per-rev errors are seen, perform a shunt sequence and then repeat the zero procedure.

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

CT2-TEL 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, position, and Autotune controls are located on the front panel.

Power Switch

Note: It is good practice to first connect all cables to the CT2 electronics before powering it up. In addition, the CT2-TEL reads important transducer information, from the Transducer ID dongle, at startup. Incorrect offsets and gain settings will be used if the dongle was not plugged in at power-up (Fault light would also be lit in this case).

The power switch turns the power on and off. When the CT2-TEL is turned on, it defaults to Run Mode. This will be indicated by green lights on the front panel. Sensor offsets, sensitivities and other information is read from the smart sensor during power up.

Data Valid, Induction Error, and Induction Tuning lights.

When the DATA VALID green led is lit, the Telemetry Stator is receiving good signal from the Telemetry Transmitter. Data valid led should be lit throughout testing.



The INDUCTION ERROR red led is lit when the Telemetry Stator is not receiving signal from the Telemetry transmitter location in the WFT. There are two possible reasons the Telemetry Stator may not be receiving signal. 1; Induction power is not providing sufficient power to the transmitter or 2; the Telemetry Stator is set to a frequency that does not match the Telemetry Transmitter for the WFT it is mounted with.

The INDUCTION TUNING blue led is lit while the Induction system is in the tuning process, which will happen after the AUTO TUNE button has been pressed.

Autotune Button

The AUTO TUNE button located on the front on the CT2-TEL starts the Induction Tuning process. This process finds the optimal frequency at which the Induction Power will operate.

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 Transducer ID dongle therefore it is not lost when power is interrupted or a different CT2-TEL is used. The CT2-TEL 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 on the next 2 revolutions. If the CT2-TEL 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. The shunt calibration sequence lasts about 30 seconds.

Mode

The Mode lights indicate whether the module is in Setup or Run Mode. The Mode button on top of the enclosure toggles between these two 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-TEL has been switched to Setup mode.

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 when 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.

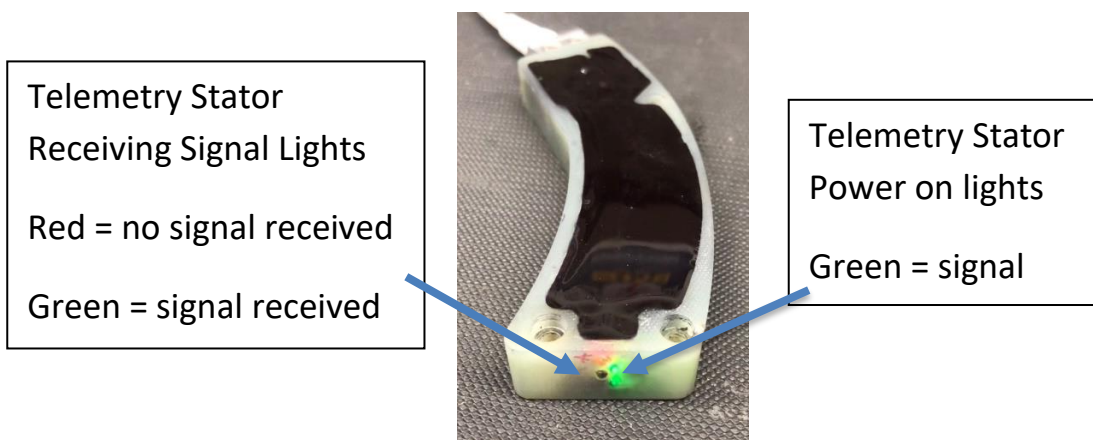
Position

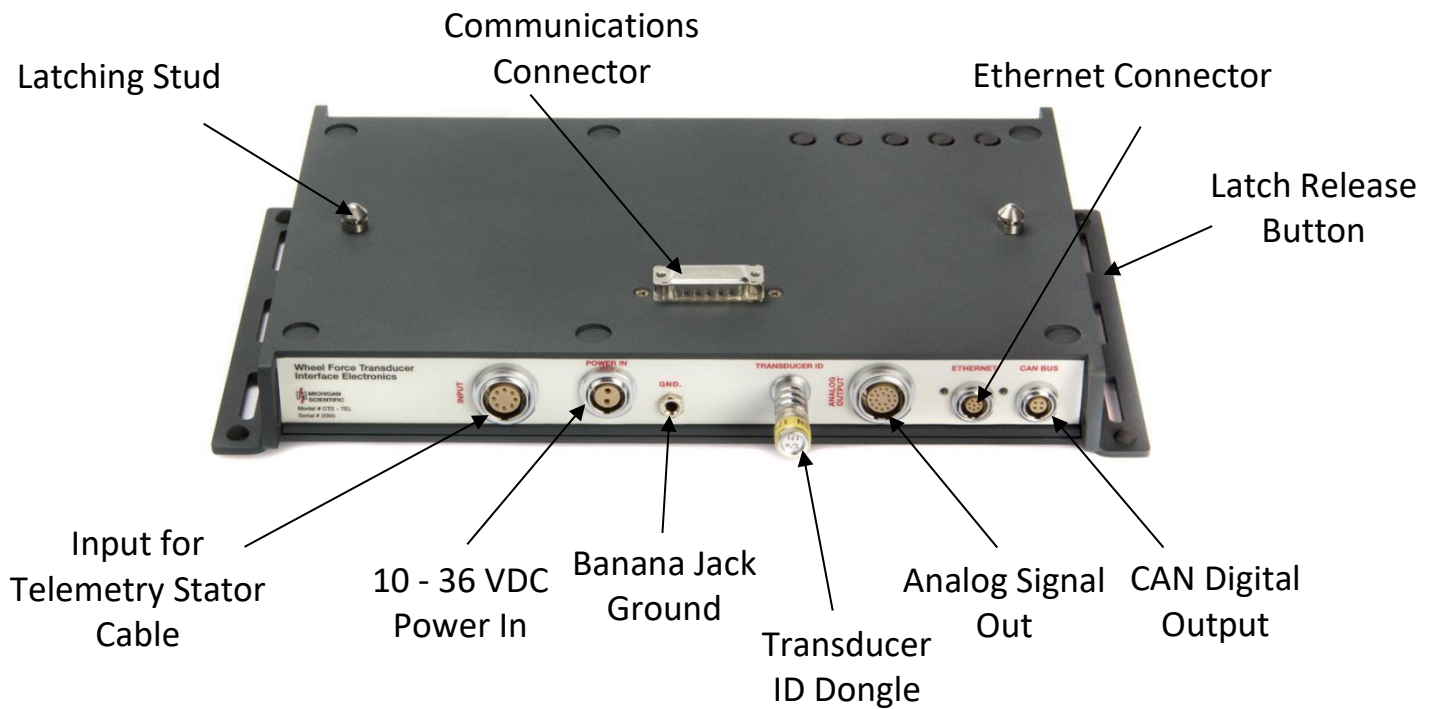
The position button allows the user to indicate to the CT2-TEL what wheel position the transducer is mounted. Different coordinate transformation equations are used on the right vs. the left side of the vehicle. This information is also used by the CT2-TEL electronics to indicate in the CAN DBC file 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-TEL units, the position information is shared between the CT2-TEL electronics. If two or more CT2-TEL electronics are assigned to the same wheel location, the position lights on those electronics will blink slowly to alert the user.

Indicator Light on Telemetry Stator

Each Telemetry Stator has four indicator lights. The two outer lights indicate if the Telemetry Stator is powered on. Flashing Green is powered on. The two inner lights indicate if the Telemetry Stator is receiving signal from the Telemetry WFT. Flashing Red means no signal is being received. Flashing Green means good signal is being received.





Connectors

Connectors located on the back panel of the CT2-TEL are for power, ground, Telemetry Stator Cable, analog output signal, Ethernet connection, CAN digital Signal output, and the Transducer ID dongle. The connectors located on top and bottom of the enclosure are used for communications between multiple CT2-TEL 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 or Ethernet output.

Output Channel Sensitivities

The output channels for all systems are scaled as shown below. The CT2-TEL allows the user to choose analog output ranges of $\pm 10V$, $\pm 5V$, $\pm 2.5V$, and $0-5V$. 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 $7,000 \text{ N/V}$ ($70,000 \text{ N} / 10 \text{ volts}$). If the analog outputs are set to $0-5$ Volt, X Force the sensitivity will be $28,000 \text{ N/Volt}$ with a 2.5 volt offset.

Output Channel Full Scale Sensitivities	
	LW65
X Force	7,000 N/V (1,574 lbs/V)
Y Force	4,000 N/V (899 lbs/V)
Z Force	7,000 N/V (1,574 lbs/V)
X Moment	1,100 N-m/V (811 lb-ft/V)
Y Moment	1,100 N-m/V (811 lb-ft/V)
Z Moment	1,100 N-m/V (811 lb-ft/V)
Velocity	200 RPM/Volt (default setting)
Position	0-360 deg

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

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

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

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

System Delay

Analog Signal Outputs

Due to filtering in the telemetry system there is a signal delay on the analog channels of the system. The delay is a fixed delay of 20.69 milliseconds and applies to all the channels. When using the wheel force transducers with other sensors the signal delay should be corrected. The correction can either be done in post-processing or by creating calculated channels in the data acquisition and performing a time based shift in real time.

CAN Bus Signal Outputs

If using the CAN Bus signal outputs there will be an additional 18 to 32 millisecond delay. This delay is in addition to the 20.69 millisecond analog delay. The total system delay will be between 38.7 and 52.7 milliseconds. The CAN Bus signal delay depends on the Output Rate selected. The filtering changes at different Output Rates and affects the signal delay. The delay for your sample rate can be found in Appendix 5, page 75.

Multiple CT2-TELS



Each CT2-TEL is used with one Wheel Force Transducer. When using multiple Wheel Load Measurement systems, the CT2-TEL 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-TEL electronics communicate with each other using a digital bus interface. This allows the operator to control all of the CT2-TELS with one set of controls. Notice that the control buttons are located on top of the enclosure. When one CT2-TEL is stacked on top of another, the buttons on the lower one are covered. All functions are controlled by the top CT2-TEL 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-TEL.

The power supply cable can be connected to any one of the CT2-TEL electronics. That CT2-TEL will supply power to the rest in the stack.

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

Up to four CT2-TEL 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-TEL requires 9 to 36 VDC power. Power draw is less than 1.5 amps, typically under 1 amp at 13.8 volts for each WFT system.

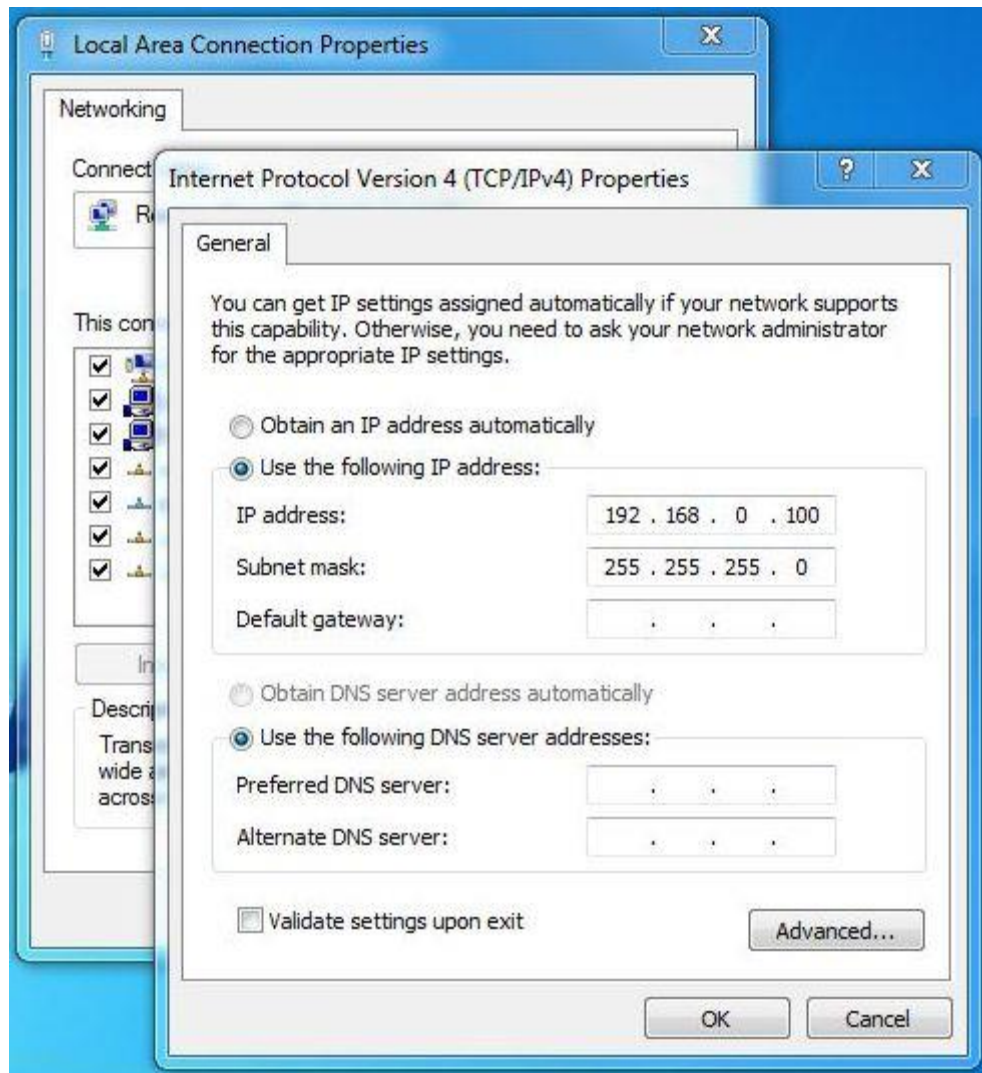
One power cable can power up to four stacked CT2-TELs. Michigan Scientific provides a power cable for every two CT2s purchased. If additional cables are required, contact Michigan Scientific.

Web Page Selectable Options

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

To access the web page.

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



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

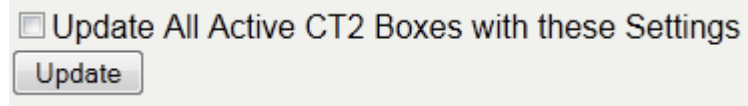
Note: To make system changes, all CT2s must be connected to their respective wheel force transducer and powered up.

CT2 Serial Number

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

The CT2 that the Ethernet cable is connected to will check for the presence other CT2 electronics. These other units need to be stacked together and all units need to be

turned on. If other units are present, and turned on, the serial numbers of these units will appear in the pull down menu. Selecting a different serial number allows the user to set up each CT2 separately.



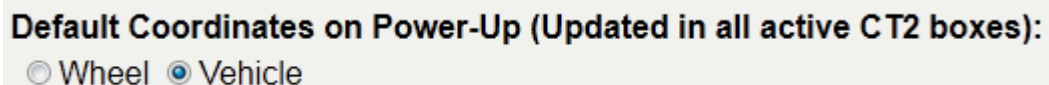
☐ Update All Active CT2 Boxes with these Settings

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

The Wheel Force Transducer Information shown below serial number is information for the WFT that is connected to the selected serial number.

Default Coordinates on Power-Up

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

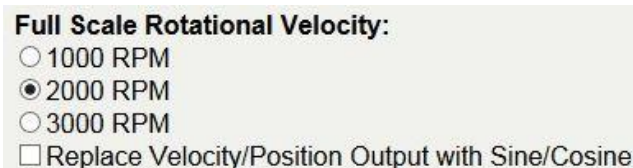


Default Coordinates on Power-Up (Updated in all active CT2 boxes):
☐ Wheel ☒ Vehicle

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

Full Scale Velocity

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



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

Analog Output Sensitivities Options.

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-TEL changes the output sensitivity to use the full scale range.

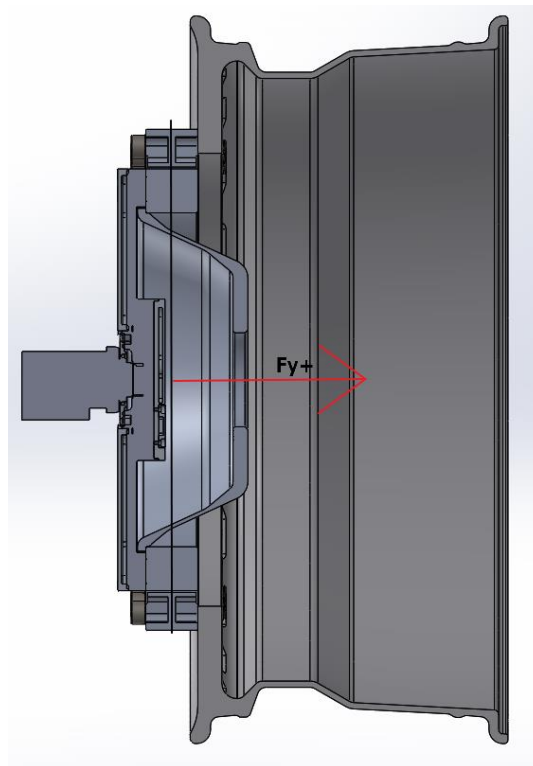
Analog Output Range:

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

Note: The Analog outputs use a 16 bit DAC. When a different voltage range is selected, the resolution of the data is no longer 16 bits because the CT2-TEL 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.

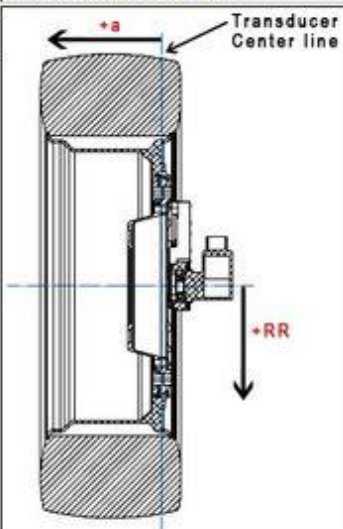
Measurement Origin

The default measurement origin of the LW65 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 0.70" (17.78 mm).



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

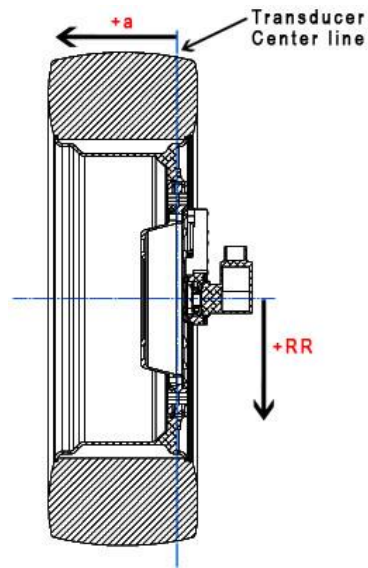
MSC recommends leaving ‘RR’ value at 0, as this will leave the measurement origin on the center of rotation. While the feature is available, entering the ‘RR’ will move the measurement origin to the tire patch. Since the Rolling Radius does change dynamically during testing MSC recommends leaving the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

Measurement Origin	Definition of "a" & "RR"
☐ Center of WFT ☒ User Defined with Respect to Center of WFT	 The diagram shows a cross-section of a tire assembly. A horizontal line represents the 'Transducer Center line'. A vertical line represents the 'Center of WFT'. The distance between these two lines is labeled '+a'. The distance from the 'Center of WFT' to the 'Rolling Radius' is labeled '+RR'.
Units of Entered Values: ☒ Inches ☐ Millimeters	
Measurement Center Offset along Y-Axis (a): 5.00 (-43 to 43 inches) Rolling Radius (RR): 0.00 (0 to 157 inches)	

To use this option:

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

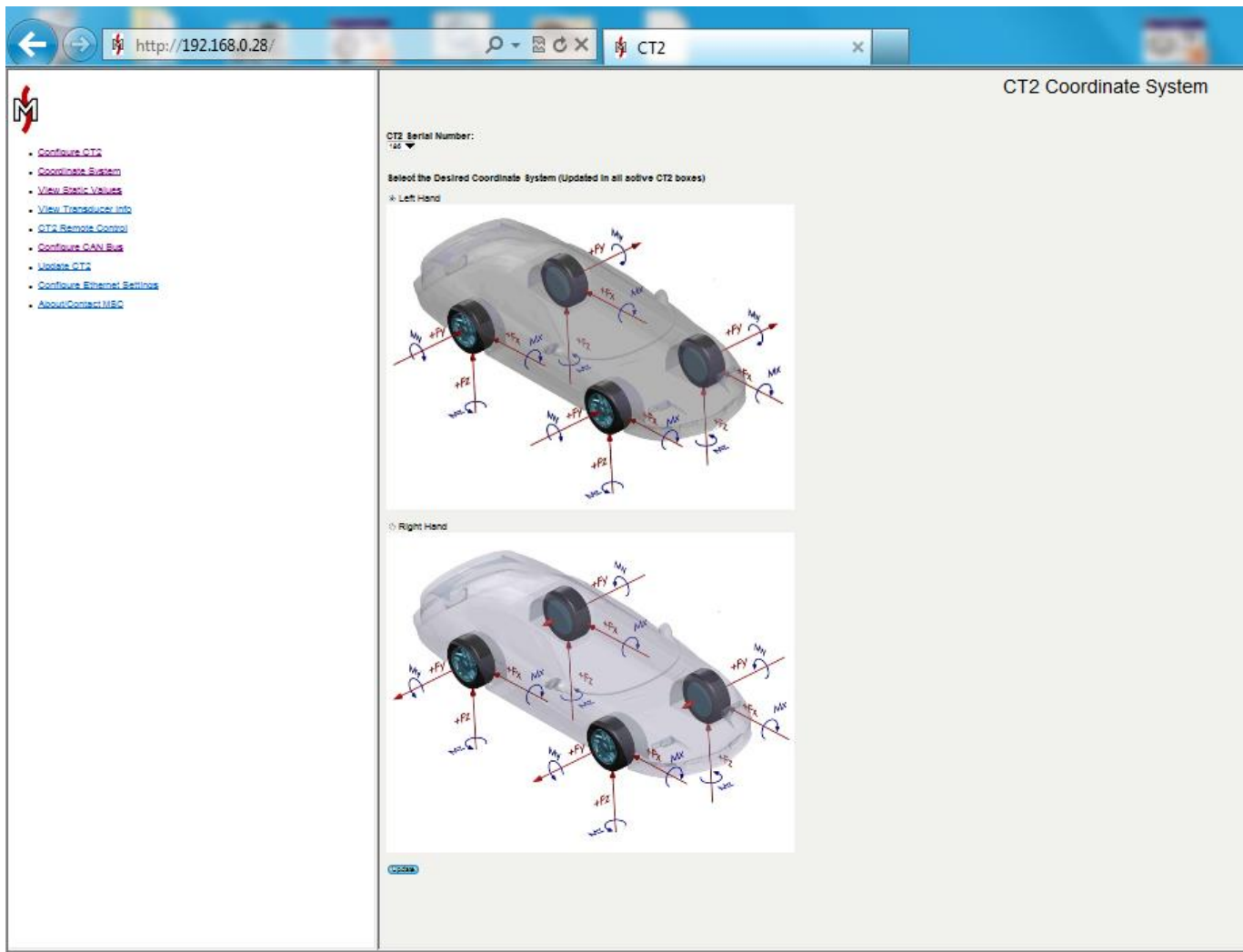
The image below indicates “a” and “RR” values.



Note: Only the M_x and M_z 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. M_y is not changed because the location of the tire patch can vary enough to introduce large errors into the calculation.

Changing WFT Coordinate System

The default WFT coordinate system is the Left Hand Coordinate System shown below. In the Coordinate System tab on the CT2 webpage the WFT coordinate system can be switched to a Right Hand Coordinate System by checking the button labeled “Right Hand” then clicking update at the bottom of the page. This will update all CT2 boxes stacked and powered up. The WFT Coordinate System is explained further on page 59.



Static Values

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



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

Static Values

Forces: N, Moments: Nm, Acceleration: g

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

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

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

Page Refresh Rate:

☐ None
☐ 1 Second
☒ 3 Seconds
☐ 5 Seconds

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

Transducer Information

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

Transducer Info

CT2 Serial Number:
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 Remote Control

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

CT2 Remote

Remote Control the CT2(s) Here:

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

CT2 CAN Bus Configuration

CAN bus data output settings are configured using the “CT2 CAN Bus Configuration” option located on the left side of the web page. Here the Baud Rate, Output Rate, and Desired Units are set. After making any changes click update and these setting will update for all CT2 boxes that are stacked together.

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

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

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

If using a 1 mbps Baud rate the following output rates can be used. If a lower Baud rate is used, the output rates must be lowered proportionally.

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

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

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

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

500.0 Samples/Second

There is signal delay caused by filtering performed by the CT2 to decimate the data down to the selected output rate. The exact delay depends on output rate selected by is usually around 25 milliseconds. See Appendix 5 for the exact delay. The -3db point of the decimation filter is approximately 40% of the selected output rate.

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

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

☒ lbs, lb-ft

☐ N, Nm

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

Output Accelerometers on CAN Interface

☒ Output Accelerometers

CAN Bus Termination

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

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

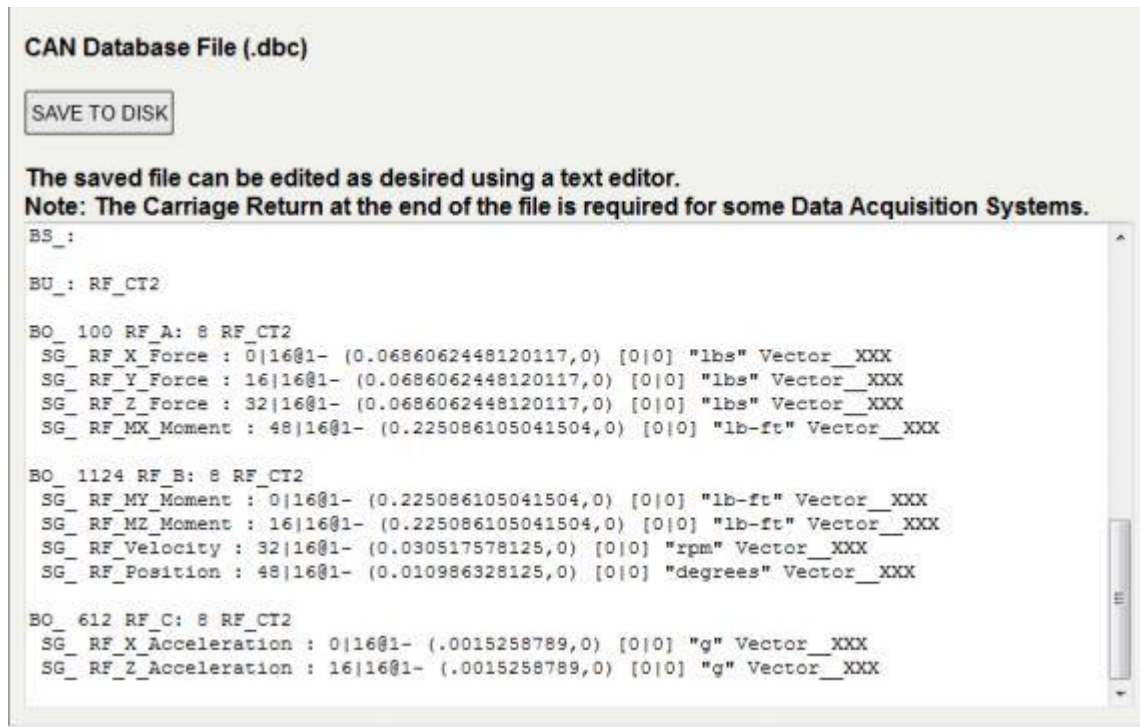
Msg ID(Hex)	Box SN	Box Pos	Msg Channels	CAN Bus Termination
0x 19A	445	LF	FX, FY, FZ, MX	☒
0x 59A	445	LF	MY, MZ, Velocity, Position	
0x 39A	445	LF	X Accel, Z Accel	
0x 1C8	446	RF	FX, FY, FZ, MX	☐
0x 5C8	446	RF	MY, MZ, Velocity, Position	
0x 3C8	446	RF	X Accel, Z Accel	
0xNA	NA	LM	FX, FY, FZ, MX	NA
0xNA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

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

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

DBC file creation

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



Firmware version CT2_T005_T023_D016_E.frm and higher have the CAN message IDs fixed based on Wheel Position. That means you only need 1 .dbc file per WFT model. Previous firmware versions assigned CAN message IDs based on CT2 serial number.

Updating Firmware in CT2

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

Update CT2

CT2 Firmware Information & Last 10 History Codes:

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

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

Upload a New Firmware File to the Highlighted CT2 Above:

Upload Progress:

Writing Progress:

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

To update the CT2:

- Connect the Ethernet cable to the electronics to be updated.
- Press the Browse button and select the installation file.
- Press the Upload button
- The file will be uploaded. Follow the prompts on the web page.

- Once complete you will be prompted to cycle power on the CT2.
- Once power has been cycled, the new firmware is ready to be used.

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

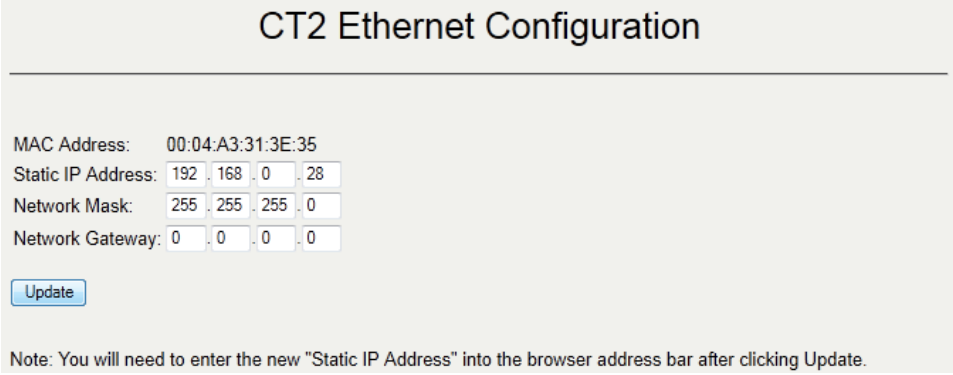
Note: *Only the CT2 connected to the Ethernet Cable will be updated. Each CT2 electronics must be updated separately.*

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

With firmware version CT2_T005_T019_D009_E.frm or higher, MSC can send a calibration file to update the dongle smart sensor which can be loaded through the CT2-TEL. This could be helpful is a dongle needs to be replaced.

CT2 Ethernet Configuration

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



CT2 Ethernet Configuration

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

Static IP Address: 192 . 168 . 0 . 28

Network Mask: 255 . 255 . 255 . 0

Network Gateway: 0 . 0 . 0 . 0

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

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

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

- Shut off the power switch on the CT2

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

WFT Stator Reprogramming

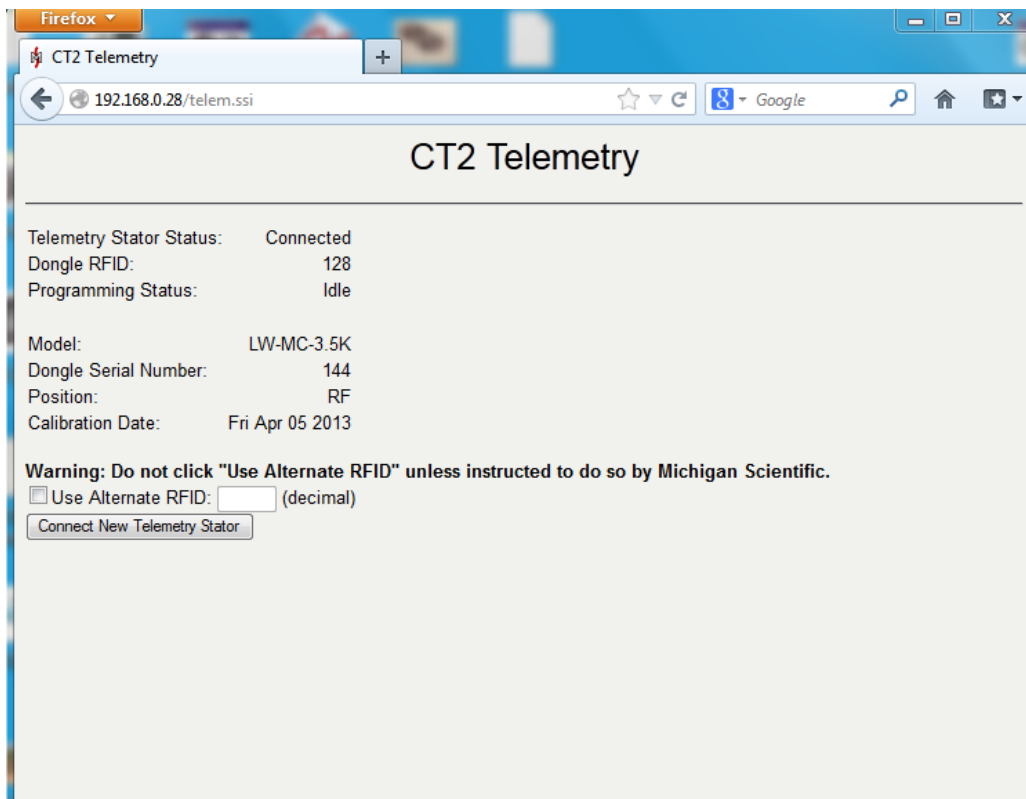
Background

WFT Stator Reprogramming is only needed if a spare Telemetry Stator needs to be swapped for an originally mated Telemetry Stator.

Procedure

Find out the serial number of the transducer that you want to use this Telemetry Stator with. Find the dongle with the matching serial number and plug it into the CT2-TEL and plug the new Telemetry Stator into the same CT2-TEL.

Power up the CT2-TEL and connect to the webpage. Add the extension “/telem.ssi” to the web address.



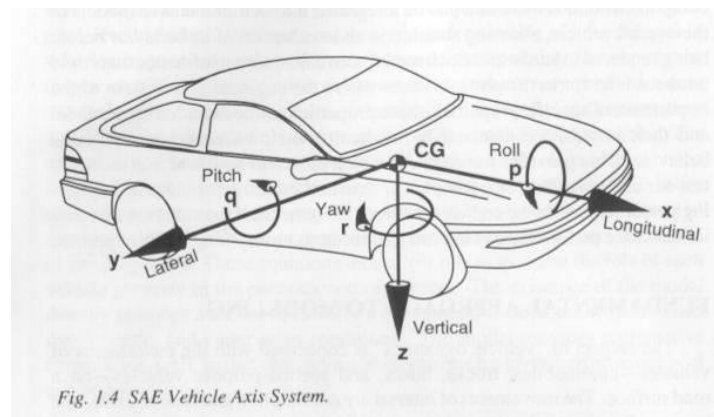
The webpage above should appear and list a transducer/Dongle RFID. Click on the “Connect New Telemetry Stator” button. Once the Telemetry Stator has been reprogrammed the Telemetry Stator Status will be “Connected”. Once this is complete, proceed with installation. Record which Telemetry Stator is programmed at which frequency if you make a change.

Sampling Frequency

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

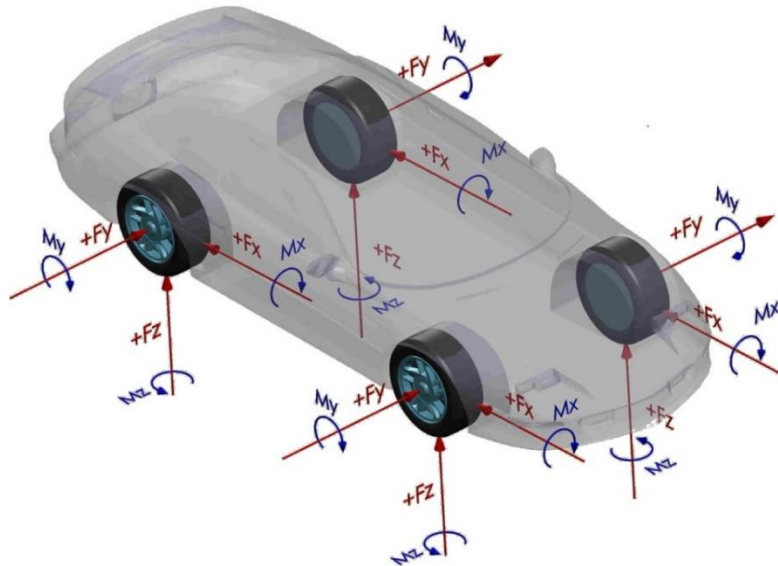
WFT Coordinate System

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



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

moment application (i.e. forces applied to the tire in the direction indicated by the arrows will result in a positive output).



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

The WFT channels are defined as:

Fx = Longitudinal Force

Fy = Lateral Force

Fz = Vertical Force

Mx = Roll Moment (Wheel Camber)

My = Pitch Moment (Wheel Torque)

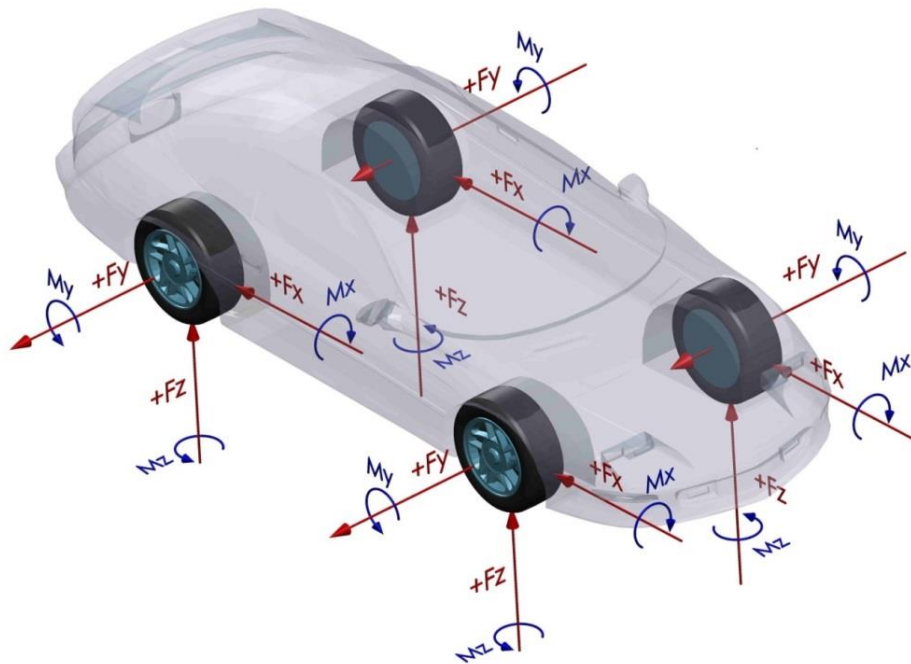
Mz = Yaw Moment (Wheel Steer)

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).



Weatherproofing

The WFT system is IP67 rated when Telemetry Ring is mated to the Transducer.

Recommended Static Load Rating and Overload

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

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

Transducer Field Checks

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

1. Perform a Shunt Calibration. If no fault light comes on, this means the Shunt value is within 2.5% of the Factory Shunt calibration.
2. The transducer off-set is reported on the NIST calibration sheet. If the transducer bridge has some damage, it would likely change the transducer off-set. If the off-set has not changed by less the 0.10 volts, and the WFT passes the Shunt, it should be in good condition

To check the transducer off-set perform the following.

- Remove hub and wheel adapters.
- Set the transducer flat on the bench.
- Place the Telemetry Stator in proximity to the Telemetry Ring of the WFT. Align them with the Alignment Tool.

- Connect the Telemetry Stator to the CT2-TEL.
- Power up the CT2-TEL. Autotune if Data Valid light is not lit.
- Press the *Mode* button to put the CT2-TEL into *Setup* mode.
- Record the output for each channel.

Factory Calibration

MSC recommends bi-annual calibrations for all its Wheel Force Transducers. These can only be performed properly by MSC. MSC can calibrate all WFTs in Charlevoix, MI USA. Calibrations for car to light truck sized WFTs can also be performed in Shanghai, China.

Calibration values and cross-axis sensitivity coefficients are programmed into the dongle smart sensor for each transducer. The wheel force transducer was statically calibrated in an Automated calibration machine with calibration adapters replicating rim and hub adapters.

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

Troubleshooting

Symptom	Possible Causes	Solution
CT2-TEL Does not power up when the power switch is turned on.	Power cord not connected to power. Power supply polarity is incorrect.	Check that power cord has power supplied to it and try to power up the CT2-TEL again. Check polarity, if incorrect, reverse power supply leads and try to power up the CT2-TEL again.
Fault light illuminates at startup	Transducer ID Dongle not plugged in.	Plug in Transducer ID dongle corresponding to transducer being used with CT2-TEL
Induction Error LED is lit ON Power Up	Telemetry Stator not receiving signal from WFT transmitter or not plugged in.	1. Check alignment of TEL-STATOR to WFT 2. Perform Induction Autotune. 3. Reprogram Telemetry Stator to match frequency of WFT transmitter.
Induction Error LED is lit AFTER AUTOTUNE SEQUENCE IS FINISHED	Telemetry Stator not receiving signal from WFT transmitter. Insufficient Power to CT2-TEL	1. Check alignment of TEL-STATOR to WFT 2. Reprogram Telemetry Stator to match frequency of WFT transmitter, then repeat Autotune Make sure power supply has enough current. If power by vehicle, keep vehicle running.
During Angle Zero procedure, the LED does not start flashing	Index pulse is not seen by encoder pick-up.	Alignment between Telemetry Stator and Transducer not set properly. Specifically check concentricity with Alignment Tool.
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. Transducer is out of tolerance. CT2 failed to record data in memory chip. Insufficient power provided by Induction	Jack up vehicle, cycle power, and repeat the shunt sequence. Send the transducer in for checkout and possible repair. Check the cable connections, cycle power, and repeat the shunt sequence. See Induction Error LED is lit ON Power Up or Induction Error LED is lit AFTER AUTOTUNE SEQUENCE IS FINISHED

Symptom	Possible Causes	Solution
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 adapter. If offset goes away, check adapter to see that it is not damaged. If offset does not go away, unbolt the hub adapter. If offset goes away, check adapter to see that it is not damaged. If offset does not go away, send transducer in to Michigan Scientific for Checkout and repair.
Data has once-per-revolution wave form.	The zero is not correct. The Zero Angle is not correct. The tire can have stiffness variations, which will appear as once-per-revolution variations. This is a real force.	Perform zero procedure. Perform a Zero Angle Procedure If force variation is not acceptable, replace the tire.
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 Sine 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.	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
	Angle Zero not performed.	Perform Angle Zero
	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 minimal force on the WFT. 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.
	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. Signal cable from sensor has been disconnected. Signal Cable from sensor 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. Also check alignment between transducer and TEL-STATOR with alignment tool. 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.	A severe event caused some shifting in the bolted joints between the sensor and adapters. A severe event overloaded the sensor.	While it is not common, a severe event could cause some offset in channels. Perform the zero sequence. Check the sensor offsets. Remove the wheel and hub adapters. Change the CT2 to Setup Mode Check the offsets for each channel with a voltmeter. If the offsets have changed, send the sensor 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 Transducer ID dongle Sensor is damaged. Telemetry 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 Transducer ID dongle is being used with the sensor. Check the sensor 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. Zero Angle not set properly Proper coordinate system not selected	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 Verify which Coordinate System has been selected in CT2 webpage
Angle reference incorrect	Reference angle not set properly	Run the Zero Angle procedure and use an inclinometer to ensure that it is set properly.

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	

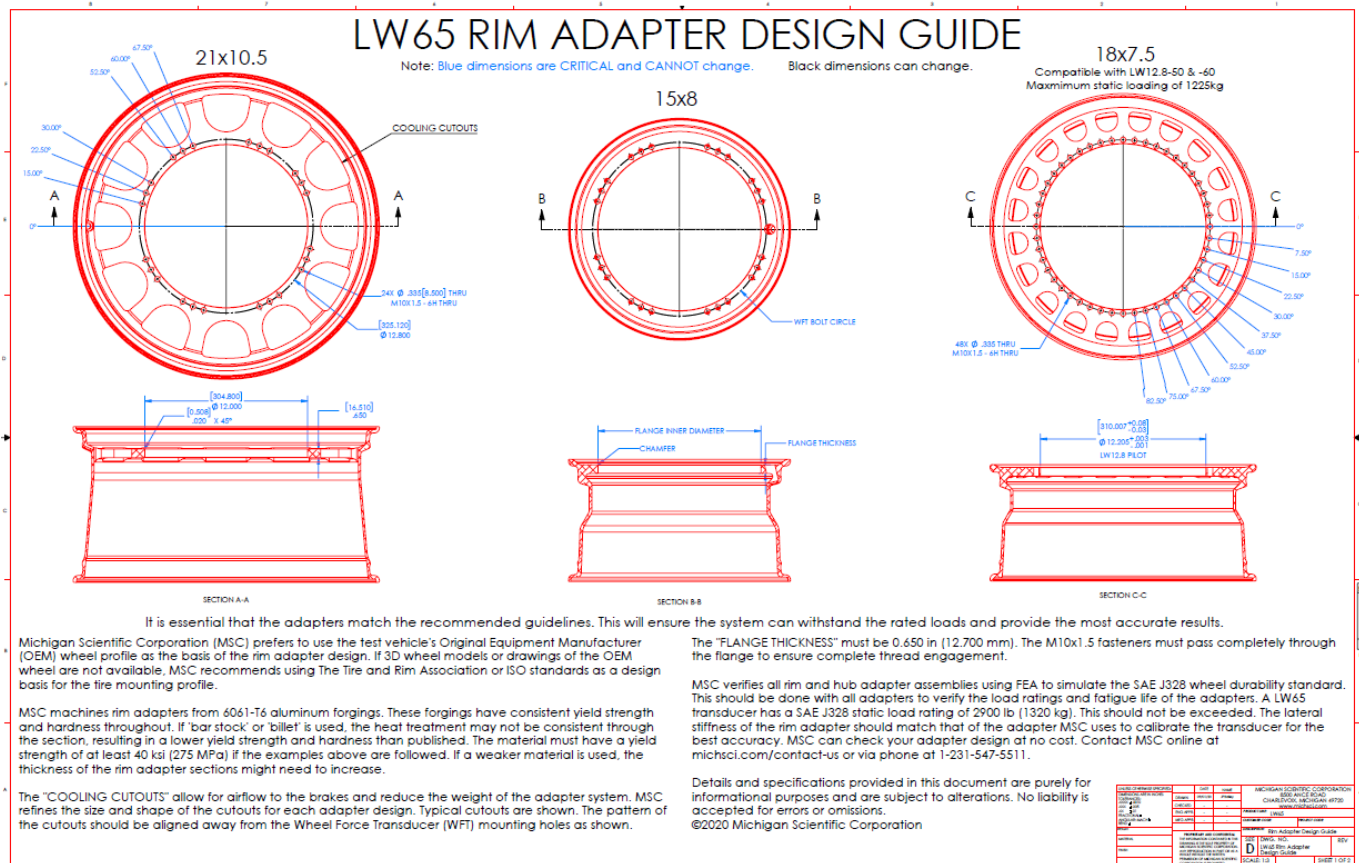
CT2 Signal Out Connector Pin-Out

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

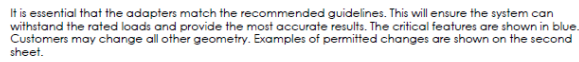
Appendix 2- Adapter Design Guidelines

The latest Adapter Guidelines can be downloaded from our website:

<https://www.michsci.com/products/transducers/wheel-force-transducers/lw65/>



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



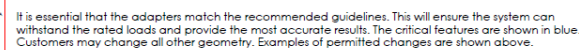
Detail D shows geometry that reduces the material stresses to increase the adapter fatigue life.

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 LW65 transducer has a SAE J328 static load rating of 2900 lb (1320 kg). This should never be exceeded.

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Michigan Scientific Corporation 13335 River Road Farmington Hills, MI 48334 Tel: 248-859-3000 Fax: 248-859-3000 E-mail: info@msc-inc.com		(Unit) (Rev) (Drawing) (Issue) (Date) (Date) (Scale) (Scale) (Notes) (Notes)	MICHIGAN SCIENTIFIC CORPORATION 13335 RIVER ROAD FARMINGTON HILLS, MICHIGAN 48334 www.msc-inc.com Tel: 248-859-3000 Fax: 248-859-3000 E-mail: info@msc-inc.com

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



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[illegible]

Appendix 3 - Example Quick Reference Calibration Sheet

 MICHIGAN SCIENTIFIC corporation		8500 Ance Road Charlevoix, MI 49720 Phone: (231) 547-5511 Fax: (231) 547-7070 www.michsci.com																																
QUICK REFERENCE SHEET TRANSDUCER CALIBRATION																																		
TRANSDUCER SERIAL NUMBER: LW65- 916	CALIBRATION DATE: September 29, 2020																																	
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: <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="text-align: center;">Fx: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">1,574 lb</td> <td style="text-align: center;">7,000 N</td> </tr> <tr> <td style="text-align: center;">Fy: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">899 lb</td> <td style="text-align: center;">4,000 N</td> </tr> <tr> <td style="text-align: center;">Fz: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">1,574 lb</td> <td style="text-align: center;">7,000 N</td> </tr> <tr> <td style="text-align: center;">Mx: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">811 lb ft</td> <td style="text-align: center;">1,100 N m</td> </tr> <tr> <td style="text-align: center;">My: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">811 lb ft</td> <td style="text-align: center;">1,100 N m</td> </tr> <tr> <td style="text-align: center;">Mz: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">811 lb ft</td> <td style="text-align: center;">1,100 N m</td> </tr> <tr> <td style="text-align: center;">Accel X: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">10 g</td> <td style="text-align: center;">98 m/s²</td> </tr> <tr> <td style="text-align: center;">Accel Z: Sensitivity :</td> <td style="text-align: center;">1 Volt =</td> <td style="text-align: center;">10 g</td> <td style="text-align: center;">98 m/s²</td> </tr> </table>			Fx: Sensitivity :	1 Volt =	1,574 lb	7,000 N	Fy: Sensitivity :	1 Volt =	899 lb	4,000 N	Fz: Sensitivity :	1 Volt =	1,574 lb	7,000 N	Mx: Sensitivity :	1 Volt =	811 lb ft	1,100 N m	My: Sensitivity :	1 Volt =	811 lb ft	1,100 N m	Mz: Sensitivity :	1 Volt =	811 lb ft	1,100 N m	Accel X: Sensitivity :	1 Volt =	10 g	98 m/s ²	Accel Z: Sensitivity :	1 Volt =	10 g	98 m/s ²
Fx: Sensitivity :	1 Volt =	1,574 lb	7,000 N																															
Fy: Sensitivity :	1 Volt =	899 lb	4,000 N																															
Fz: Sensitivity :	1 Volt =	1,574 lb	7,000 N																															
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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): <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="text-align: center;">Fx: Shunt= 4.581 V*</td> <td style="text-align: center;">7,209 lb</td> <td style="text-align: center;">32,064 N</td> </tr> <tr> <td style="text-align: center;">Fy: Shunt= 3.856 V*</td> <td style="text-align: center;">3,467 lb</td> <td style="text-align: center;">15,422 N</td> </tr> <tr> <td style="text-align: center;">Fz: Shunt= 4.576 V*</td> <td style="text-align: center;">7,201 lb</td> <td style="text-align: center;">32,032 N</td> </tr> <tr> <td style="text-align: center;">Mx: Shunt= 4.521 V*</td> <td style="text-align: center;">3,668 lb ft</td> <td style="text-align: center;">4,973 N m</td> </tr> <tr> <td style="text-align: center;">My: Shunt= 4.467 V*</td> <td style="text-align: center;">3,625 lb ft</td> <td style="text-align: center;">4,914 N m</td> </tr> <tr> <td style="text-align: center;">Mz: Shunt= 4.480 V*</td> <td style="text-align: center;">3,635 lb ft</td> <td style="text-align: center;">4,928 N m</td> </tr> </table>			Fx: Shunt= 4.581 V*	7,209 lb	32,064 N	Fy: Shunt= 3.856 V*	3,467 lb	15,422 N	Fz: Shunt= 4.576 V*	7,201 lb	32,032 N	Mx: Shunt= 4.521 V*	3,668 lb ft	4,973 N m	My: Shunt= 4.467 V*	3,625 lb ft	4,914 N m	Mz: Shunt= 4.480 V*	3,635 lb ft	4,928 N m														
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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 <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="text-align: center;">Speed Sensitivity :</td> <td style="text-align: center;">10 Volts =</td> <td style="text-align: center;">2,000 RPM</td> </tr> <tr> <td style="text-align: center;">Position Sensitivity :</td> <td style="text-align: center;">10 Volts =</td> <td style="text-align: center;">360 Degrees</td> </tr> </table>			Speed Sensitivity :	10 Volts =	2,000 RPM	Position Sensitivity :	10 Volts =	360 Degrees																										
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Speed is updated at each encoder pulse. Speed in mph, or kph, can be calculated if the rolling radius is known.																																		

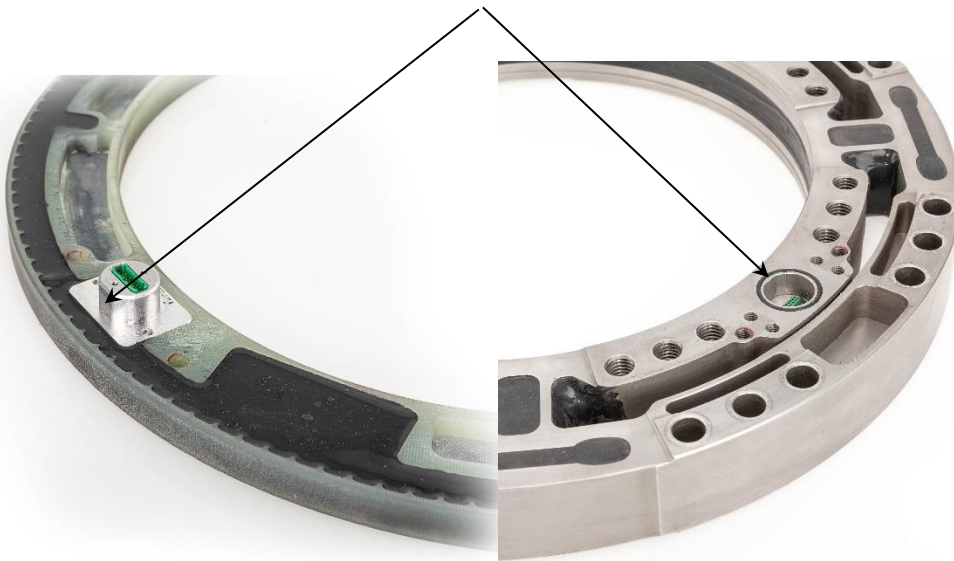
Appendix 4 – Changing from Slip Ring to Telemetry Installation

When the LW65 is used with a Slip Ring the Connectors point outward and mate with the Amplifier package. When the LW65 is used with Telemetry the connectors point inboard and mate with the Telemetry Encoder Ring. LW65 can be switched between Slip Ring system and Telemetry System by the User.

Mating with Telemetry Encoder Ring

- Identify the flat on one side of the connector guide of the Telemetry and align it with the mating flat on the transducer. Then carefully mate the Telemetry Ring with the Transducer.

Align Flat of Telemetry Package with Flat in Transducer

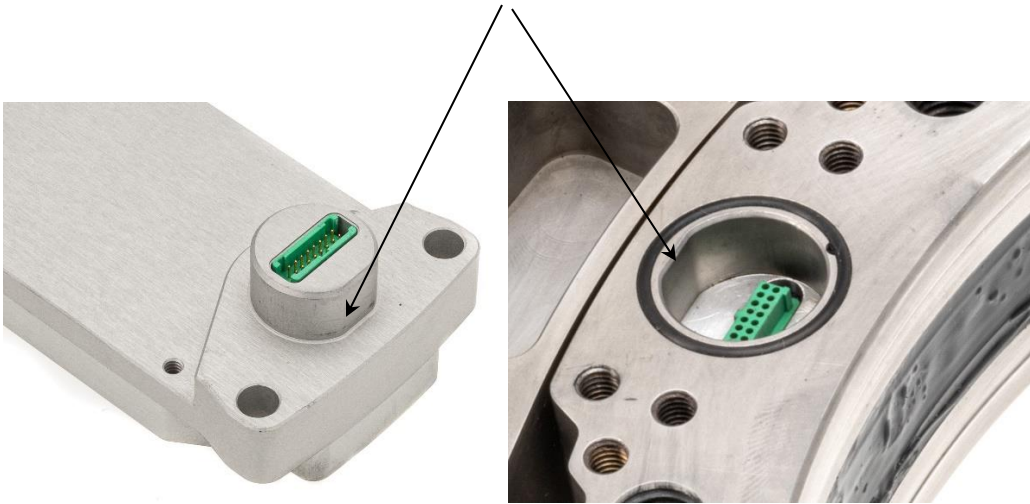


- Secure the Telemetry Encoder Ring with M5x20mm stainless steel torx-head screws a small amount of anti-seize on the thread and with provided washers. Tighten M5 Torx bolts to 7 N.m (60 in-lb) torque.

Mating with Amplifier Package

- Identify the flat on one side of the connector guide of the Amplifier and align it with the mating flat on the transducer. Then carefully mate the Amplifier with the Transducer.

Align Flat of Telemetry Package with Flat in Transducer



- Secure the amplifier with M5x20mm stainless steel socket-head screws a small amount of anti-seize on the thread and with provided washers. Tighten M5 bolts to 7 N.m (60 in-lb) torque.

Appendix 5 – CAN Signal Delay Calculation

Telemetry CT2: (Add to 20.7 ms Analog signal delay to CAN delay)

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

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

$$\text{Approximate Through Delay in ms} = ((63.5 / (\text{CAN Data Rate in Hz} * 8)) + 0.0018) * 1000$$

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

$$\text{Approximate Through Delay in ms} = ((63.5 / (\text{CAN Data Rate in Hz} * 4)) + 0.0018) * 1000$$

For CT2 CAN Output Sample Rates ≥ 1000 Hz:

$$\text{Approximate Through Delay in ms} = ((63.5 / (\text{CAN Data Rate in Hz} * 2)) + 0.0018) * 1000$$

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

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

Notes: