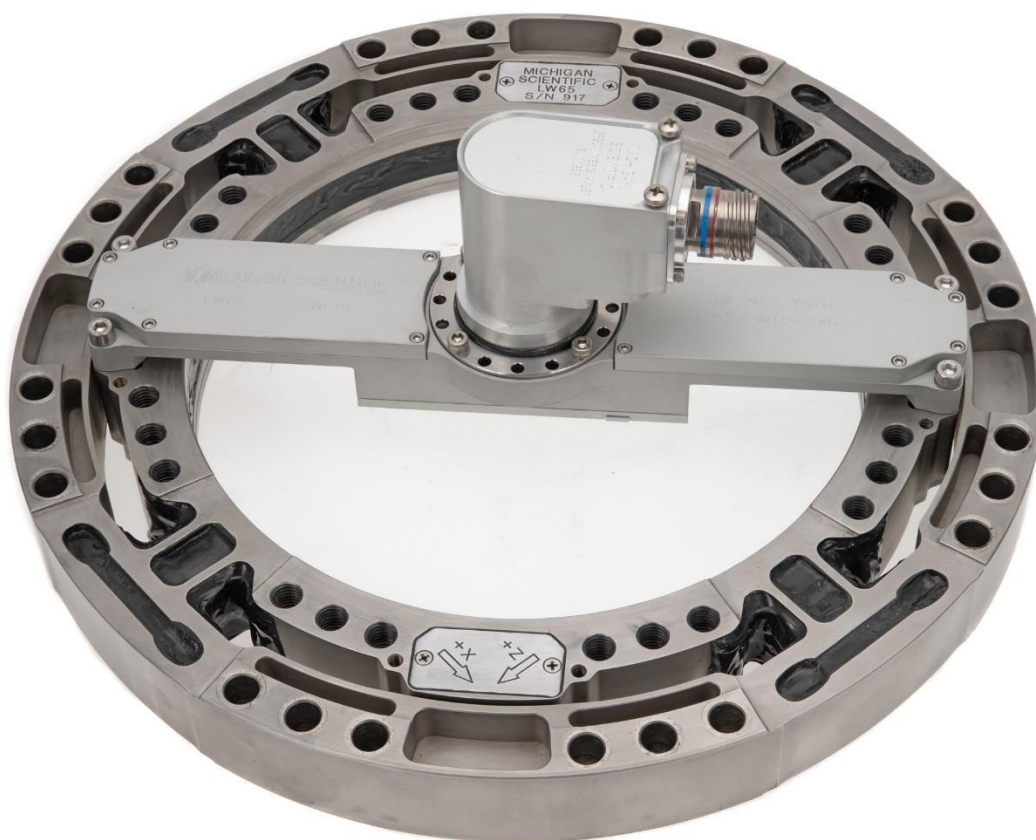


Michigan Scientific Corporation

Wheel Force Transducer System



Model: LW60 & LW65 with CT3
for Slip Ring & Non-spinning set-ups

For Cars, SUV, and Light Truck



MICHIGAN SCIENTIFIC
corporation

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Technical Support

For technical support, contact Michigan Scientific Corporation.

Michigan Scientific Corporation

Milford, MI Location

321 E. Huron St.

Milford, MI 48381

ph: 1-248-685-3000

Charlevoix, MI Location

8500 Ance Rd.

Charlevoix, MI 49720

ph: 1-231-547-5511

<http://www.michsci.com/>

mscinfo@michsci.com

wft@michsci.com

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Introduction

The Michigan Scientific Wheel Force Transducer (WFT) system is a 6-axes transducer that measures forces and moments on a vehicle wheel. Michigan Scientific WFTs are known for their accuracy, reliability, simple installation, ease of set-up, and use.

The WFT gets mounted to a Rim Adapter and hub adapter. Once bolted together, this assembly replaces the production wheel. A standard tire is mounted to the rim adapter in the same manner as it is mounted to a production wheel. The system is designed such that all forces and moments on the wheel must pass through the WFT, where they are measured, before being transferred to the vehicle hub.

The WFT has six independent strain gauge bridges that measure the forces and moments. Each WFT contains approximately 100 strain gauge elements. The transducer is designed to have low cross talk between channels and to be insensitive to temperature change and magnetic fields. An Amplifier package gets bolted to the WFT and provides excitation and amplification to the strain gauged bridges. Each Amplifier package has internal ± 100 g Triaxial accelerometers, and also digitizes all signals before transmitting them to the CT3 User Interface. Each Amplifier package contains a removable Smart Sensor. The Smart Sensor contains all the calibration information, last Zero off-set values, and test set-up selections. The Smart Sensor could be removed and installed into a spare amplifier, if needed, without any loss of accuracy.

A consequence of incorporating the sensing elements of the Rotating WFT, is that a Coordinate Transformation is required to provide the output signals in a fixed coordinate system. Coordinate transformation is handled by the CT3 User Interface Box. In addition, the CT3 handles Zeroing, Cross-talk correction, Shunt Calibration system check, Polarity Correction to put all WFTs into a global vehicle coordinate system, and movement of measurement origin. Standard signal outputs for CT3 are CAN 2.0, CANFD, and Ethernet via OpenDAQ. With additional modules, CT3 can provide Analog signal outputs or output through EtherCat. The CT3 has an internal webpage for selecting set-up options, are accessed through USB or Ethernet connection to a laptop or mobile device.

The CT3 can be operated in Spinning Mode for road tests, in which Coordinate Transformation is active, or in Non-Spinning Mode, which is used for non-spinning Test Bench application, like MTS329 or other Vehicle Simulators.

Specifications

MSC LW60 & LW65
6-Axis Wheel Force Transducer
Stainless Steel

<i>Full Scale Capacities</i>	<i>LW60</i>	<i>LW65</i>
Fx, Fz	60 kN (13,400 lbf)	65 kN (14,500 lbf)
Fy	35 kN (7850 lbf)	35 kN (7850 lbf)
Mx, Mz	8.0 kN.m (5900 lb.ft)	10.5 kN.m (7,700 lb.ft)
My	9.0 kN.m (6650 lb.ft)	10.5 kN.m (7,700 lb.ft)
Accel X, Accel Y, Accel Z	± 100g	±100g
Max Recommended Static Weight	1225 kg (2700 lb.)	1315 kg (2900 lb.)

Other

Transducer	4 arm strain gage bridges
Nonlinearity	Less than 0.25% of full-scale
Hysteresis	Less than 0.5% of full-scale
Cross Axis Sensitivity after correction	<0.5% of full-scale
Radial Sensitivity Variation	<0.3% of radial load
Bridge Resistance	233 to 1400 ohm, axis
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

Mass of Components, Typical

Component	LW60	LW65
Wheel Force Transducer	5.7 kg (12.5 lb)	8.0 kg (17.5 lb.)
Amplifier Package	0.45 kg (1.0 lb)	0.45 (1.0 lb.)
Slip Ring and Encoder	0.2 kg (0.5 lb.)	0.2 (0.5 lb.)
CT3 Electronics	1.1 kg (2.5 lb.)	1.1 (2.5 lb.)

System Components

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

Transducer



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

CT3 Electronics



CT3 Electronics. This is the User Interface for WFT System. Detailed instructions start on page 33. Pictured above with the CT3 with CT3 baseplate installed.

Amplifier



The amplifier provides excitation and amplification for the 6 transducer strain gage bridges. The amplifier package contains internal $\pm 100g$ X, Y & 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 D3 amplifiers have a removable smart sensor. The smart sensor contains all the calibration information, off-set values, and CT3 webpage settings for the WFT it is mated with.

Slip Ring



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

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 LW60/LW65 model WFTs. 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.

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 CT3 Electronics in Spinning Applications. The standard cable length is 6m (20ft). Cable lengths up to 15m available.

Simulator Cable



Signal Cable connects from the amplifier to the CT3 Electronics. The Simulator Cable is used in Non-spinning Applications (for example MTS329). Simulator cable lengths up to 30m available.

Power Cable



Power Supply cable. This cable is supplied from the factory with no connector on one end. An active fuse is located in the CT3 electronics. The white lead is for 9-36 VDC power high. The black lead is power ground.

Optional Analog Output Module



CT3 Analog Output Module. This module converts digital signals to Analog outputs.

Optional Tinned Lead Analog Output Module Cables



CT3 Analog Output Module Cables with tinned leads. Each cable can connect to four channels.

USB-A to USB-C Cable



Connect CT3 to Laptop or mobile device with USB-C cable. After cable is connect, open the web browser go to www.CT3.local

CAN Bus Cable



CAN Bus Signal output cable. They can be made with a DB9 or eDAQ connector on them. CT3s send high speed data through their interconnector, so each CT3 does not need a CAN connector plugged in.

With 4 WFTs, the max sample rate with for one CAN 2.0 Bus is 550 Hz. With 4 WFTs, the max sample rate with two CAN 2.0 Buses is 1024Hz.

CT3 Grounding Cable



CT3 Chassis Grounding cable

Optional Ethernet Cable



Ethernet Cable can be used to send signal outputs via Ethernet through OpenDAQ standards. Also connects the CT3 to a computer to access the embedded CT3 webpage as an alternative to the USB connection.

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 rim adapter as shown.



- Set the transducer on the rim adapter as shown.



- **For LW60;** Install sixteen M10-1.5 x 45mm bolts through the transducer and into the rim adapter with a small amount of anti-seize on the thread as shown.
- **For LW65;** Install twenty four M10-1.5 x 55mm bolts through 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.



- Install twenty four M10-1.5 x 18mm socket head cap screws through the hub adapter and into the transducer. Use Anti-seize on bolts as described above.
- 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).

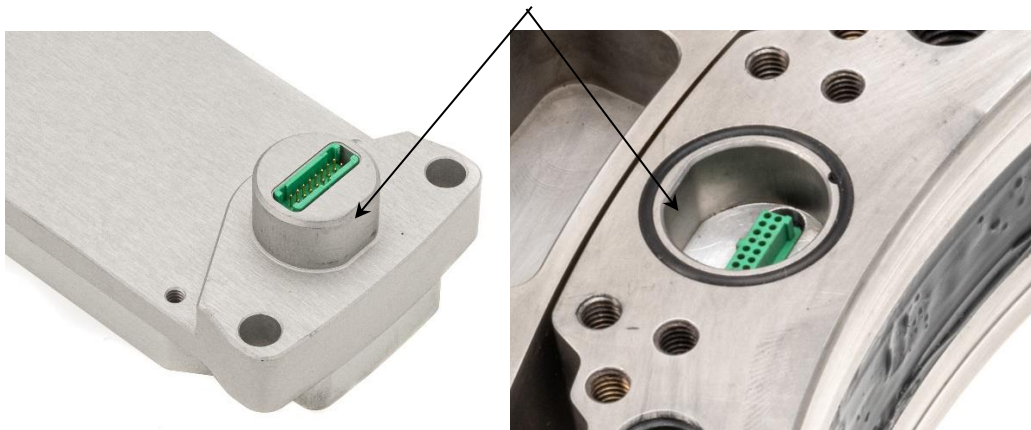
Note: if using welded aluminum rim adapter max recommended static corner load is reduced to 500 kg. Welded aluminum rim adapters over 17" are not recommended.

- 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.
- O-rings are embedded into the transducer with a dovetail cut O-ring groove, but can be changed, if required. Make sure the O-rings are in their proper place before installing the 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 Amplifier Package with Flat in Transducer

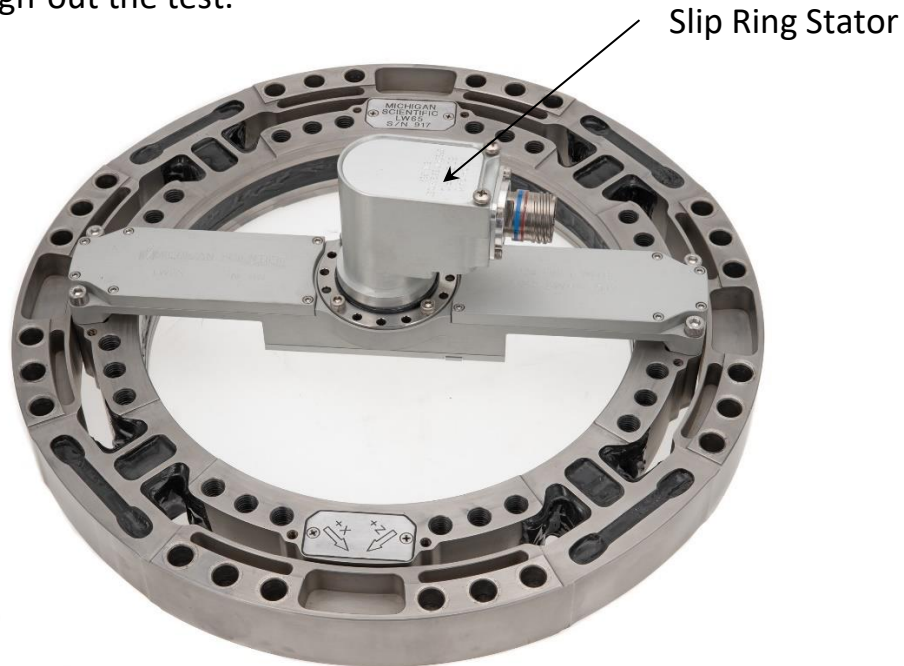


- Secure the amplifier with M5x20mm stainless steel socket-head screws a small amount of anti-seize on the thread and with provided washers. Tighten M5 bolts to 7 N.m (60 in-lb) torque.
- The slip ring is attached to the amplifier with 8-32 x 3/8-inch screws and a small amount of anti-seize. The slip ring has been shipped already installed on the amplifier housing and is normally left attached to the amplifier housing when measurement system is removed from the vehicle.

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

Slip Ring Rotational Restraints

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



Stator Restraints for Rear (Non-Steering) Wheels

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



The MVSR and restraint rod should be used to prevent the slip ring from rotating on non-steering wheels or straight line tests. The MVSR should be attached to the vehicle body with the magnet backing and should be placed directly above the slip ring. Slide the restraint rod into the 5/8" (16mm) hole in the MVSR and attached the plastic portion of the restraint rod to the Slip Ring with two M4x14mm Phillips head bolts. These bolts should be installed with Loctite and should be tightened firmly with a Screwdriver.



Use a digital protractor or level to check if the slip ring stator is vertical. As needed, make adjustment to the MVSR placement so that the slip ring is vertical. Once the MVSR is in the proper location, tape should be used to further secure the MVSR to the vehicle body. If the car body is non-ferrous, strong tape alone can be used to hold the MVSR in place. If a vertical mounting of the slip ring stator cannot be achieved, the angle of the slip ring stator must be measured and entered into the CT3 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)

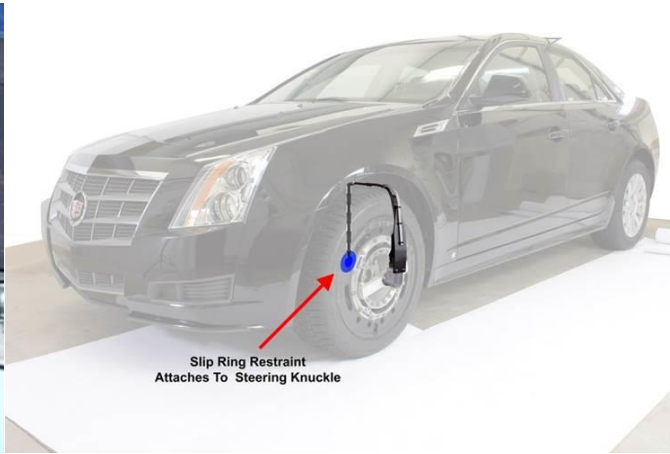
The SAC is the easiest and most accurate of the three methods. The SAC installs to the vehicle just like the MVSR, however the Stator rod is measured as it changes angle with

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

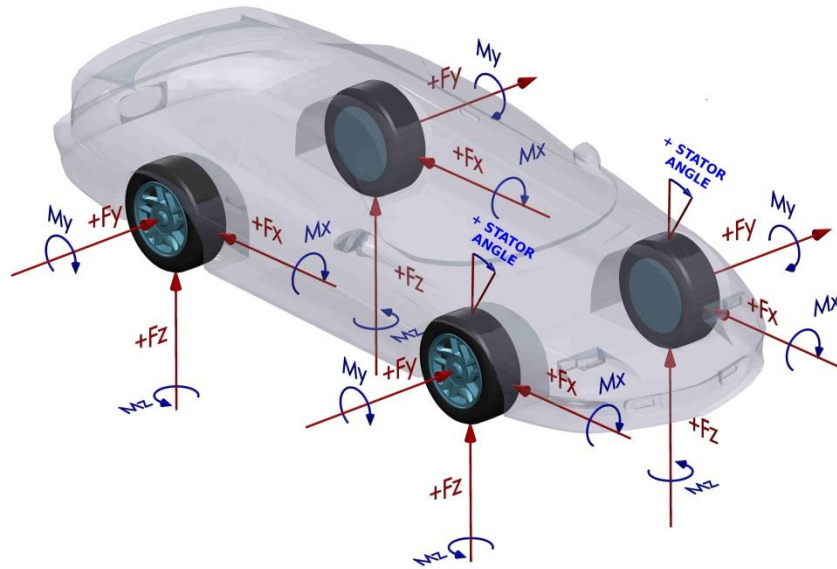
The over the wheel slip ring stator bracket will have to be custom made by the user. The reason the bracket must be custom is that the attachment points for every vehicle are unique, so there is no universal type over the wheel bracket. The over the wheel bracket should be stiff, yet lightweight. Below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

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

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

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

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

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

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

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

Spinning Assembly Cable Connections and Signal Outputs

- Connect one end of the 6 meter (20 ft) long Signal 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 CT3 electronics.
- Connect the power cable to the CT3 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 power draw from the vehicle is about 6-7 Watts per CT3/WFT system.

CAN Bus Signal Outputs

- If using CAN Bus signal output, connect one end of the CAN Bus cable to the CT3 and the other end to the data acquisition/controller. If using one CAN Bus for all CT3s, connect the cable to the top CT3 box and select 'All-to-Top' mode in CT3 webpage. If using two CAN buses select '2-to-1' mode in the CT3 webpage and plug a CAN cable into each CT3 set to Left side of vehicle. For example LF CT3 will output signals from LF & RF. If using one CAN bus for each CT3 select 'Direct Output' mode in the CT3 webpage and plug a CAN cable into each CT3. A .dbc file specific to your test can be downloaded from the CT3 webpage.

Analog Signal Outputs

- If using analog outputs, connect the CT3 Analog Module to the CT3. Then use DB9 connector output cables, to the data acquisition/controller. CT3 Analog outputs are Floating Single-Ended Outputs. The chart below output cable wiring diagram.

CT3 Analog Output Module - Output Cable Pinout			2/15/2023
Pin#	Function	Description	Color
1	GND	NC	NC
2	Output 2	Signal 2 High	White
3	GND	Signal 2 Low	Brown
4	Output 4	Signal 4 High	Yellow
5	GND	Signal 4 Low	Green
6	Output 1	Signal 1 High	Red
7	GND	Signal 1 Low	Blue
8	Output 3	Signal 3 High	Pink
9	GND	Signal 3 Low	Gray
NC = Not Connected			

CT3 Chassis Ground Connection

- In many Spinning application tests the CT3 will perform without noise issue without connection to chassis ground.
- If there is a potential noise issue or the smart sensor cannot be read or written, connect the CT3 to vehicle chassis ground. **This can be done in one of the two following ways.** Be sure to not create a grounding loop by connection the CT3 and Data Acquisition both to the vehicle chassis.

Ground Connections in vehicle (select only one of these)

- 1 Connect one end of the CT3 Grounding Cable to the banana plug in the back of the CT3 and connect the other end of the cable to the vehicle chassis or if Data logger is already connected to the vehicle chassis then connect the grounding cable to the Data logger grounding stud.
- 2 Connect the shield of the CT3 power cable to the vehicle chassis or if Data logger is already connected to the vehicle chassis then connect the grounding cable to the Data logger grounding stud.

Ground Connections in a lab (select only one of these)

- 1 Connect one end of the CT3 Grounding Cable to the banana plug in the back of the CT3 and connect the other end of the cable to the lab power ground.
- 2 Connect the shield of the CT3 power cable to the lab power ground.

CT3 Power-up

- Turn the power switch on to the CT3 with the Power button on the back of the CT3. At power-up, the CT3 will automatically read the information stored in the smart sensor of the amplifier. This information includes zero values, shunt calibration values, desired full scale outputs, transducer information, and CT3 webpage settings. Since the calibration information is stored in the Amplifier and not the CT3, the CT3s are interchangeable.
- At this time (if CT3 is in Run mode & Vehicle Coordinates), the force, moment, and position channels are held at zero until the CT3 receives an index pulse and the screen will display 'ROTATE WHEEL'.

Non-Spinning Assembly Instructions

When using the WFT on a simulator or Test Bench (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.

Assembly

- **Note: Install the transducer into the simulator with the Z+ arrow of the transducer pointing vertically towards the ground.**
- Place the transducer onto the Simulator Adapter and install twenty four M10-1.5 x 55mm bolts though the transducer and into the Simulator adapter with a small amount of anti-seize on the thread as shown.



- Place the hub adapter onto the transducer and install twenty four M10-1.5 x 18mm bolts transducer, with a small amount of anti-seize on the thread as shown above.



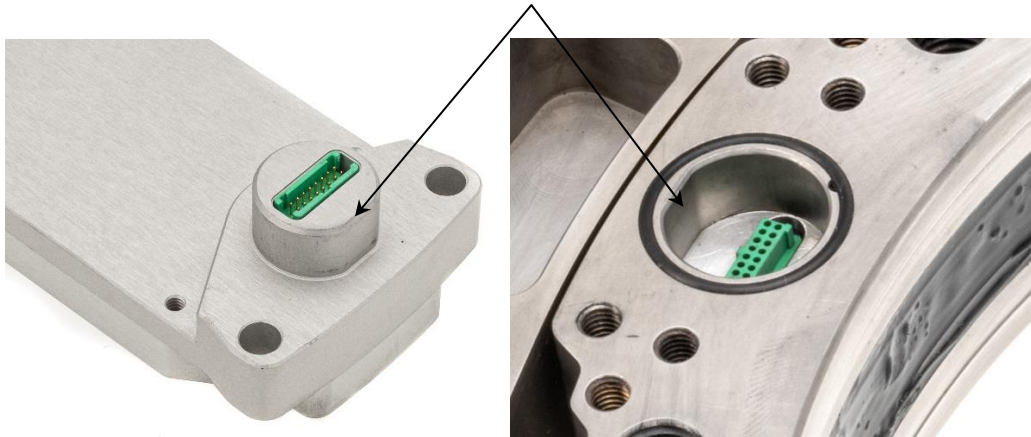
- Torque all of the M10 bolts to 60 lb-ft (81 N.m) using a crisscross pattern.



Amplifier Installation

- The amplifier is installed after the lug nuts have been tightened. Note that each amplifier and transducer is a matched pair. This is important; data is stored in the amplifier package for each specific transducer.
- O-rings are embedded into the transducer with a dovetail cut O-ring groove, but can be changed, if required. Make sure the O-rings are in their proper place before installing the 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 Amplifier Package with Flat in Transducer

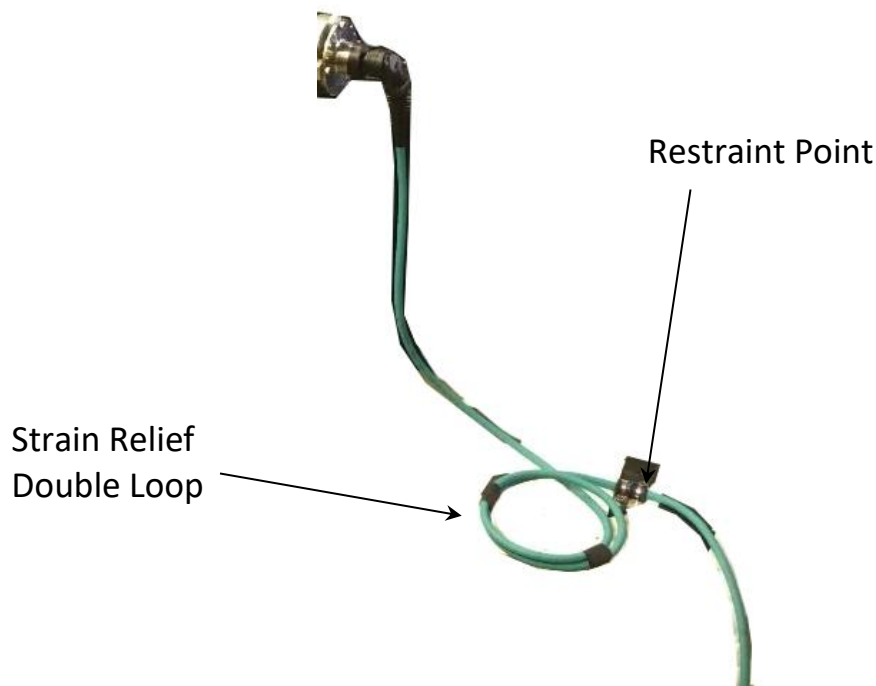


- Secure the amplifier with M5x20mm stainless steel socket-head screws a small amount of anti-seize on the thread and with provided washers. Tighten M5 bolts to 7 N.m (60 in-lb) torque.

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.*

Non Spinning Application - Cable Installation, Strain Relief, and Signal Outputs

- The Simulator cable can be attached to the amplifier with 8-32 x 3/8-inch screws with a small amount of Loctite on the threads. Tighten 8-32 stainless steel bolts to 2.25 N.m (20 in-lb) torque.
- 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 to the CT3 electronics.
- Connect the power cable to the CT3 electronics.
- Connect other end of the power cable to a quality DC voltage source in the range of 9 to 36 volts. The current draw from the vehicle is less than 1 amp per CT3 at 12 volts and reduces proportionately at higher supply voltages.

CAN Bus Signal Outputs

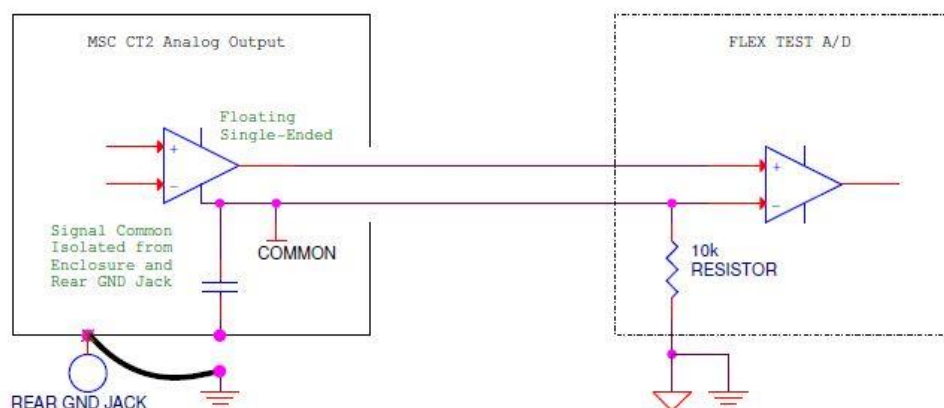
- If using CAN Bus signal output, connect one end of the CAN Bus cable to the CT3 and the other end to the data acquisition/controller. If using one CAN Bus for all CT3s, connect the cable to the top CT3 box and select 'All-to-Top' mode in CT3 webpage. If using two CAN buses select '2-to-1' mode in the CT3 webpage and plug a CAN cable into each CT3 set to Left side of vehicle. For example LF CT3 will output signals from LF & RF. If using one CAN bus for each CT3 select 'Direct Output' mode in the CT3 webpage and plug a CAN cable into each CT3. A .dbc file specific to your test can be downloaded from the CT3 webpage.

Analog Signal Outputs

- If using analog outputs, connect the CT3 Analog Module to the CT3. Then use DB9 connector output cables, to the data acquisition/controller. The chart below output cable wiring diagram.

CT3 Analog Output Module - Output Cable Pinout			2/15/2023
Pin#	Function	Description	Color
1	GND	NC	NC
2	Output 2	Signal 2 High	White
3	GND	Signal 2 Low	Brown
4	Output 4	Signal 4 High	Yellow
5	GND	Signal 4 Low	Green
6	Output 1	Signal 1 High	Red
7	GND	Signal 1 Low	Blue
8	Output 3	Signal 3 High	Pink
9	GND	Signal 3 Low	Gray
NC = Not Connected			

- CT3 Analog outputs are Floating Single-Ended Output, so one ground should be connected to data acquisition/controller ground to prevent common mode drift. All grounds are common in CT3. See diagram below.



- Connect the CT3 chassis ground to lab power ground. This can be done in one of the two following ways.
 - 3 Connect one end of the CT3 Grounding Cable to the banana plug in the back of the CT3 and connect the other end of the cable to the lab power ground.
 - 4 Connect the shield of the CT3 power cable to the lab power ground.

CT3 Power-up

- Turn the power switch on to the CT3. At power-up, the CT3 will automatically read the information stored in the smart sensor of the amplifier. This information includes zero values, shunt calibration values, desired full scale outputs, transducer information, and CT3 webpage settings. Since all calibration information is stored in the Amplifier and not the CT3. The CT3s are interchangeable. For Non-spinning application, the CT3 should be set to Wheel Coordinates. In Wheel Coordinates, the CT3 does not look for a Encoder signal.

CT3



Introduction

One CT3 is used for each wheel force transducer. The CT3 is the User Interface. It also performs coordinate transformation, cross-talk correction, zero off-set adjustments, and vehicle position polarity adjustment in real time. The CT3 buttons can initiate a Zero function, a Shunt Calibration function, Zero Angle, and be set for Vehicle position of installed WFT. The CT3 also has an embedded webpage to access additional set-up options, configure CAN Bus output, and create a .dbc file. The front of the CT3 has a

display which will tell you the SN of the WFT connected, current User selected settings in the CT3 and any current Faults or Errors in the system.

Main CT3 Set-up Functions

The main set-up functions that should be done at every new test installation and set-up are Position, Zero, Shunt, and Zero Angle. The position button allows the user to indicate to the CT3 what wheel position the transducer is mounted and this should be done first so all stacked CT3s can communicate. The remaining functions can be done in any order. The Shunt button performs a Shunt calibration and compares it to the factory Shunt calibration. This verifies that the Transducer and Amplifier are working properly. The Zero adjusts the off-set of each WFT channel. This must be done each time the transducer re-bolted to the adapters. The Zero Angle sets the Z reference angle of each WFT. Details of each main set-up function are described further below.

Important CT3 Website selections

One main set-up function that should be checked in the CT3 Webpage for each Test set-up is the Measurement Origin. The default Measurement Origin is the center of the transducer. See page 49, to change the WFT Measurement Origin. You should also verify that the Coordinate system set in the CT3 webpage matches your desired Measurement Origin. The current Measurement Origin setting can be seen on the Display. If being used in a Non-spinning application, you should check the 'For Simulator Use' Box on the CT3 webpage.

CT3 Basics

Lights and Controls

All controls located on top of the enclosure are momentary contact switches. They correspond to the labels located on the front panel. Power button is located on the rear panel and position/screen advance control is located on the front panel.

Powering Up

Note: It is good practice to first connect all cables to the CT3 electronics before powering it up. If this is not done, possible damage may occur. In addition, the CT3 reads

important transducer information, from the smart sensor in the amplifier package, at startup. If the smart sensor is not read on power-up, the FAULT light will be lit.

The power switch turns the power on and off. When the CT3 is turned on, it defaults to Run Mode. This will be indicated by green light on the front panel. Transducer offsets, sensitivities and other information is read from the smart sensor during power up.

Display

The CT3 has a display on the Front. The display will always show the user which Serial Number WFT it is connected and which Wheel Position is selected. In RUN mode, pressing the POSITION/ADVANCE button will jog through various CT3 User selected option, for easy viewing without connecting to the CT3 webpage. To change any of these setting, the user must connect to the CT3 webpage.

If there are any FAULTs or ERROR codes, these will be displayed on the Display as well.

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. If an error occurs during the Zero process 'ZERO ERROR' will be indicated on the display. The zeroing sequence records data and calculates an offset value. This offset is recorded into the smart sensor located in the amplifier package so it is not lost when power is interrupted or a different CT3 is used. When set to Spinning Mode, the CT3 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 CT3 senses that the wheel is turning above 15 rpm, it uses 8 revolutions to get a better on-road-averaged value. (The is referred to as rolling zero). When set to Non-Spinning Mode, the CT3 nulls all channels.

Zero Angle

To initiate a Zero Angle, ensure the CT3 is in Set-up mode with the wheels off of the ground and able to rotate freely. Then press the Zero Angle button, rotate the wheel until the Zero Angle light starts to flash. Then point the Z+ arrow on the transducer or amplifier vertically towards the ground and press the Zero Angle button a second time. If the wheel has already been rotated while the CT3 has been powered on, then the Zero

Angle light will flash immediately upon pressing the button the first time. A level or digital protractor should be used across the bolts of the WFT to ensure that the Z+ arrow is completely vertical before pressing the Zero Angle button the second time.

Note: If a Zero Angle function is not performed, the CT3 will use the default slip ring encoder index angle as the Z reference angle. This was the method used in CT2.

Shunt

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

Mode

The Mode lights indicate whether the module is in Setup or Run Mode. The Mode button on top of the enclosure toggles between the modes. Run mode is used whenever data is being collected. Setup mode is only used for Set-up and Troubleshooting. Zero, Shunt, Zero Angle, and Position features cannot be accessed unless the CT3 has been switched to Setup mode. In set-up mode, coordinate transformation and zero off-set adjustment are not performed.

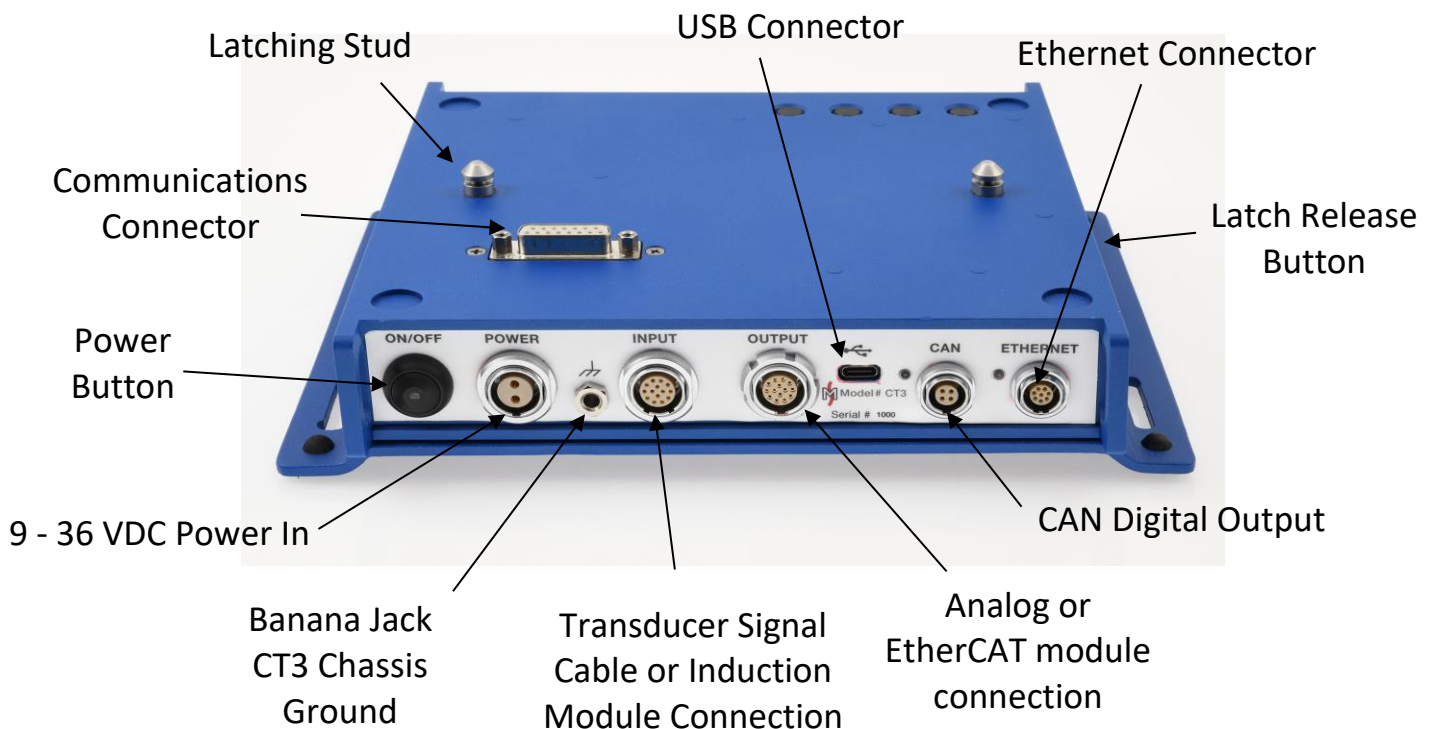
Fault

The fault light indicates that there is a problem with the module. It can be lit in conjunction with other lights or by itself. The corresponding fault message will be indicated on the display.

Position

The position button allows the user to indicate to the CT3 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 CT3 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 CT3 units, the position information is shared between the CT3 electronics. If two or more CT3 electronics are assigned to the same wheel location, 'DUPLICATE POS' message will be displayed on the display.



Connectors

Connectors located on the back panel of the CT3 are for power, ground, Transducer signal cable/Induction Module, Analog output module/EtherCAT output module, USB connection to webpage, Ethernet connection, and CAN digital Signal output. The D-sub connectors located on top and bottom of the enclosure are used for communications between multiple CT3 electronics.

Multiple CT3s



Each CT3 is used with one Wheel Force Transducer. When using multiple Wheel Force Transducers systems, the CT3 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 CT3 electronics communicate with each other using a digital bus interface. This allows the operator to control all of the CT3s with one set of controls. Notice that the control buttons are located on top of the enclosure. When one CT3 is stacked on top of another, the buttons on the lower one are covered. All functions are controlled by the top CT3 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 CT3.

The power supply cable can be connected to any one of the CT3 electronics. That CT3 will supply power to the rest in the stack, therefore only one power cable is required.

Each CT3 retains its own power switch and must be turned on individually. At power up, the CT3 checks the state of the other boxes and then sets itself to match.

Up to four CT3 electronics can be stacked together. If you want to stack more together, please contact Michigan Scientific to discuss your specific application.

Power Requirements

The CT3 requires 9 to 36 VDC power. Power draw is 6-7 watts for each WFT system.

One power cable will power a stack of CT3s (up to 4)

Individual CT3 Shunt or Zero

If you have a stack of CT3s, pressing the SHUNT button on the top CT3 perform a SHUNT for all CT3 boxes in the stack. If you only want to perform the SHUNT for one WFT, then hold in the Position/Advance button, then press the SHUNT button on the top box.

If you have a stack of CT3s, pressing the top ZERO button if perform a ZERO for all boxes in the stack. If you only want to perform the ZERO for one WFT, then hold in the Position/Advance button, then press the ZERO button on the top box.

Signal Outputs

Eleven signal outputs are available from each CT3. The channels are for force and moments about the x, y, and z axes, and also Wheel Speed, Wheel position, Acceleration X, Acceleration Y, and Acceleration Z. In the CT3 webpage you have the option to replace Wheel Speed and Wheel Position with Sine and Cosine Outputs.

Using CAN Signal Outputs

The CT3s send high speed data through their internal connection allowing the CAN data to all be output from the top CT3, if desired. There are three user selectable CAN output option, 'All-to-Top', '2-to-1', and 'Direct Output'. With 'All-to-Top' selected all the data from the stacked CT3s will be output on a single Bus from the Top CT3 CAN connector. With '2-to-1' selected the data from a single axle will be output to the Left side CT3. For example LF CT3 will output signals from LF & RF.

With 'Direct Output' Selected the data from each WFT will be output on their own CT3 CAN port. For example with 4 CT3s stacked, you will have 4 CAN Buses to connect to the data logger.

CAN cables can be built with either a DB9 or Turk connectors (for eDAQ).

See more about this is in CT3 CAN Bus configuration section, on page 54.

A .dbc file can be created and downloaded from the CT3 webpage. Once the .dbc file is loaded into the data acquisition, and the systems are connected, all the channels will be properly labeled (according to Wheel Position) and scaled (in engineering units). The drawback of using CAN signal outputs is the signal delay which is dependent on output rate. It is 2 milliseconds for 2000/2048 Hz, 4 milliseconds for 1000/1024 Hz, and 7.5 milliseconds for 500/512 Hz.

Using Analog Signal Outputs

An Optional Analog Output Module and output cables can be purchased. The default voltage for the Analog output is +/- 10 VDC. This voltage can then be converted to their engineering units by multiplying by the sensitivity listed on the Quick Reference Calibration Sheet supplied with the WFT. Also see Appendix 3 on page 75.

All the analog outputs are single ended and isolated from power ground. See diagram in appendix 1. The CT3 webpage allows the user to replace Wheel Speed and Wheel Position with Sine and Cosine, if desired.

The time delay when using Analog Signal Outputs is 0.5 milliseconds.

Shunt Calibration Sequence

Shunt Sequence - The CT3 calculates an internal fine digital gain, used to make output sensitivities match the values programmed into the Smart sensor.

To invoke a shunt sequence.

- Press the *Mode* Button to enter *Setup Mode*
- Press and release the Shunt button.
- The Shunt light will illuminate to indicate a shunt sequence is in progress. Once the Shunt light goes out (about 9 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. If this happens the display would indicate 'SHUNT ERROR'. The shunt sequence commands the amplifier package to invoke a shunt calibration resistor at each strain gage bridge in the transducer. The CT3 reads the voltage change, caused by the shunt, and adjusts the gain of each channel to match the sensitivity programmed into the *smart sensor*. This calculated gain is recorded into the smart sensor located in the amplifier package so this information is not lost when power is interrupted or a different CT3 is used. If the calculated gain is more than 2.5% different than what is programmed into the smart sensor, the Fault light will come on indicating a likely problem with the transducer or amplifier.

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

Shunt Hold - The CT3 can be commanded to invoke and hold shunt calibration. This can be used to write down the transducer off-sets and shunt voltages.

To invoke the shunt hold:

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

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

Spinning Use System Set-up

The CT3 has a Zero feature that automates the zeroing process. With any zeroing method used below, **it is recommended that the transducers be exercised before any zeroing is done. To exercise the transducers, perform a figure 8 maneuver, and two or more hard brake stops.**

There are two zeroing procedures for Spinning Applications.

Zeroing on the Hoist

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

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

- Turn on the CT3.
- 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 *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 CT3 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 CT3s

- You may rotate each transducer independently.
- To zero only one wheel, you will need to turn off the CT3 electronics, on the wheels that you do not want to zero, or un-stack them.

When the CT3 completes the zero procedure, it will write the calculated offset value to the smart sensor located in the amplifier. This way the transducer does not need to be zeroed every time the power is interrupted or if a different CT3 is used with the transducer.

Rolling Zero on the Road

This Zero method occurs when the wheel speed is above 15 rpm, and 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 CT3 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 CT3 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 CT3 is used with the transducer.

Verifying the Zero Procedure

To check the quality of the zero, set the CT3 to *Run* mode and *Vehicle* coordinates. Observe the output from each channel with the wheel lifted off of the ground. The x and y-axes forces should have very little output. While hoisted the Fz force should read the negative weight of the wheel and tire. The My and Mz moments should have little output. The Mx moment should have some output proportional to the weight of the wheel and tire multiplied by the moment arm from the wheel centerline to the transducer centerline. (if the measurement origin is at the default, transducer centerline.)

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

Non-Spinning Use – System Set-up

- Operate CT3 in Non-Spinning mode which can be selected in the CT3 webpage. Fz+ axis should be pointing vertically towards the ground. (If Fz+ axis is not mounted vertically towards the ground, see page 51) Also make sure the 'For Simulator Use' Box is checked in the CT3 webpage, see page 51. A Simulator Cable should be used.
- A Zero in Wheel Coordinates will null out all the channels (zeroing out the static weight of the vehicle), so there are three options to account for the static weight of the vehicle so that the road loads recorded properly match the loads measured on the simulator. They are:
 1. Zero the WFTs after they have been bolted to adapters but before the vehicle has been attached to the hub adapters.
 2. Zero the WFTs once car has been attached to the WFTs and simulator. Then add the static weight of the vehicle to WFT data through a calculated channel. The road data would not have to be modified.
 3. Remove static vehicle weight from previously recorded road data. Then zero the WFTs once car has been attached to the WFTs and simulator.
- Analog signal outputs are commonly used, because the time delay on the these signal outputs is only 0.5 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.

Stationary Zero

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

- Make sure the CT3 is in Wheel the Coordinates.
- Press the *Setup Mode* button.
- The blue *Setup Mode* light will illuminate.
- Press the *Zero* button.
- The amber *Zero* light will illuminate.
- Once the procedure is complete, the light will go out.
- When the CT3 completes the zero procedure, it will write the calculated offset value to the smart sensor located in the amplifier. This way the transducer does not need to be zeroed every time the power is interrupted or if a different CT3 is used with the transducer.

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

Web Page Selectable Options

The CT3 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 use a USB-C cable.

- Plug the USB C connector of the provided cable into the top CT3 and connect the USB A connector into the laptop.
- Open a web browser and type CT3.local and click enter.

- The web page, shown on the following page, will appear in the web browser

Note: To make system changes, all CT3s must be connected to their respective wheel force transducer and powered up.

CT3 User Interface

Menu

- Configure CT3
- Coordinate System
- Static Values
- Transducer Info
- CAN Data Settings
- CT3 Info
- Network Settings
- About/Contact MSC

CT3 Configuration

CT3 Serial Number: 1051 RF

Wheel Force Transducer

Model: LW-ZT-40K
Serial Number: T163
Position: RF
Calibration Date: Fri Nov 10 2023

Default Coordinates on Power-Up (Updated in all active CT3 boxes):

☒ Spinning ☐ Non-Spinning

Full Scale Rotational Velocity:

☐ 1000 RPM ☒ 2000 RPM ☐ 3000 RPM ☐ 4000 RPM
☐ Replace Velocity/Position in CAN Output with Sine/Cosine

Analog Output Range:

☒ +/-10V ☐ +/-5V ☐ 0 to 5V

Synchronization Setting:

☒ Local ☐ PTPv2 ☐ EtherCAT

Enter Slip Ring/Encoder Reference Angle:

0.00 Degrees Clockwise from Vertical

Measurement Origin:

Units of Entered Values:

☐ Inches ☒ Millimeters

Measurement Center Offset along Y-Axis (a):

0.0 (-1,829 to 1,829 mm)

Definition of "a" & "RR"

Diagram showing the transducer center line and the offset 'a' and 'RR'.

☐ Update All Active CT3 Boxes with these settings

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CT3 Serial Number/Wheel Position

Near the top of the page is a drop down box allowing the user to select CT3 serial numbers paired with the selected Wheel Position for that CT3, shown below.

A screenshot of a web interface showing a label "CT3 Serial Number:" followed by a dropdown menu. The dropdown menu is open, showing "1051 RF" as the selected option, with a small downward arrow to its right.

The CT3 that the USB cable is connected to, will check for the presence other CT3 Boxes. 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 with the selected Wheel Position will appear in the pull down menu. Selecting a different serial number allows the user to set up each CT3 separately.

☐ Update All Active CT3 Boxes with these settings

Update

If settings for all the CT3 units are to be the same, the "Update All Active CT3 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 CT3 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 CT3 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 CT3 boxes):

☒ Spinning ☐ Non-Spinning

Note: All CT3 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 CT3 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, 3,000, and 4,000 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 ☐ 4000 RPM
☐ Replace Velocity/Position in CAN Output with Sine/Cosine

Analog Output Sensitivities Options.

The default Analog output range is $\pm 10V$. The CT3 allows the user to choose analog output ranges of $\pm 10V$, $\pm 5V$, and 0-5V. Because of that, the number shown in the chart below 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 for LW65 will be 7,000 N/V (70,000 N /10 volts). If the analog outputs are set to 0-5 Volt, X Force the sensitivity will be 28,000 lbs/Volt with a 2.5 volt offset.

NOTE: When Using Analog signal outputs, it is recommended to perform a Shunt Calibration and compare the Delta Shunt through the data acquisition to the Shunt value listed on the Quick Reference Calibration sheet, to ensure proper scaling.

Output Channel Full Scales		
	LW60	LW65
X Force	65,000N (14,610 lb.)	70,000N (15,740 lb.)
Y Force	35,000N (7,870 lb.)	40,000N (8,999 lb.)
Z Force	65,000N (14,610 lb.)	70,000N (15,740 lb.)
X Moment	10,000 N-m (7,380 lb-ft)	11,000 N-m (8,110 lb-ft)
Y Moment	10,000 N-m (7,380 lb-ft)	11,000 N-m (8,110 lb-ft)
Z Moment	10,000 N-m (7,380 lb-ft)	11,000 N-m (8,110 lb-ft)
Velocity	2000 rpm (default)	
Position	0 - 360 deg	
Accel X, Y, & Z	$\pm 100g$	

Changing Analog Output Range

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

Analog Output Range:

☒ +/-10V ☐ +/-5V ☐ 0 to 5V

Synchronization Settings:

The stack of CT3s can synchronize in three ways, Locally, through PTPv2, or through EtherCAT. The default setting is local which synchronizes all stacked CT3s to each other.

Synchronization Setting:

☒ Local ☐ PTPv2 ☐ EtherCAT

Slip Ring/Encoder Reference Angle

In some situations, the slip ring body cannot be oriented with the cable exiting the top. The slip ring stator is encoder angle reference for the coordinate transformation calculations. If the slip ring cannot be mounted vertically, measure the angle that the slip ring body is from vertical in the clockwise direction. Enter that number into the box shown below. The CT3 uses this information to correct the reference angle when performing the coordinate transformation.

Enter Slip Ring/Encoder Reference Angle:

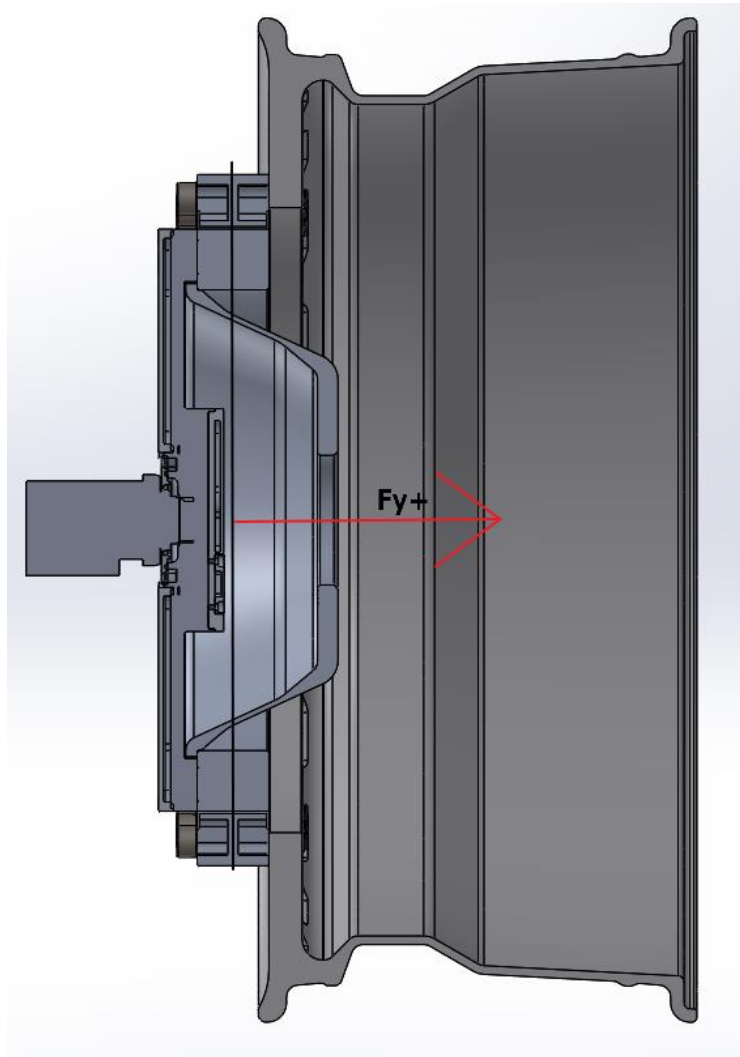
Degrees Clockwise from Vertical

If the ZERO Angle function has been performed, the resulting angle value found from this process will be displayed.

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).

The default measurement origin of the **LW60** 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 0.525" (13.335 mm).



To move the measurement origin to the hub face or tire center, input the “a” value in the CT3 webpage. The value of “a” is provided on adapter assembly drawing if MSC made your adapters. Value “a” can also be measured.

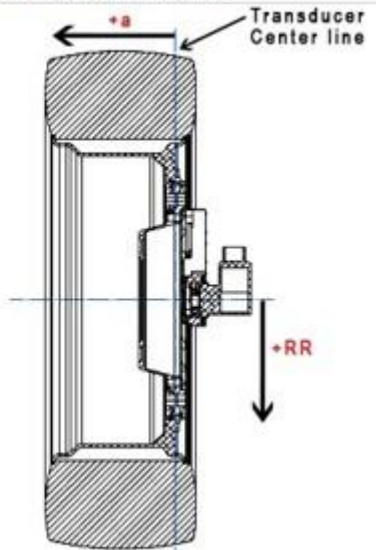
If the user wants to move the measurement origin to the tire patch surface, this input box can be accessed by clicking the “RR” over the diagram.

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.

Measurement Origin:	Definition of "a" & "RR"
Units of Entered Values: ☒ Inches ☐ Millimeters Measurement Center Offset along Y-Axis (a): 0.00 (-72 to 72 inches)	 The diagram illustrates a vertical transducer with a center line. A horizontal arrow labeled '+a' points from the center line to the left, representing the offset 'a'. A vertical arrow labeled '+RR' points downwards from the center line, representing the offset 'RR'.

Note: Only the Mx and Mz channels are affected by these calculations.

Non-Spinning Applications

In the CT3 webpage, only when Non-Spinning Coordinates has been selected, the “For Simulator Use Only” box will appear. If the transducer is mounted with the Z+ arrow pointing vertically towards the ground, leave this box at 0.00. If the transducer is not mounted with the Z+ arrow pointing vertically towards the ground, measure the degrees clockwise from Vertical of the Z+ axis, then enter it into the box and click Update.

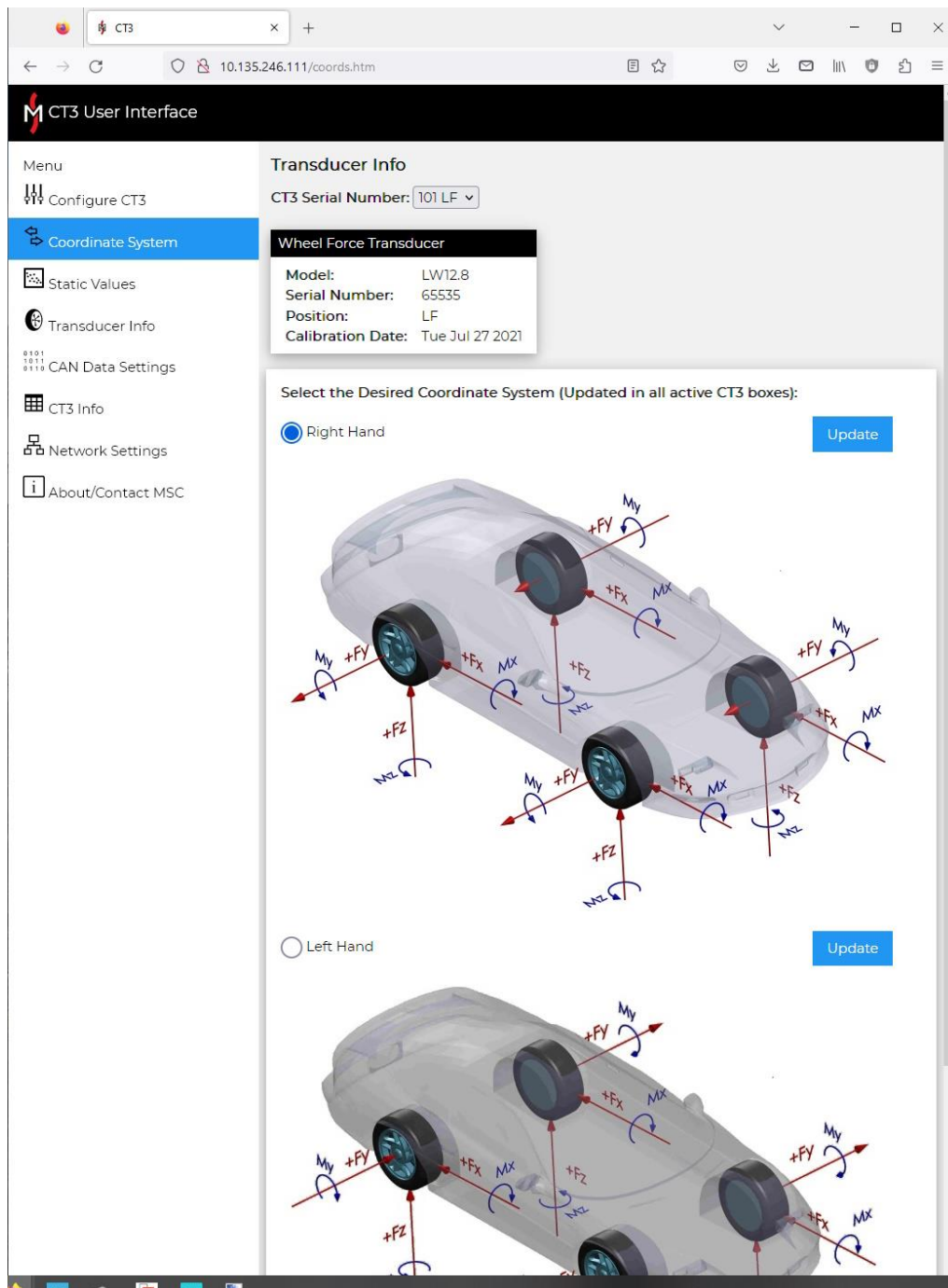
For Simulator Use Only

Mounting Angle Degrees Clockwise from Vertical:

☐ Update All Active CT3 Boxes with these settings

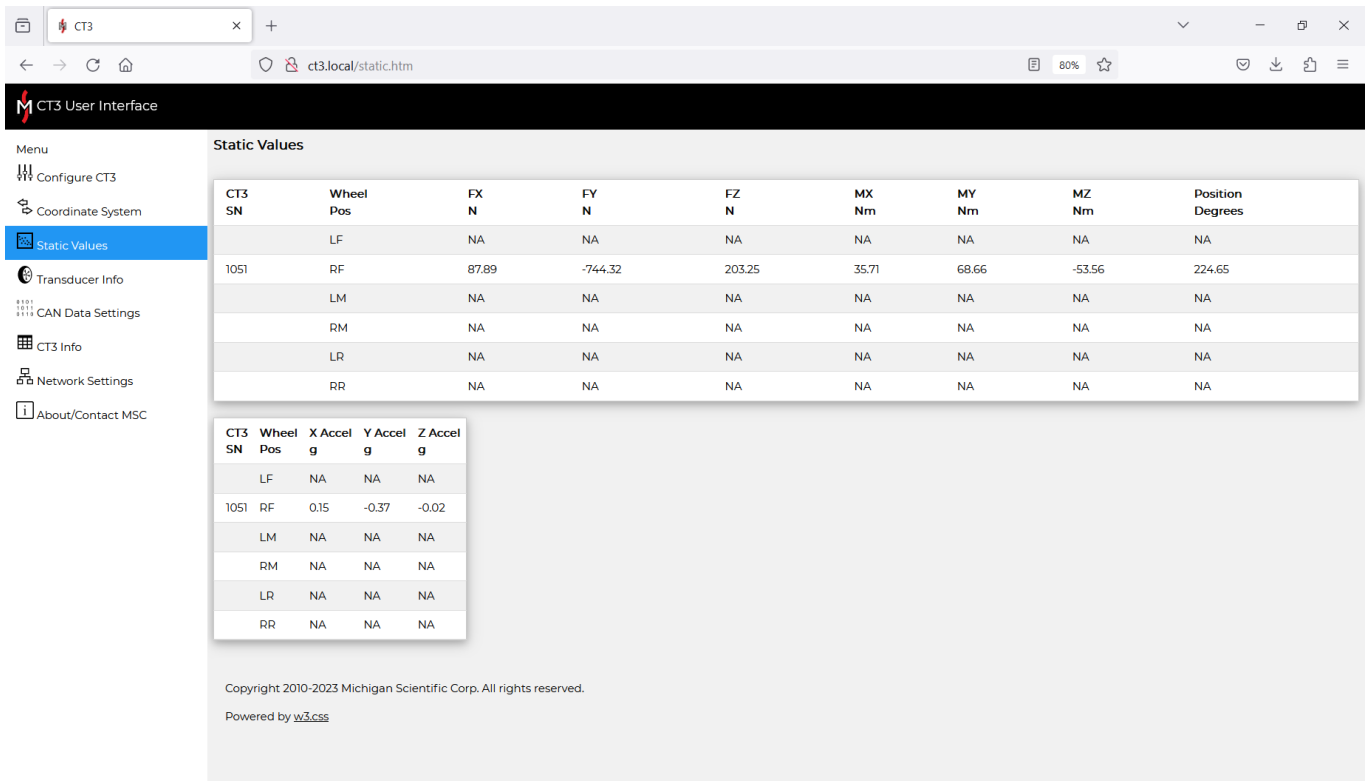
Changing WFT Coordinate System

The default WFT coordinate system is the Right Hand Coordinate System shown below. In the Coordinate System tab on the CT3 webpage the WFT coordinate system can be switched to a Left Hand Coordinate System by checking the button labeled “Left Hand” then clicking update at the bottom of the page. This will update all CT3 boxes stacked and powered up. The WFT Coordinate System is explained further on page 61.



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.



Refresh rates for the Static Values is once per second.

Transducer Information

Information for each WFT system can be viewed by clicking on “Transducer Info”. The CT3 Serial number/Wheel Position drop down menu allows the user to select which system the information is for.

CT3 User Interface

Menu

- Configure CT3
- Coordinate System
- Static Values
- Transducer Info**
- CAN Data Settings
- CT3 Info
- Network Settings
- About/Contact MSC

Transducer Info

CT3 Serial Number: 1051 RF

Wheel Force Transducer Information

Model:	LW-2T-40K	Report Date:	Thu Nov 30 2023
Serial Number:	1163	Report Time:	10:55:53 AM
Position:	RF		
Calibration Date:	Fri Nov 10 2023		

	X Force	Y Force	Z Force
Shunt Cal Value (N)	92058.0	47226.0	91769.0
Factory Scale Factor	1.042	1.410	1.036
Field Scale Factor	1.044	1.411	1.037
Scale Factor % Difference	0.119	0.073	0.038
Analog Full Scale Output(+/-N)	180000.00	90000.000	180000.00
Transducer Offset(Volts)	0.032	-0.216	-0.008
Transducer Offset(N)	574.753	-1940.011	-136.650

	X Moment	Y Moment	Z Moment
Shunt Cal Value (Nm)	25115.0	20095.0	25190.0
Factory Scale Factor	1.385	1.094	1.389
Field Scale Factor	1.386	1.094	1.390
Scale Factor % Difference	0.075	0.002	0.086
Analog Full Scale Output(+/-Nm)	45000.000	45000.000	45000.000
Transducer Offset(Volts)	0.079	0.013	-0.009
Transducer Offset(Nm)	353.538	57.820	-40.096

Configuration Settings:

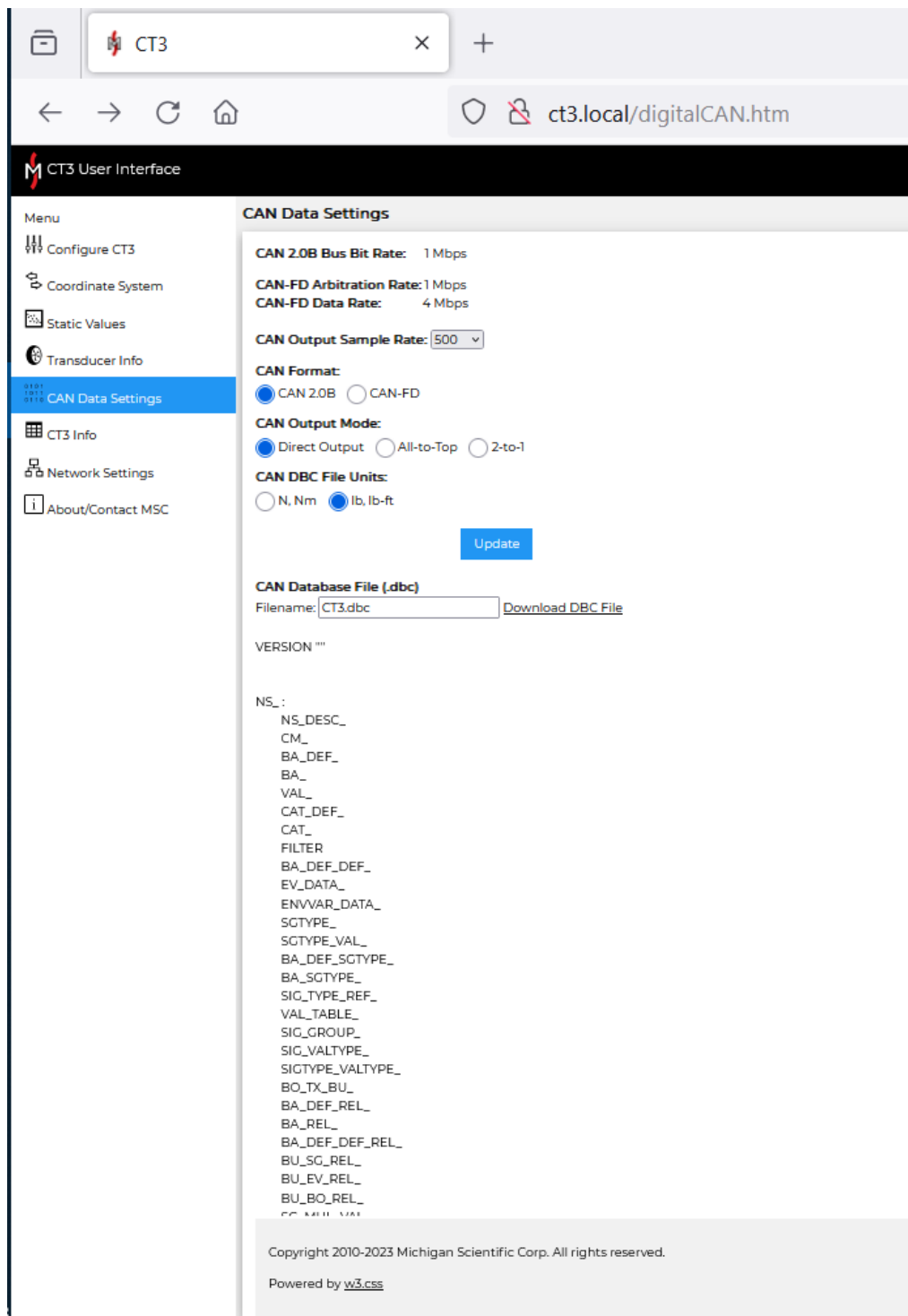
Full Scale Rotational Velocity: 2000 RPM

Spinning Mode Slip Ring/Encoder Reference Angle: 0.000 Degrees Clockwise from Vertical

Transducer Z-Axis is Set to Vertical (Affects Non-Spinning Outputs Only): 0.000 degrees

CT3 CAN Bus Configuration

CAN bus data output settings are configured using the “CT3 Data Settings” tab located on the left side of the web page. Here the CAN type (2.0 or CAN-FD), Output Sample Rate, CAN output mode (Direct, All-to-Top, or 2-to-1) and Desired Units are selected. After making any changes click update and these setting will update for all CT3 boxes that are stacked together.



The Baud Rate of the Data logger must be set to 1 mbps for CAN 2.0. This is the amount of data that can be transferred on a standard CAN Bus.

Note: It is necessary that the CT3 box receive a CAN acknowledge bit from the connected data acquisition system. Do not use passive (listen-only) mode on your data acquisition.

Maximum Output/Sample Rates with CAN 2.0

The following sampling rate limitations apply to CAN 2.0.

If connecting 4 WFTs to one CAN bus (All-to-Top) the max output rate is 512 Hz.

If connecting 2 WFTs to one CAN bus (using 2-to-1 for 4 WFTs or using 'All-to-Top' with two WFT connected) the max output rate is 1024 Hz.

If connecting 1 WFTs to one CAN bus (Direct Output) the max output rate is 2048 Hz.

Delay

There is signal delay caused by filtering performed by the CT3 to decimate the data down to the selected output rate.

The delay is 2 milliseconds for 2000/2048 Hz, 4 milliseconds for 1000/1024 Hz, and 7.5 milliseconds for 500/512 Hz.

Unit Selection

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

There are 3 CAN messages output per sample for each CT3 box

CAN Bus Termination

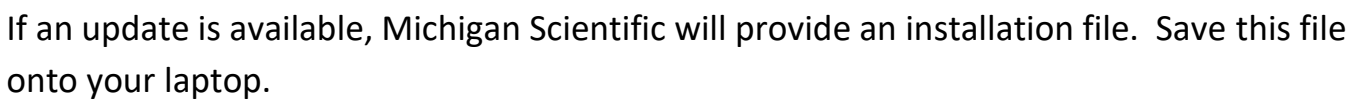
A 120 Ohm CAN termination resistor is automatically turned on in the CT3s. The CAN Bus termination should also be turned on in the Data Acquisition.

DBC file creation

A CAN database (.dbc) file is needed by the data acquisition to de-code the digital data sent by the CT3. A .dbc file is created by the CT3, by clicking the 'Download DBC File' 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.

CT3 Info

The embedded web page allows the user to easily update firmware without having to send the CT3 back to the factory. Current CT3 firmware is available for download from MSC's website. This allows updates or repairs to be done in the field. This page also shows past Error Codes from the CT3 & WFT.



To update the CT3:

- Connect the USB cable to the CT3 to be updated and laptop.
- Click 'Update CT3 Firmware'
- 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 CT3.
- Once power has been cycled, the new firmware is ready to be used.

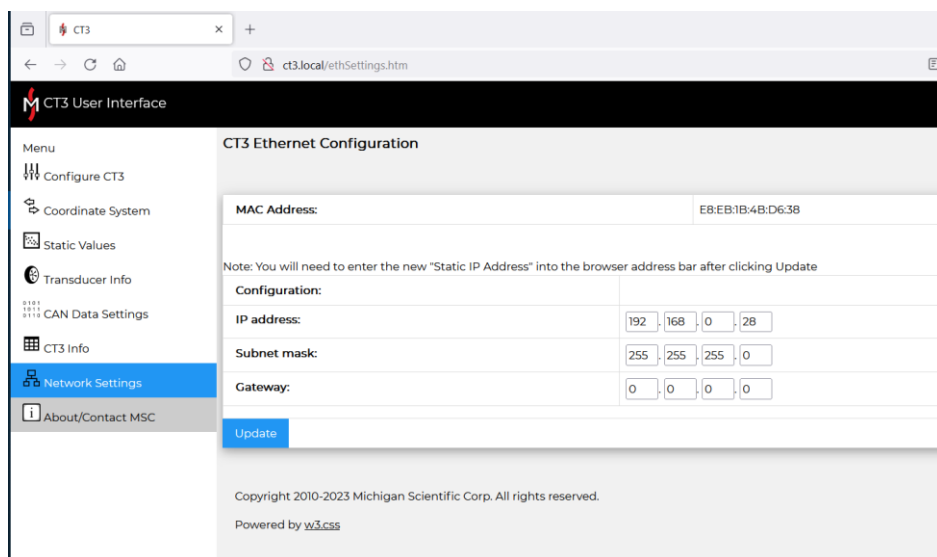
Caution: Do not disconnect the CT3 or power down the computer or CT3 during the update.

Note: Only the CT3 connected to the USB Cable will be updated. Each CT3 electronics must be updated separately.

Note: Update all CT3 electronics with the same version of firmware before using them in a stacked configuration.

Network Setting

Default IP addresses are set at 192.168.0.28 at the factory for all CT3s. A new IP address can be set by going to the "Network Settings" 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.



Display Messages

The table below gives possible CT3 display message and their definition and possible remedy.

CT3 Screen Message	Definition	Remedy
ROTATE WHEEL	WFT has not passed the index pulse after power cycle	Rotate WFT until encoder passes the index pulse
DIFF CAN RATES	WFTs are set to different CAN output rates	Go into the CT3 webpage with all CT3s stacked and set the CAN output rate
NO SMART SENSOR	The CT3 did not read the smart sensor on power up.	Make sure the cable is connected to the CT3 and amplifier on power up. Possible damaged cable.
NO DATA FROM AMP	No digital stream of data from the amplifier.	Make sure the cable is connected to the CT3 and amplifier on power up. Possible damaged cable.
SHUNT ERROR	The field Shunt values differ from the factory Shunt values	Possible transducer or amplifier damage.

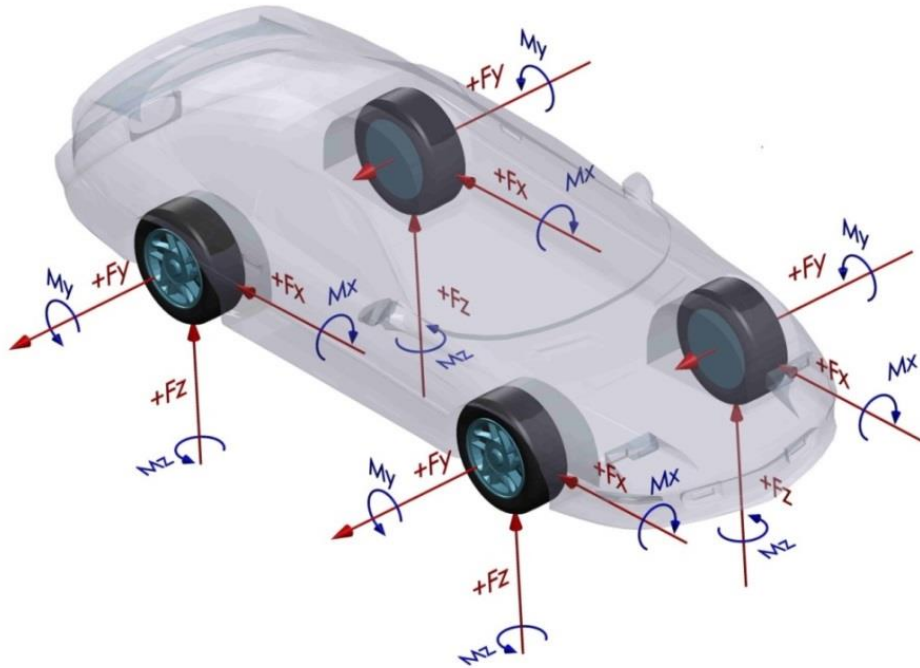
	by more than 2.5%.	
ZERO ERROR	The CT3 is trying to Zero out more than 40% of the full scale.	Check for mechanical short. Possible damage to the transducer or amplifier.
I2C3 ERROR	Internal communication error on I2C3	Cycle power on CT3
TELEM ERROR	Telemetry Error	
POD COM ERROR	Error communicating with Induction Module	Cycle power on CT3
CDBUS ERROR	Internal communication error on CDBUS	Cycle power on CT3
ERROR	Undefined Error	

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 Right Hand Rule. With the Vehicle hoisted, pressing on the bottom of any tire will produce positive Fz force. Pressing on the front of any tire will produce a positive Fx force. Associated moments are per *the right hand rule*. See figure below.



The WFT channels are defined as:

F_x = Longitudinal Force

F_y = Lateral Force

F_z = Vertical Force

M_x = Roll Moment (Wheel Camber)

M_y = Pitch Moment (Wheel Torque)

M_z = Yaw Moment (Wheel Steer)

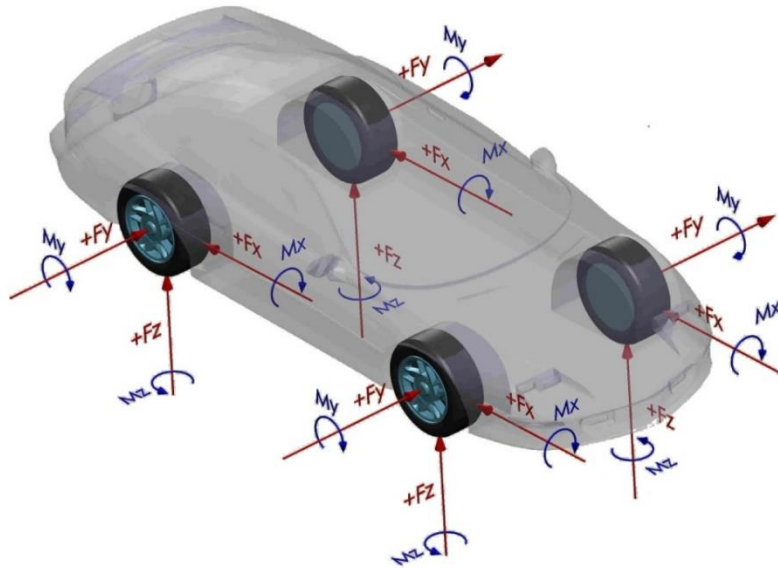
Accel X = Longitudinal Acceleration

Accel Y = Lateral Acceleration

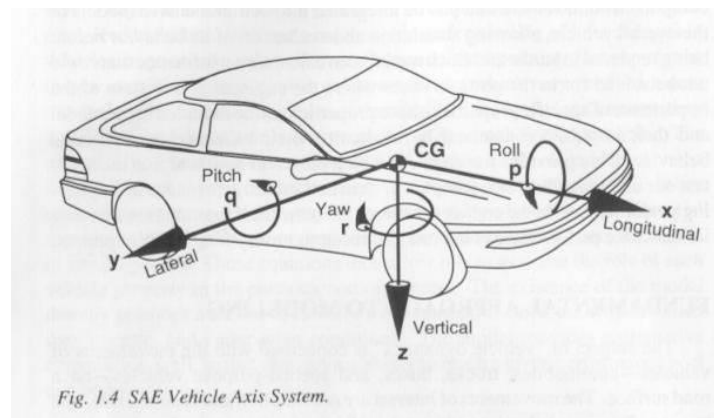
Accel Z = Vertical Acceleration

Left Hand Rule Coordinate System (Optional)

The Optional Left Hand Rule Coordinate will switch the polarity of the F_y and M_y outputs only.



The Left Hand Rule Coordinate System gives the reaction force for a vehicle traveling in the SAE defined directions, per the drawing below.



Weatherproofing

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

Recommended Static Load Rating and Overload

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

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

Transducer Field Checks

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

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 0.05 volts, and the WFT passes the Shunt, it should be in good condition

To check the transducer off-set perform the following.

- Remove hub and wheel adapters.

- Set the transducer flat on the bench.
- Connect the amplifier to the transducer.
- Connect the cable to the slip ring and CT3.
- Power up the CT3.
- Press the *Mode* button to put the CT3 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 amplifier smart sensor for each transducer. The wheel force transducer was statically calibrated in an Automated calibration machine with calibration adapters replicating rim and hub adapters.

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

Optional Transducer Connector Covers are available for purchase

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



Troubleshooting

Symptom	Possible Causes	Solution
CT3 Does not power up when the power switch is turned on.	Power cord not connected to power.	Check that power cord has power supplied to it and try to power up the CT3 again.
	Power supply polarity is incorrect.	Check polarity. See appendix 1. If incorrect, reverse power supply leads and try to power up the CT3 again.
	Internal overload circuit is tripped.	Cycle the power on the CT3.
Fault light illuminates at startup	Signal cable not connected properly.	Check signal cable connections. Cycle power, leave box off for 5 seconds before turning back on
	Smart Sensor information not read by CT3	Cycle power, leave box off for 5 seconds before turning back on. Check for grounding loops and ensure proper CT3 grounding. Swap components to troubleshoot.
Fault light is flashing	No digital data stream from amplifier	Check signal cable for damage.
Zero light does not go out.	Did not complete two full revolutions.	Continue rotating wheels.
	Encoder Issue	Swap slip rings
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 CT3 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 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. CT3 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 CT3 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	CT3 is set to wheel coordinates. CT3 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.	CT3 is in Set-up mode Data channels have error due to rolling zero procedure Slip Ring is not oriented properly. Incorrect zero, direction of wheel rotation was changed during the zero procedure. External forces were imposed during the zero procedure on the hoist. Incorrect zero, on-the-road zero was performed on a rough surface. Data acquisition system has some offset. CT3 electronics are damaged. Offsets are too large for the CT3 to zero them. Damage to transducer.	Switch CT3 to RUN mode 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 See “Angle reference incorrect” below Be sure that the wheel is turned only in one direction during the zero procedure. When turning the wheels, be sure to apply force only on the amplifier package. This insures that no forces are imposed through the transducer. Redo the zero procedure. For best accuracy, perform the zero on the hoist. Using a volt meter, check the outputs from the CT3. If the outputs are indeed zero, null the offsets in the data acquisition system. Swap the CT3 with another unit, if available, and try to zero it. If the problem goes away, send the CT3 electronics in for checkout and repair The wheel may have been damaged. Remove from the wheel and hub adapters and place on the bench. Change the CT3 to setup mode. Check the offset. If it is out of range, send in for checkout and repair.

Symptom	Possible Causes	Solution
Outputs from CT3 stay zero for all channels even when force is present.	CT3 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 CT3 is disconnected or damaged. The data acquisition cabling is not connected improperly.	Check to see if the CT3 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 CT3 electronics, reconnect the cable and turn the CT3 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 CT3 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 CT3 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.

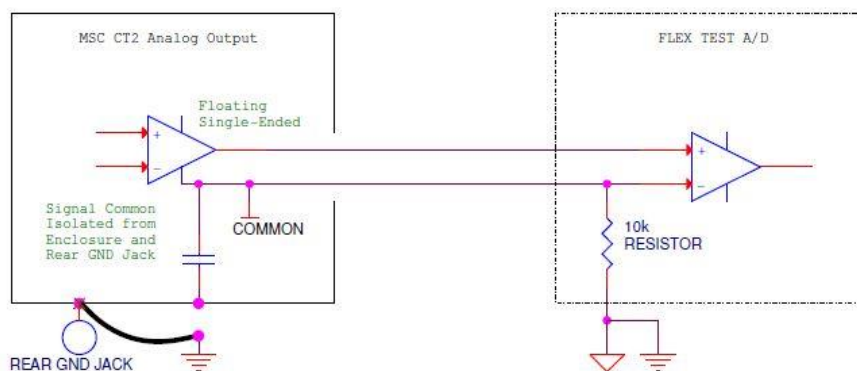
Symptom	Possible Causes	Solution
Higher or lower than expected output from one or more channels	The data acquisition system sensitivities are incorrect. Incorrect amplifier package Transducer is damaged. Amplifier package is damaged.	Check data acquisition system. The correct sensitivities are listed 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 CT3. If correct, check pin-out for signal cable to the data acquisition system. Check the voltage from the CT3. If correct, check the sensitivities in the data acquisition system. See “Angle reference incorrect” below Check the selected Coordinate System in the CT3 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 CT3webpage, 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	CT3 chassis ground not connected to vehicle chassis	Connect one end of a banana plug cable to the CT3 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 CT3 power cable to the vehicle chassis.

Appendix 1- Wiring and Shielding

CT3 Power Connector Pin-Out

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

Proper CT3 Power and Signal Grounding Diagram



CT3 Analog Output Module Cable Pinout

CT3 Analog Output Module - Output Cable Pinout			2/15/2023
Pin#	Function	Description	Color
1	GND	NC	NC
2	Output 2	Signal 2 High	White
3	GND	Signal 2 Low	Brown
4	Output 4	Signal 4 High	Yellow
5	GND	Signal 4 Low	Green
6	Output 1	Signal 1 High	Red
7	GND	Signal 1 Low	Blue
8	Output 3	Signal 3 High	Pink
9	GND	Signal 3 Low	Gray
NC = Not Connected			

Slip Ring to CT3 Cable

WIRING DIAGRAM FOR CT3 w/ 'D3' AMP

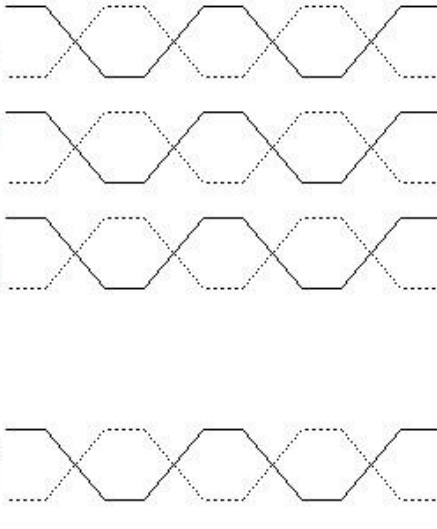
Sep 14, 2022
D. Wheeler

Cable is QUABBIN '5083' from High Flex Industrial CAT5e Series

----- 4x2x26AWG (Paired), Braid Shield, TPE Jacket, 0.245" Overall

CT3 Electronics
S22LFC-P14PFG0-720S

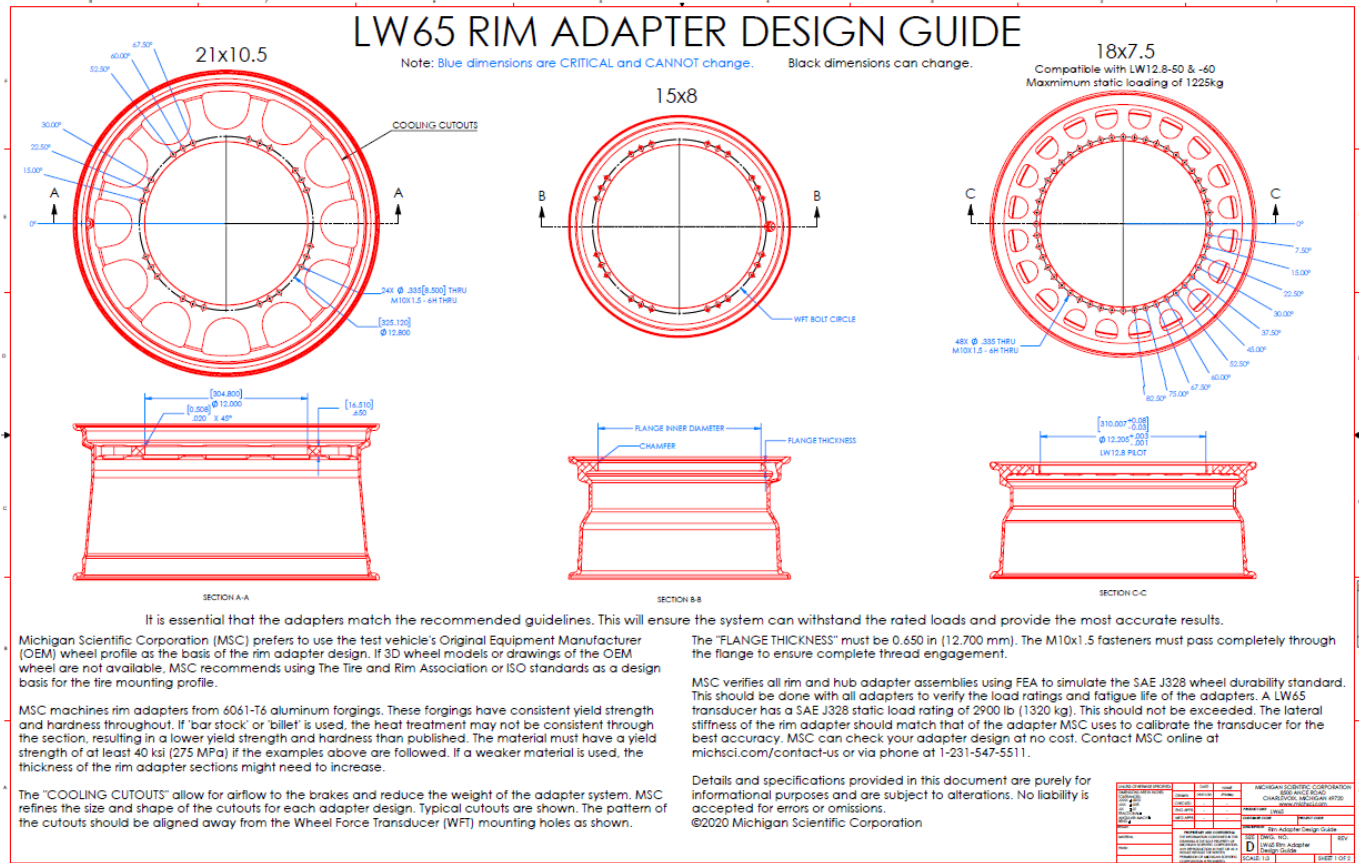
SR Stator

FUNCTION	PINOUT	COLOR		PINOUT
+12VDC	2	Blue		A
-12VDC	3	Wht/Blu		B
CAL Control	5	Wht/Grn		C
Smart Sensor	6	Green		D
ENC +12VDC	4	Orange		E
Ground	1	Wht/Org		F
Data_P	10	Wht/Brn		G
Data_N	9	Brown		H
Overall Shld	Collet/Shell			K

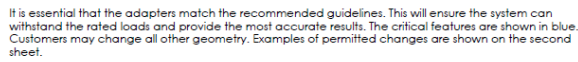
Appendix 2- Adapter Design Guidelines

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.

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.

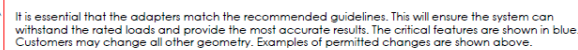
MSC verifies all rim and hub adapter assemblies using FEA to simulate the SAE J328 wheel durability standard. This should be done with all adapter systems to verify the load ratings and fatigue life of the adapters. A LW65 transducer has a SAE J328 static load rating of 2900 lb (1320 kg). This should 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.

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[illegible]

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



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PROJECT INFORMATION PROJECT NO. 13-0000000000000000 (13-0000000000000000) DATE 10/1/2013 TIME 10:00 AM PROJECT NAME PROJECT LOCATION PROJECT OWNER	DATE 10/1/2013 TIME 10:00 AM PROJECT NAME PROJECT LOCATION PROJECT OWNER	MICHIGAN SCIENTIFIC CORPORATION 8800 ARDEN BOULEVARD CHARLEVOIX, MICHIGAN 49730 www.mscorp.com PHONE NO. 231-549-1100 FAX NO. 231-549-1101 E-MAIL info@mscorp.com
PROJECT DESCRIPTION PROJECT LOCATION PROJECT OWNER PROJECT CONTACT PROJECT CONTACT PHONE PROJECT CONTACT FAX PROJECT CONTACT E-MAIL	PROJECT DESCRIPTION PROJECT LOCATION PROJECT OWNER PROJECT CONTACT PROJECT CONTACT PHONE PROJECT CONTACT FAX PROJECT CONTACT E-MAIL	MICHIGAN SCIENTIFIC CORPORATION 8800 ARDEN BOULEVARD CHARLEVOIX, MICHIGAN 49730 PHONE NO. 231-549-1100 FAX NO. 231-549-1101 E-MAIL info@mscorp.com
PROJECT DESCRIPTION PROJECT LOCATION PROJECT OWNER PROJECT CONTACT PROJECT CONTACT PHONE PROJECT CONTACT FAX PROJECT CONTACT E-MAIL	PROJECT DESCRIPTION PROJECT LOCATION PROJECT OWNER PROJECT CONTACT PROJECT CONTACT PHONE PROJECT CONTACT FAX PROJECT CONTACT E-MAIL	MICHIGAN SCIENTIFIC CORPORATION 8800 ARDEN BOULEVARD CHARLEVOIX, MICHIGAN 49730 PHONE NO. 231-549-1100 FAX NO. 231-549-1101 E-MAIL info@mscorp.com

Appendix 3 - Example LW60 & LW65 Quick Reference Calibration Sheets



Calibration: ISOMSC-1163113373-1016



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

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

Quick Reference Sheet

Transducer Serial Number:

LW60 1270

Calibration Date:

11/01/2023

Wheel Force Transducer Electronics: CT3

Gain and offset adjustments are handled in the CT3. The CT3 uses a shunt calibration sequence to adjust the gain so that the following sensitivities are correct. It is good practice to invoke the Shunt sequence by pressing the Shunt button at the start of each new test set-up. The Shunt sequence also compares the factory Shunt output to the field Shunt output. If these values differ by more than 2.5%, the fault and shunt lights will stay lit. This indicates a likely issue with the transducer or amplifier.

Sensitivity

Fx	1 Volt =	1,461 lb	6,500 N
Fy	1 Volt =	787 lb	3,500 N
Fz	1 Volt =	1,461 lb	6,500 N
Mx	1 Volt =	738 lb.ft	1,000 N.m
My	1 Volt =	738 lb.ft	1,000 N.m
Mz	1 Volt =	738 lb.ft	1,000 N.m
Accel X	1 Volt =	10 g	98 m/s ²
Accel Y	1 Volt =	10 g	98 m/s ²
Accel Z	1 Volt =	10 g	98 m/s ²

The Sensitivities listed above are the default settings which correspond with a ± 10 Volt Analog Output range. In the CT3 webpage it is possible to change the Analog output range. If the Analog output range is changed the above listed sensitivities will also change correspondingly.

Shunt Calibration

Fx	4.725 V* =	6,905 lb	30,715 N
Fy	4.852 V* =	3,818 lb	16,982 N
Fz	4.745 V* =	6,934 lb	30,844 N
Mx	3.883 V* =	2,864 lb.ft	3,883 N.m
My	4.399 V* =	3,245 lb.ft	4,399 N.m
Mz	3.852 V* =	2,841 lb.ft	3,852 N.m

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

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

Speed and Position

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

The Speed Sensitivity listed above is the default setting (this corresponds to 2000 RPM full scale). The Speed Sensitivity can be changed to 100 or 300 RPM per volt in the CT3 webpage (corresponding to 1000 or 3000 RPM full scale). Check the CT3 webpage for current settings. Speed is updated at each encoder pulse.



Calibration: ISOMSC-1163113373-723

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

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

Quick Reference Sheet

Transducer Serial Number:

LW65 1089

Calibration Date:

01/19/2023

Wheel Force Transducer Electronics: CT2

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

Sensitivity

Fx	1 Volt =	1,574 lb	7,000 N
Fy	1 Volt =	899 lb	4,000 N
Fz	1 Volt =	1,574 lb	7,000 N
Mx	1 Volt =	811 lb.ft	1,100 N.m
My	1 Volt =	811 lb.ft	1,100 N.m
Mz	1 Volt =	811 lb.ft	1,100 N.m
Accel X	1 Volt =	10 g	98 m/s ²
Accel Z	1 Volt =	10 g	98 m/s ²

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

Shunt Calibration

Fx	4.636 V* =	7,295 lb	32,451 N
Fy	3.884 V* =	3,493 lb	15,537 N
Fz	4.634 V* =	7,293 lb	32,440 N
Mx	4.566 V* =	3,704 lb.ft	5,022 N.m
My	4.500 V* =	3,651 lb.ft	4,950 N.m
Mz	4.515 V* =	3,663 lb.ft	4,967 N.m

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

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

Speed and Position

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

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

Appendix 4 – Changing Amplifier Smart Sensor

Michigan Scientific 'D3' 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: