FOCUS APPLIED TECHNOLOGIES
DYNAMOMETER SYSTEM
CHASSIS DYNAMOMETER
MODELS SCD-75, 100, 200, 300
SCCD-50, 75, 100, 200
CONTROLLER MODEL DC5

Manual Rev. 3-0618

SUPERBIKE DYNAMOMETER
WITH CONTROLLER

FOCUS APPLIED TECHNOLOGIES SDN. BHD.
Lot 463 Jalan Relau K134
Nibong Tebal 14300
PENANG, MALAYSIA
www.FocusAppliedTechnologies.com

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T E C H N O L O G I E S

1. INTRODUCTION

The "Superbike Chassis Dynamometer" (SCD) and "Superbike Compact Chassis Dynamometer" (SCCD) series is intended for workshop and R&D testing, measurement and tuning of performance motorcycles. All of the units share a similar design air-cooled eddy current load unit, overall design, controller and software. As a loading type dynamometer the load can be adjusted to maintain a constant speed, torque or "road load" for testing/tuning as required. With proper maintenance this equipment can last for many decades. New software is constantly being developed, and optional equipment added, so please check our website to make sure you have the latest tools and software: www.FocusAppliedTechnologies.com

This manual is intended for servicing and maintenance of the Superbike Chassis Dynamometer series of dynos. Very little maintenance is required: Bearings require periodic lubrication, belts need to be tensioned, inspected and replaced, and the torque measurement requires occasional calibration. Various accessories may also require some minor maintenance, such as wheel clamps requiring lubrication, or "consumable" type exhaust gas sensors which need occasional replacement.
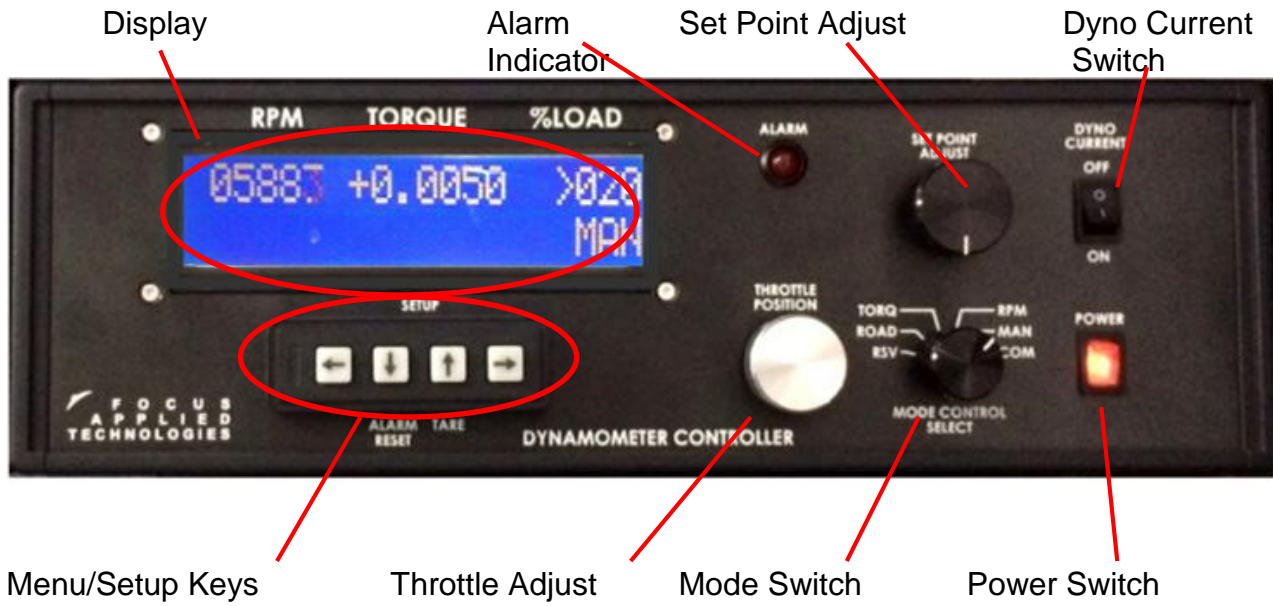
In general testing includes loading the test vehicle on the dyno, clamping the vehicles un-powered wheel(s), securing the vehicle (ie. With tie down straps or similar), selecting the desired control mode (ie. Road Load, Constant Speed, Constant Torque, Manual Load, "Dyno Pull", Batch or Automatic testing profile) and operating the vehicle at the desired throttle setting. Speed and Torque are displayed on the dynamometer controller, and much more data can be displayed and logged to a computer if connected. Testing often includes measuring the speed, torque and power, and may also include things such as the exhaust gas oxygen (O2 or Air Fuel Ratio), fuel flow rate, engine or exhaust gas temperatures and etc. Test sessions may also include tuning of the engine in order to achieve the desired power, AFR or other target output. In some applications the dynamometer is used for verification of specifications of production vehicles, for example confirmation of emissions, power, speed and etc.

As with any measurement tool, getting good data requires proper use of the equipment. This dynamometer includes many compensations which can affect the reported data (such as inertia, friction, and atmospheric temperature and pressure). Make sure your unit is properly calibrated for the best results. It is a common complaint among dynamometer users that results from one dyno often do not match another dynamometer. This is generally to the improper calibration, especially of compensation factors. Additionally engine dynamometers generally read 10 to 20% more power than chassis dynamometers because there are several losses of power between the engine and the wheels including transmission losses, and tire losses. Dyno results, therefore, are often used on a comparison basis, ie. *How much did changing the new exhaust system change the torque by?* A "baseline" torque curve is taken before a modification, and then compared to an identical measurement after modification. "Back to back" tests like this will give the most accurate evaluation of a modification.

Finally, because of the power involved any dynamometer can be dangerous if it is improperly used. Remember that the power of the engine is present in the moving parts, and can cause injury if transmitted to your body. Make sure the test area is kept clean and free of loose clothing and straps. Avoid contacting moving parts, always keep a fire extinguisher on hand, and provide adequate cooling for the engine/vehicle and exhaust gas ventilation.

CONTROLLER FRONT VIEW

Display — Alarm Indicator — Set Point Adjust — Dyno Current Switch

RPM TORQUE %LOAD

05883 +0.0050 >020
MPH

ALARM

SET POINT ADJUST

DYNO CURRENT OFF ON

SETUP

THROTTLE POSITION

TORQ RPM
ROAD MAN
RSV COM

POWER

ALARM RESET TARE

DYNAMOMETER CONTROLLER

MODE CONTROL SELECT

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Menu/Setup Keys — Throttle Adjust — Mode Switch — Power Switch

CONTROLLER REAR VIEW

Fan — Speed2 Input 12V Power Out — Analog Inputs — Ignition Cutoff Relay — Cutoff Inputs — Analog Outputs

MAIN CIRCUIT BREAKER — OUTPUT CIRCUIT BREAKER

INPUT: 240VAC 50/60Hz

DYNO POWER OUTPUT

DYNO SIGNAL INPUT

RS-232

Breakers — Controller Power — Dyno Power output — Dyno Power Input — Speed & Torque Inputs — Serial Coms
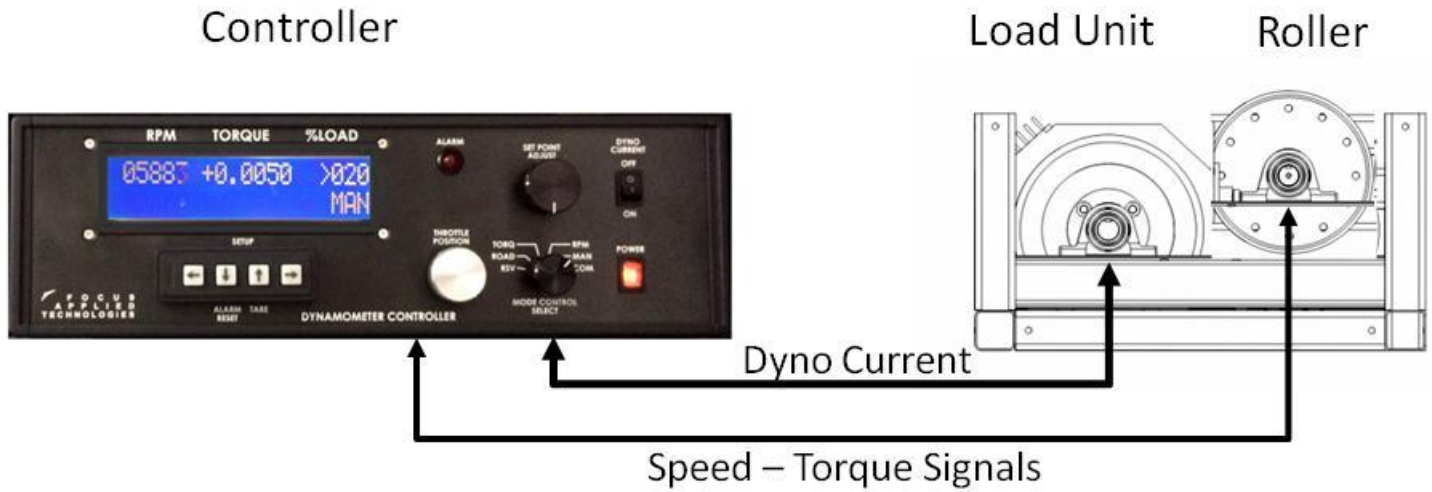
EXTERNAL WIRING DIAGRAM

The controller is connected to the dyno via two quick connect electrical connections. The dyno current (load current) is carried in a heavy cable while the signals (torque and speed) are carried in a thinner cable.

Current to the dynamometer coils is typically provided at 100V DC, with up to 35A. The load, or torque of the unit is approximately proportional to dyno current, but decreases as the dynamometer warms up.

The speed signal comes from a Hall Effect sensor reading the "teeth" on a rotating shaft. The sensor should be aligned to give a consistent "high/low" signal as the teeth pass the tip of the sensor. One of the important parameters is the number of teeth on the shaft, called the "Pulses Per Revolution" or PPR. This number (typically 30, 40 or 60) is entered into the dynamometer controller so that it reads the rollers rpm accurately. The most common issues with the speed signal are poor alignment of the sensor with respect to the "target wheel" teeth, or broken/miss connected wires.

Torque is measured by a strain gage load cell. This 4-wire device has an excitation voltage of 5 to 10V applied to it, and gives a small differential voltage between the two intermediate voltage wires. As the load cell is loaded (ie. Torque is applied), the voltage between these two signal lines grows proportionally, but remains small, typically a few millivolts, thus requiring a high gain amplifier. The most common issues with the torque measurement are broken/miss connected wires, or incorrect amplifier gain/offset. If exposed to vibrations load cells may fail as fine wire connections within them fatigue from the vibrations. Replacement parts are available.

There are 2 external power lines to the dynamometer: a normal gage electrical connection for powering the controller, and a heavy gage electrical connection for dynamometer coil current. The controller only consumes about 1 A of current, while the dynamometer coils may require up to 18A. It is recommended that the dynamometer coils be powered from a special high power outlet with a 30A breaker, and the controller and computer system be powered from a separately fused line.

CONTROLLER OVER VIEW

The controller reads the Torque from the dynamometer via four wires connected to the load cell input at the back of the controller. These wires are RED (Excite +), Black (Excite -), White (Signal +) and Green (Signal -). In case the torque signal is reversed, simply reverse the positions of the WHITE and GREEN wires. Excite+ is a 5V reference voltage, so make sure not to short it to ground.

Speed of the roller is read by a Hall Effect type Speed Sensor which delivers a "pulse" for every passing tooth of the Speed Target Wheel on the rollers shaft. The Speed Sensor should be located approximately 2mm from the target wheels teeth. The sensor is wired to the RPM1 input at the back of the controller (YELLOW wire), Ground (GREY wire) and Excite+ (BROWN wire).

The dynamometer controls the load on the dynamometer by supplying a current to the coils. This current comes from the DYNO+ and DYNO- lines at the back of the dyno controller which are to be connected to the dyno via heavy gage wires. In operation DYNO + and DYNO – will have large DC voltages, which are NOT ISOLATED from the AC Line Voltage. This means the shorting either DYNO + or DYNO- to ground may cause a "Ground Fault Interupt" breaker to shut off current. Also the voltage on these lines MAY BE HAZARDOUS.

WARNING: Both the DYNO + and DYNO – lines may have hazardous voltages on them any time the controller is connected to line voltage. NEVER touch these lines as it could cause injury or death.

As the dynamometer load is increased, the DYNO + voltage will increase relative to DYNO-. At full load this may be as much as 200V DC depending on the model of dynamometer.

Current supplied to the dynamometer load unit creates magnetic fields which penetrate the moving rotor disks of the load unit. As the dynamometer rotates in the magnetic field, eddy currents are induced in the rotor disk, resulting in a retarding force on the disk, and an opposite force on the coils of the dynamometer. As the coils are mounted on a free rotating hub, the force on the coils is transmitted to the load cell retaining the hub. This results in compression of two of the strain gages in the load cell, and extension of the other two strain gages, yielding a small signal on the Signal+ and Signal– lines. This signal must be amplified by a special differential amplifier located inside the dynamometer controller.

The Speed, Toque and Load are displayed on the screen on the front of the dynamometer, and sent via the serial communications link to a computer (optional) for display and recording.

The dynamometer can control the Dyno load in various modes including: Manual mode, Speed Mode, Torque Mode and Road Load Mode. The Set Point of the various modes can be adjusted by rotating the Set Point Adjust knob. The vehicle's engine or motors output power can be regulated by the Throttle control knob, if the appropriate throttle servo motor or power supply is used. Additionally in Computer Controlled Mode, the actual mode and set point as well as the Throttle can be adjusted from the computer.

DYNAMOMETER SIDE VIEW (SCD)

Dynamometer (Inside)

Roller

Front Wheel
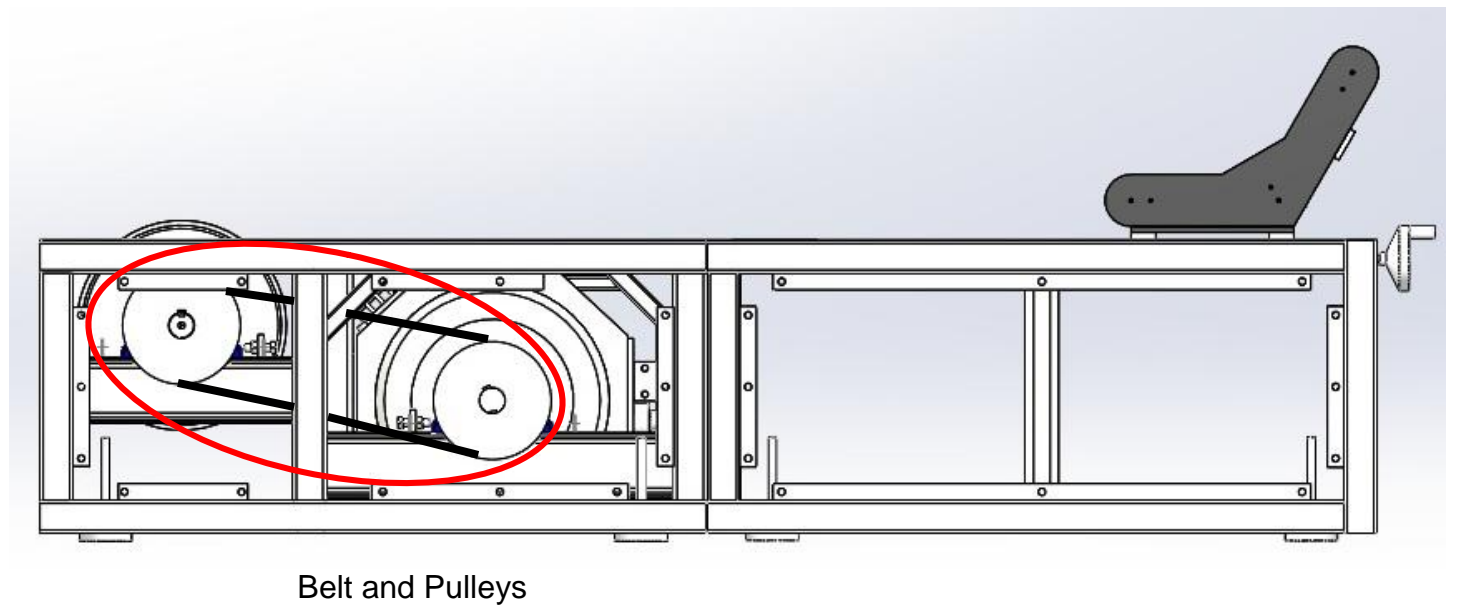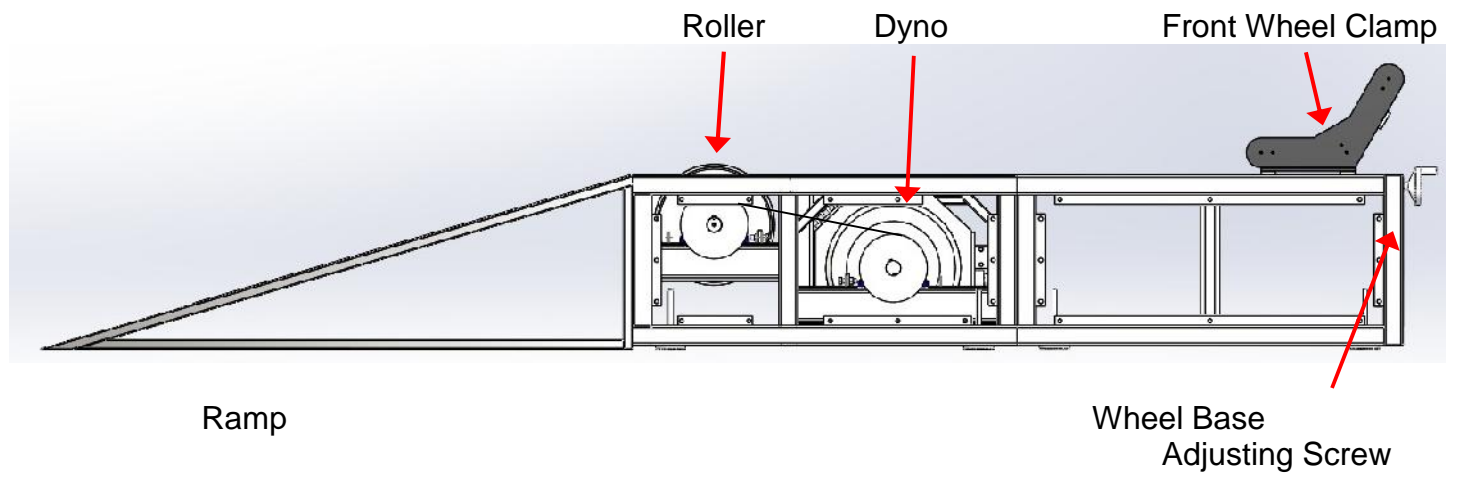Tie Down Strap

Wheel
Base
Adjusting Screw
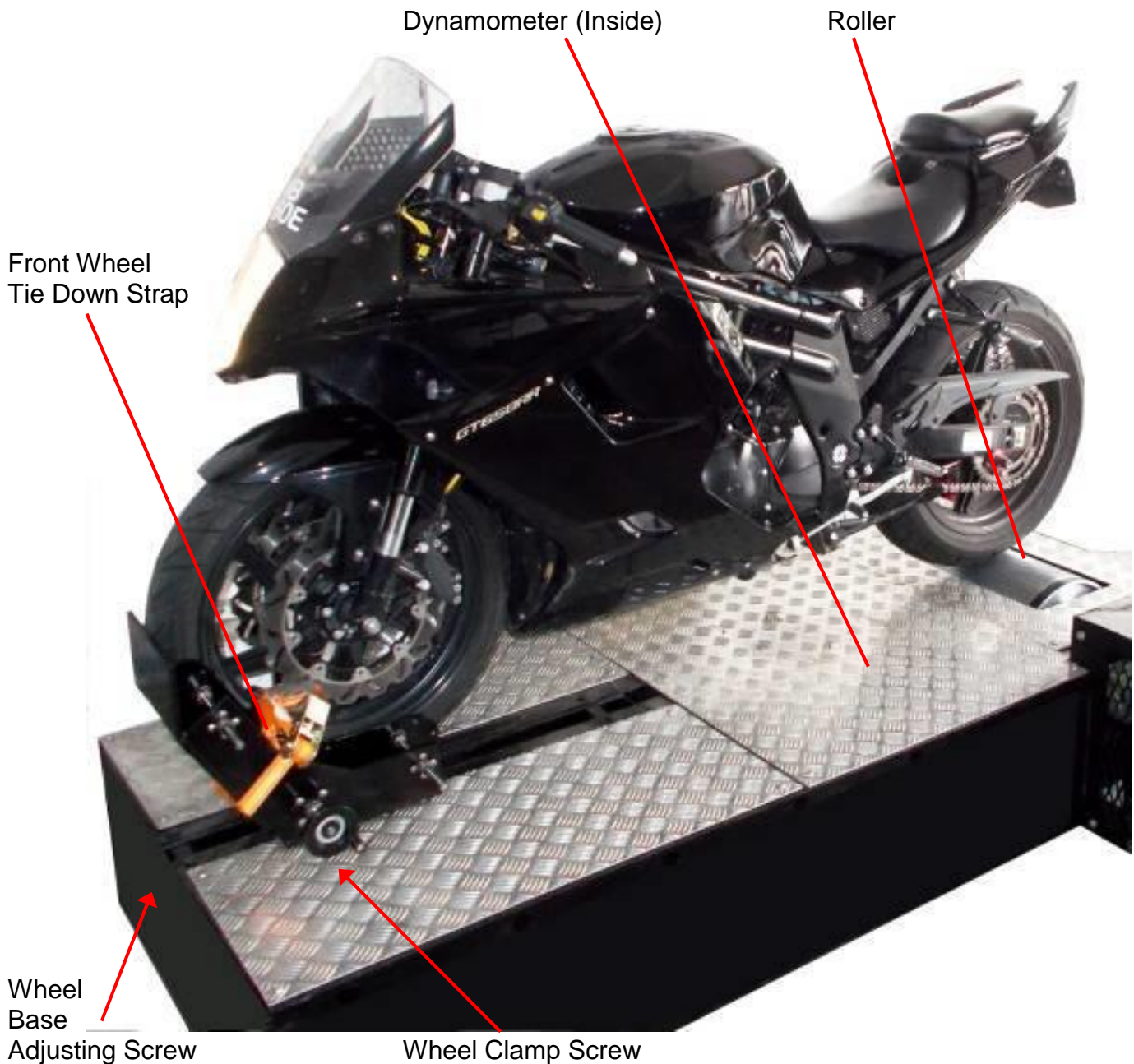
Wheel Clamp Screw

To mount a motorcycle, open the wheel clamp, and then carefully ride it up the ramp (for above ground frames), and pilot the front tire directly into the Wheel Clamp. Tighten the wheel clamp by turning the Wheel Clamp Screw clockwise. The Wheel Base Adjusting screw should be adjusted tso that the centerline of the rear wheel is directly above the center line of the roller. For narrow wheels you may want to use a spacer (such as a piece of wood or hard rubber) between the wheel and the wheel clamp. For lightly loaded testing the wheel clamp is sufficient to keep the motorcycle in place, however it is recommended to use a front wheel tie down strap (as shown above). Also for automated testing and high-torque testing it is best to apply a tie down strap across the seat of the bike, pulling it down onto the roller to avoid wheel slip.

In some cases it may be necessary to apply a grounding wire between the frame of the motorcycle and the dynamometer's frame, and the dynamometer controller.

Exploded View

Roller   Dyno   Front Wheel Clamp

Ramp

Wheel Base
Adjusting Screw

Belt and Pulleys

DYNAMOMETER SIDE VIEW (SCCD)

Nose Clamp   Roller   Electrical Connections

Nose Frame   Middle Frame   Belt and Pulleys

Torque Cell   Load Unit

Dist: 226.5mm

Bearing (1/4)   Speed Pickup

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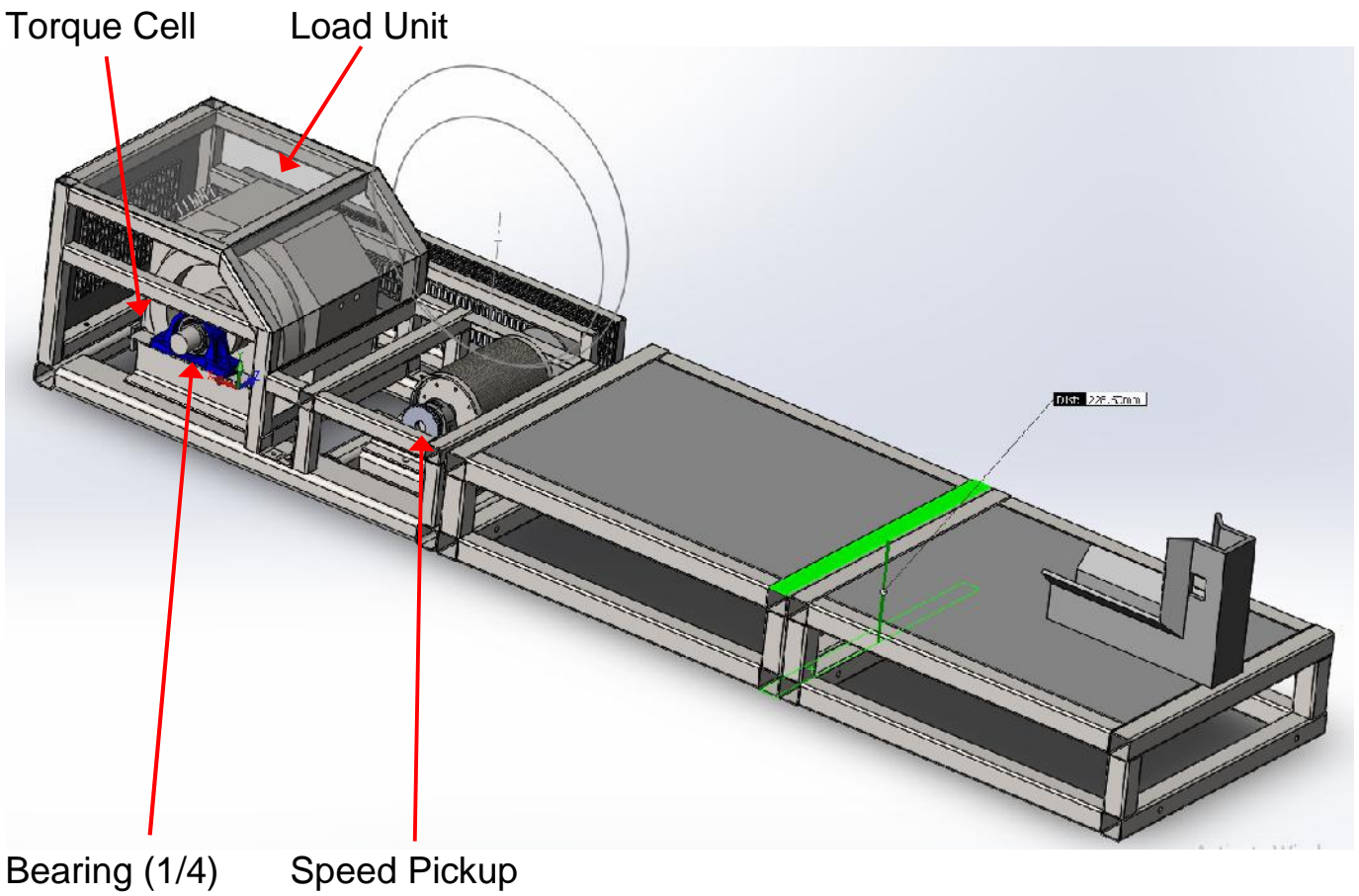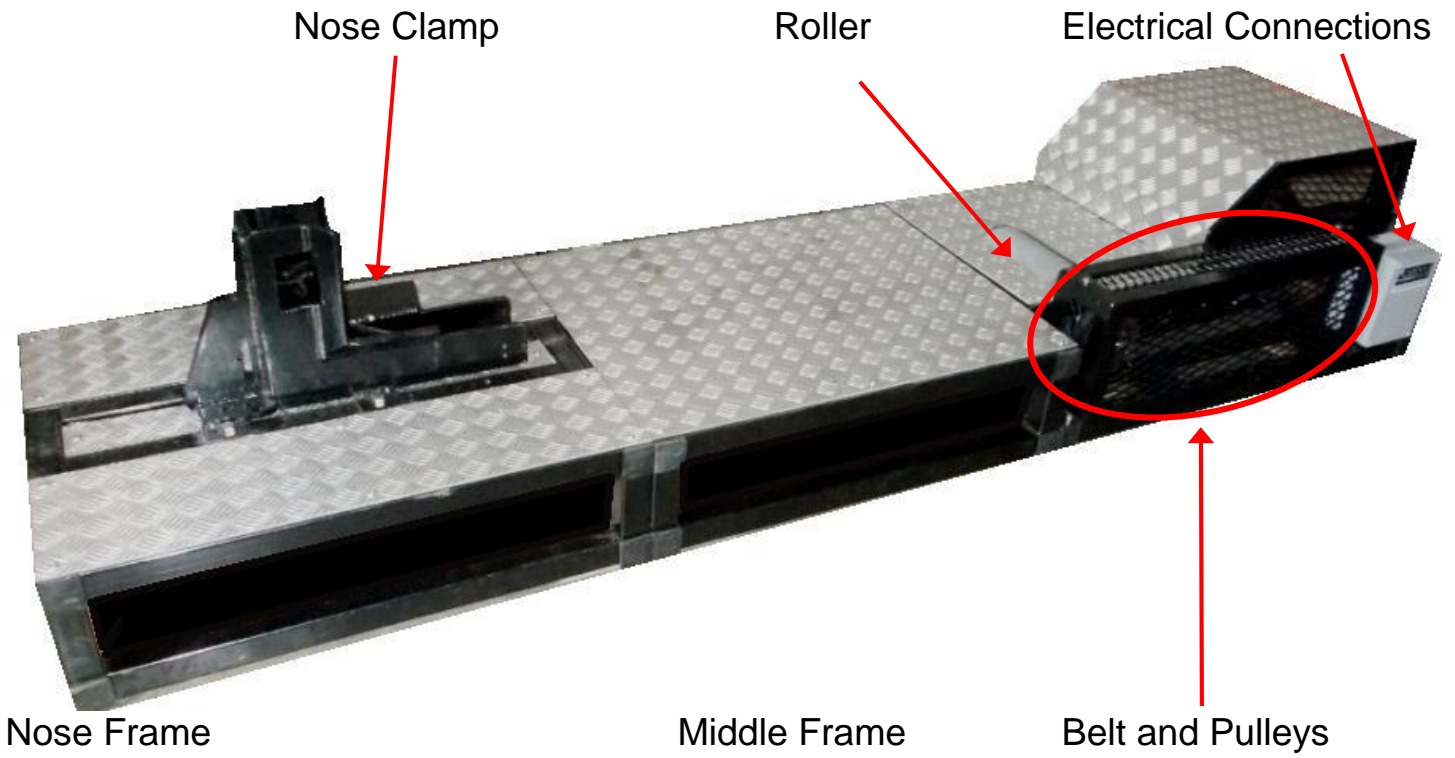
DYNAMOMETER CONTROLLER FEATURES

Dynamometer

The dynamometer is an eddy current dynamometer especially designed for easy testing and tuning of high powered motorcycles. Power from the vehicles rotates the main roller, which in turn rotates the load unit. The dynamometers axial magnetic field is controlled by the dynamometer current with more current giving a stronger stator magnetic field, inducing more eddy current in the rotating disk and thus load on the vehicle and a torque on the dynamometer which is measured by a load cell. Power from the vehicle is dissipated as heat in the spinning disk.

Dynamometer Controller

This dynamometer controller allows the user to control the dynamometer in several different modes: Manual, Speed, Torque, Road Load and Computer (remote) mode. Which of these modes to use depends on the specifics of your testing. For simple loading of a vehicle (ie. adding or reducing the load) the easiest mode is the Manual Control mode. For constant speed operation (Torque will vary) use the Speed Control mode. Road Load mode is commonly used to simulate the aerodynamic load a vehicle when operated on the road. Note that inertia/mass is not matched unless the eddy disk has the same inertial as the target vehicle, however vehicle mass effects can be simulated in the Road Load mode. Computer control mode is used for automated testing, often in conjunction with the throttle control, which can also be operated remotely from the computer.

Computer Communications

A computer can be connected to the dynamometer controller for logging data from the Dynamometer Controller, Fuel Scale and Data Acquisition systems via Serial Ports. If serial ports are unavailable then a USB-Serial Port converter may be used. Serial port communications are via RS232: 9600 baud, No parity, 1 Stop bit. The cable should be a "straight through" cable connecting pins 2, 3, and 5 at both ends. In Verbose mode the controller automatically sends data out in the format shown below at approximately 4Hz. During power on the controller sends out a "Power On" message with the firmware code. Data can be logged from various serial communications programs including Hyperterminal. Various controller parameters can be modified from the computer interface, and data can be logged by the computer as well. In Verbose mode the controller will automatically output data to the serial port every 250ms. When the control is NOT in Verbose mode sending the character "A" will cause the controller to respond with the data.

In general the computer data is output in the following format:

ZSSSS1_SSSS2_TT.TTT_LLL_Mode_SP_TTL_Alarm_A1_A2_A3_A4 [CR]

Where:
S is speed in RPM (S1 is rpm1, displayed on the front panel, S2 is rpm2 which is not displayed on the front panel)
T it torque in Nm
L is load in %
Mode is the mode:
    NM for front panel Manual mode, CM for Computer Manual

NS for front panel Speed mode,   CS for Computer Speed
NT for front panel Torque mode,   CT for Computer Torque
NR for front panel Road Load mode,   CR for Computer Road Load

SP is the set point
TTL is the throttle position (0-1023 is 0 to Wide Open)
Alarm is 0 for no alarm, and 1 for alarm
A1 .. A4 is the Analog input in 0-1023 (ie. 10 bit) 5V resolution.
The separator between the fields is a space character

For example:

Z2510 6500 12.345 20 NS 2500 53 0 123 345 678 1023

Speed is 2510 RPM
Speed 2 is 6500 rpm
Torque is 12.345Nm
Load is 20%
Mode is Front Panel, Speed Mode
Set Point is 2500
Throttle is 53
No Alarm state present
Analog Input 1 is 0.601V   (ie. 5*123/1023)
Analog Input 2 is 1.686V
Analog Input 3 is 3.314V
Analog Input 4 is 5.00V

Data Acquisition System

This dynamometer controller includes a basic Data Acquisition System (DAQ). This system is for reading signals from various sensors commonly used in engine testing such as Thermocouples, Pressure Sensors, Voltages and etc. Several channels are available for the use, and are logged along with the standard controller data (eg. Speed, Torque, %Load, Control Mode, Alarm Status). All of these sensors can be read by the computer data logging software for display and recording.

NOTE: Analog input voltages are limited to 0 to 5V. If measuring voltage above 5V you must use a voltage divider to reduce the voltage to below 5V max.

Fuel Scale

Some test systems are equipped with a fuel scale. This digital gravimetric fuel scale measures fuel weight as it is consumed by the engine under test. The data is fed to the computer via serial (RS-232) communications link, allowing seamless integration with our dynamometer and DAQ systems. The weight of fuel is measured as a function of time allowing direct measurements of fuel consumption, and calculation of Break Specific Fuel Consumption (BSFC), and Fuel Mass Flow rate, for calculation of actual Air Fuel Ration (AFR) when combined with an air flow sensor.

Dynamometer Operating Range

The dynamometer is designed to operate at 4,500 rpm max. There are a few bearings exerting a resistive load on the roller which require compensation for best results. In general the SCD series

has a static friction of 5Nm with about 5Nm addition per 1000 rpm. This is compensated for using the following Torque Friction Correction equation (numbers used are for the AC Motor):

Compensated Torque = Measured Torque + (5.0+ RPM x .005)

For example if you are measuring 100Nm of torque at 2000rpm, the compensated torque is about 215 Nm total. If the DynoParameters file is set up correctly, the Torque displayed on the computer will be correct. The raw torque reading is saved to the datologing file, along with the compensated torque (which includes friction and accelerational torque based on the declared inertia). The SCD series dynamometer has an inertia of approximately 1.7 kg m^2.

The maximum steady state load torque of the dynamometer is approximately 500Nm (SCD/SCCD-200), and the maximum speed is 4500 rpm. This gives a maximum mechanical power of approximately 230kW (304hp) at 4,500rpm. When accelerating the inertia the dynamometer can absorb about twice this power.

SCD-200 TORQUE CURVE
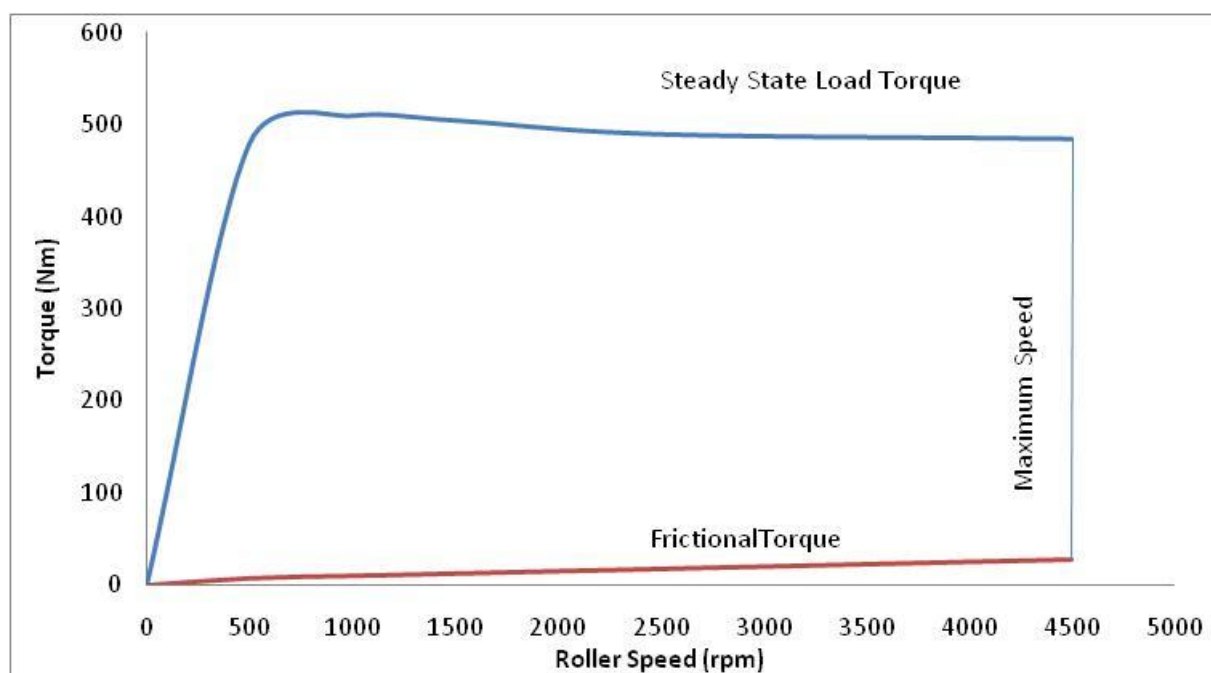
Torque is limited by the available voltage from the dyno at low speeds. At higher speeds, the torque is relatively constant as the dynamometer operates in a current (torque) limited mode. The lower limit of torque is the total friction, which depends on the motor or engine being tested. The SCD-200 torque curve is shown above, and the SCCD-200 curve is shown below. The SCCD curve varies from the SCD curve due to the different gearing ratio.

The steady state operating range of the dynamometer includes all speeds and torques between the maximum torque curve and the frictional curve up to the maximum operating speed.

SCCD-200 TORQUE CURVE

Chart: Torque (Nm) vs Roller Speed (rpm). Curves labeled "Maximum Torque", "Maximum Speed", and "Frictional Torque".

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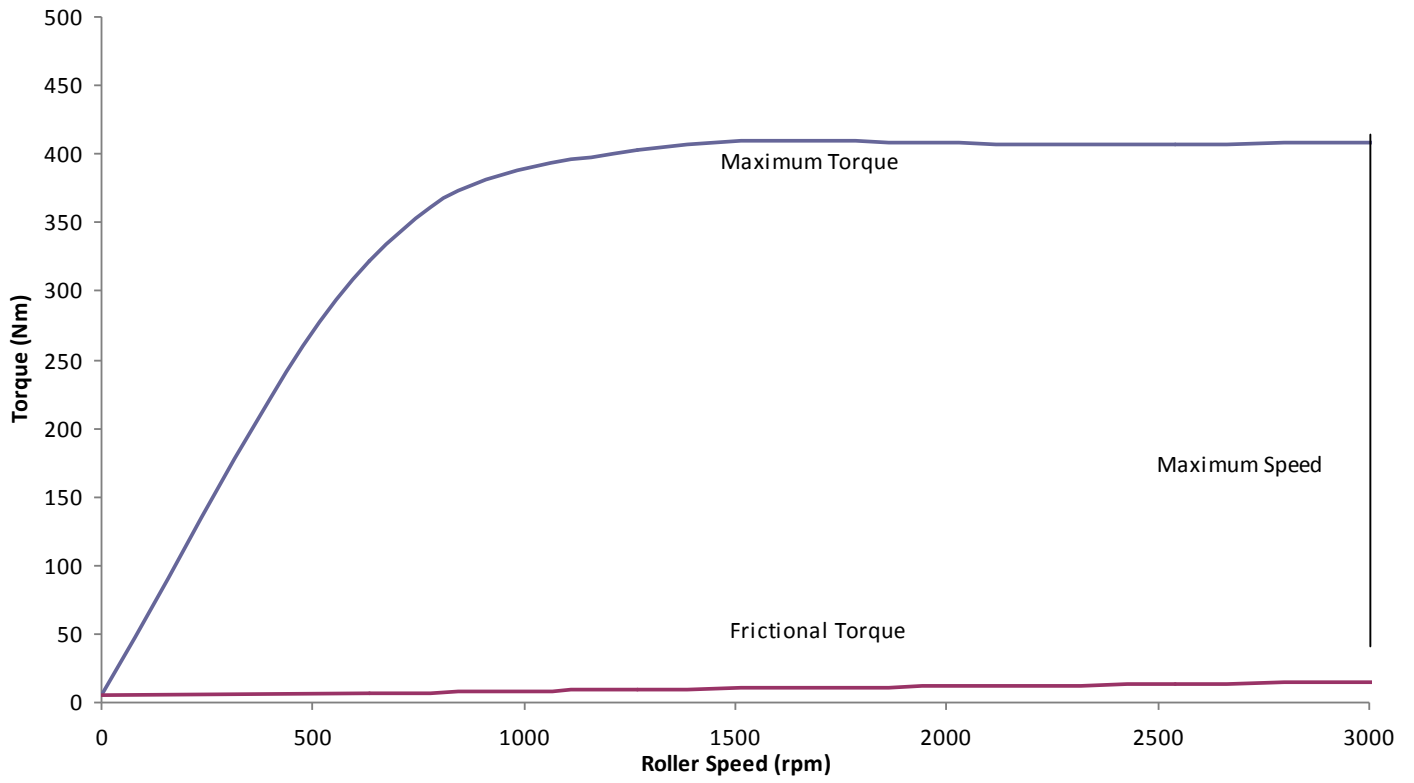
CONTROL MODES

Modes of Control

This dynamometer controller allows the user to control the dynamometer in several different modes: Manual, Speed, Torque, Road (RPM²) and Computer Control mode. Which of these modes to use depends on the specifics of your engine testing. For simple loading of an engine (ie. adding or reducing the load) the easiest mode is the Manual Control mode. For constant speed operation (Torque will vary) use the Speed Control mode. For automated testing, use the COMputer controlled mode, which also allows control of the Throttle setting. In all operating modes the **TARE** key zeros out the torque reading, and **Alarm Reset** resets the alarm state, assuming the cause of the alarm condition has been cleared.

Manual Control

In Manual Control mode the Set Point Adjust knob directly controls the current going to the dynamometer. For a given speed, the load will be directly proportional to the knob setting: 0% load at one end, 100% load at the other end.

The most common engine testing is done using manual mode control. For a torque/power curve of the engine, the engine can be started and throttled up to "redline" (ie. the maximum rated speed). Dyno load is increased as the throttle is opened to keep the engine just at redline speed. Once the throttle is fully open, the torque and speed are recorded. Subsequently the load in increased in small steps, causing the engine speed to decrease. At each new speed the torque and speed are again recorded. Repeating this in steps of 500 rpm allows the wide open throttle (WOT) torque curve to be determined.

NOTE: Engines operating at Wide Open Throttle can generate a lot of heat. Make sure you supply the engine or motor with sufficient cooling air.

Speed Control

In Speed control mode the Set Point Adjust knob sets the desired speed. If the engine is operating above the set speed, the controller will increase the current to the dynamometer, increasing the load on the engine, and slowing it down to the set speed. If the engine is incapable of reaching the set speed at a given throttle, the engine will operate at a speed below the set point, and the dynamometer will be completely unloaded. For best results the PID gains must be carefully adjusted.

Torque Control

In Torque control mode the Set Point Adjust knob sets the desired Torque. If the dyno is operating below the set torque, the controller will increase the current to the dynamometer, increasing the load on the engine, and slowing it down, while the torque increases to the set point. If the engine is incapable of reaching the set torque at a given throttle, the dynamometer will continue to add load until the engine stalls, the clutch slips, or maximum load is attained. If the dyno torque is above the set point, then the load will be reduced, dropping the torque, and increasing the speed.

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ROAD: Road Load Control

In Road Load control mode the load is varied as a function of speed to mimic acceleration, aerodynamic and rolling resistance of a vehicle. Aerodynamic load is increased proportional to the square of the speed, with no load at zero speed. Rolling friction is set to a constant load whenever the speed is non-zero. Accelerational load is applied proportional to acceleration. In this mode the **Set Point Adjust** knob adjusts the overall load, from 0 to 250%. Normally if the various load factors are tuned properly the **Set Point Adjust** knob would be set to 100% in this mode. A larger constant is used for physically larger vehicles, while a smaller constant is used for smaller or more aerodynamic vehicles. A good way to calibrate the constant is to operate the vehicle at a known throttle/speed combination. If the vehicle speed is higher than the desired operating point the constant can be increased, and if the speed is lower, the constant should be decreased. This calibration should be performed in the mid-point of the desired test speed range. Once the constant is established for a given vehicle, it should always be re-used for that particular model.

Computer Control

In Computer control mode the operating control mode and set point and throttle position are received from the computer via the serial port. The command sequence to be sent from the computer is as follows:

CSSSSS

Where:
C is a character indicating the control mode:
>   M for Manual
>   S for Speed
>   T for Torque
>   R for Road Load
SSSSS is the appropriate set point

For Example here are several valid mode/setpoint commands:

M128	Manually Sets Load to 128/10 or 12.8%
S12250	Sets Speed control mode to 12250 rpm
T01234	Set Torque control mode to 12.34Nm
R50	Set Road Load with factor of 50%

For throttle Position control send the following sequence:

PXXXX

Where XXXX is the desired load (0 to 1000 for 0V to 5V)

For Example the following sequence sets the throttle output voltage to 50% (ie. 2.5V):
T0500

Internal Strain Gage Amplifier

This dynamometer controller features an internal strain gage amplifier. This amplifier can be connected to any standard Wheatstone bridge configuration 4-wire strain gage load cell. The amplifier may be bypassed if the load cell does not require further amplification.

Internal Dynamometer Power Supply

This dynamometer controller features an internal power supply providing DC current to the dynamometer coils. Make sure not to exceed the power supply ratings. In general the dynamometer coil resistance should be more than 10 ohms.

Serial Port Data Logging

Along with the controller a "serial port data logging" program called "Dyno Monitor" is also supplied. This program communicates from any PC via the serial port directly to the dynamometer controller and can display and record the mode specific set point (ie. set speed or torque), dynamometer speed, torque, and dynamometer load (duty cycle). The simple serial port communications protocol can also be reproduced in user defined programs for customization.

The Dynamometer controller can be set up to "broadcast" its data automatically by turning the "Verbose" mode ON. This can be done from the front panel menu in manual mode. When verbose mode is OFF the controller will only send out data in response to a received character "A". This is done on some systems to help synchronize data acquisition. Make sure not to issue the A command to the controller more than once very 250ms.

Controller Setup

From the main menu you can access the setup menus using the **right** or **left** arrow keys. Different menus are available for the different modes, as selected by the mode switch. To adjust any of the parameters use the **Up** and **Down** arrow keys. To permanently save changes you make to the configuration use the Up arrow to change the **Save Config?** Value to **YES** then hit the **right** arrow key to exit the menu.
In Manual mode you can select the over speed and torque limits, and the "Pulses Pre Revolution" for the RPM1 and RPM2 speed signals. If a target wheel has 30 teeth, then the appropriate PPR would be 30. Finally in Manual mode you can set the appropriate position for the decimal in the torque display.

In Speed mode you can adjust the Speed Maximum Set Point, and the Proportional, Integral and Differential gain values for the Speed PID Control. For extended PID resolution denominator factors for P, I and D are also provided. If you want finer resolution, and lower gain on a given factor, increase the appropriate factor.

In Torque mode you again have a the Torque Maximum Set Point and the Proportional, Integral and Differential gain values for the Torque PID Control. For extended PID resolution denominator factors for P, I and D are also provided. If you want finer resolution, and lower gain on a given factor, increase the appropriate factor.

Controller Configuration Menu Map

Set the Mode Select Switch to get access to the various menus. Use the **Right/Left** arrows to page through the menu. Use the **Up/Down** arrow keys to change the individual values. To save the configuration use the **Up** arrow key to change **NO** to **YES** at the **Save Config?** screen.

MAN (Manual Control Mode)

```
     R P M        T O R Q U E      % L O A D
   0 0 0 0 0    + 0 . 0 0 0 0        0 0 0
                                     M A N
```

```
     R P M        T O R Q U E      % L O A D
o v e r   s p d   l m t :   > 0 5 0 0 0
o v e r   t r q   l m t :     9 9 9 9 9
```

```
     R P M        T O R Q U E      % L O A D
                  P P R 1 :   > 3 0
                  P P R 2 :   > 3 0
```

```
     R P M        T O R Q U E      % L O A D
                + 0 . 0 0 0 0
                  t r q   d p :   > 4
```

```
     R P M        T O R Q U E      % L O A D
         S a v e   c o n f i g ?
                      > N o
```

In Manual mode the right arrow ( ) will step you through the following values:
Over Speed Limit (Alarm speed at which the ignition relay is turned OFF)
Over Torque Limit (Alarm Torque at which the ignition relay is turned OFF)
Pulses Per Revolution in RPM1 signal
Pulses Per Revolution on RPM2 signal
Position of Decimal Point in Torque Display

RPM (Speed Control Mode)

```
     R P M        T O R Q U E      % L O A D
   0 0 0 0 0    + 0 . 0 0 0 0        0 0 0
> 0 2 5 0 0                          R P M
```

```
     R P M        T O R Q U E      % L O A D

S P   r a n g e   m a x :   > 5 0 0 0
```

```
     R P M        T O R Q U E      % L O A D
P I D   c f g :     P         I         D
s p e e d     > 0 2 0     0 0 5     0 0 0
```

```
     R P M        T O R Q U E      % L O A D
         S a v e   c o n f i g ?
                      > N o
```

In RPM mode the right arrow ( ) will step you through the following values:
Set Point Range Maximum Value (Highest RPM selectable as Set Point)
Proportional Gain Constant for Speed PID

Integral Gain Constant for Speed PID
Differential Gain Constant for Speed PID

TORQ (Torque Control Mode)

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
	0	0	0	0	0		+	0	.	0	0	0	0				0	0	0
							>	0	.	1	5	0	0				T	R	Q

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
							+	0	.	0	0	0							
S	P		r	a	n	g	e		m	a	x	:		>	1	9	3		

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
P	I	D		c	f	g	:		P				I				D		
t	o	r	q	u	e		>	0	2	0		0	0	5		0	0	0	

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
				S	a	v	e		c	o	n	f	i	g	?				
									>	N	o								

In TORQ mode the right arrow (   ) will step you through the following values:
Torque Calibration Factor
NOTE: actual torque using this calibration value will be displayed on the top line of the display
Proportional Gain Constant for Torque PID
Integral Gain Constant for Torque PID
Differential Gain Constant for Torque PID

ROAD (Road Load Mode)

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
	0	0	0	0	0		+	0	.	0	0	0	0				0	0	0
K	>	1	0	0													N	^	2

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
	K	f						K	a						K	m			
>	0	0	0	2	0			0	7	5	0	0			0	0	0	0	0

			R	P	M			T	O	R	Q	U	E			%	L	O	A	D
				S	a	v	e		c	o	n	f	i	g	?				
									>	N	o								

Kf: Rolling Resistance
Ka: Speed at which Aerodynamic Resistance becomes 100%
Km: Acellerational Drag

Load% at a given speed (RPM) is then calculated (approximately) as:
Load% = Kf + 100 x (RPM/Ka)² + Km x (RPM')

Where: RPM' is the differential of the speed (ie. acceleration)

Tuning the Road Load Parameters

A convenient way to "tune" in these parameters for a given vehicle is to measure the low-speed (30 kph) steady state cruise throttle setting, the high speed steady-state cruise throttle setting (80kph or higher) and the time required to go from a low engine speed to a high engine speed at Wide Open Throttle (eg. 3000 rpm to 7000 rpm) in a single gear, typically 3rd or 4th gear. These should be measured on a flat, straight road with no wind.

Now the same vehicle is mounted on the dynamometer, and the Road Load calibration parameters are tuned in to get the same performance on the dyno.

First, zero out the Kf and Km settings and set the Ka to the maximum. For the following procedure keep the "Set Point" at 100%. On the dynamometer the set the Rolling Resistance (Kf) to get the same throttle setting at the "low speed" cruise speed. If the vehicle had a throttle position of 0.75V in 3rd gear at 30 kph on the road, it should get 30kph on the dyno with a throttle setting of 0.75V in 3rd gear.

Next set the Aerodynamic Resistance (Ka) to get the appropriate throttle setting at the "high speed" cruise speed. Be sure to use the same gear which was used during the road test. Also recall that *increasing* the Ka value *decreases* the load on the vehicle.

Finally increase the Acellerational Drag (Km) to get the appropriate acceleration time. Again make sure you're in the same gear ratio as was used on the road, and accelerate with maximum throttle.

This should give you dyno performance very similar to the road performance. For minor adjustments you can change the "Set Point". For more load, increase it beyond 100%, for less load decrease it.

COM (Computer Controlled Mode)

```
  R P M        T O R Q U E      % L O A D
 0 0 0 0 0   + 0 . 0 0 0 0     > 0 0 0
                                 C O M
```

```
  R P M        T O R Q U E      % L O A D
    V e r b o s e    M o d e ?
                  > N o
```

```
  R P M        T O R Q U E      % L O A D
    S e r i a l    M o d e ?
                  > T T L
```

```
  R P M        T O R Q U E      % L O A D
    S a v e   c o n f i g ?
                  > N o
```

Computer control mode is used when you want to control the dynamometer from the computer interface, rather than the dynamometer front panel during "Dyno Pulls" and when running batch files. This allows the computer to programmatically control the dynamometers mode, set point and throttle position.

NOTE: In computer control mode the dynamometer front panel Set Point and Throttle controls are not functional.

FOCUS APPLIED TECHNOLOGIES

Verbose Mode:

      On causes controller to output data every 250ms

      Off will cause controller to send output data only when an "A" is received on the communications lines

Serial Mode:

      Serial inverts the output serial data stream (required for RS232 devices)

      TTL does NOT invert the serial data stream (used with WiFi/BlueTooth)

**RSV (Reserved Mode):** As the name implies, this mode is not made available to customers.

CALIBRATION AND ADJUSTMENTS

Speed Calibration and Adjustment

Speed is determined from the frequency of teeth passing the speed pickup. As such the only calibration required is setting the proper number of teeth on the speed target wheel. The standard speed target wheel has 30 teeth and is mounted on the roller shaft, thus the controller should be set up for **30 pulses per revolution (PPR)** to give the appropriate roller speed. This can be set from the front panel by hitting the right arrow in Speed mode, and following the prompts on the screen.

To properly read the teeth is it important that the speed pickup be clean, and in close proximity to the target wheel. The gap between the speed pickup tip and the target wheel should be approximately 2mm. The acceptable range is 2mm to 5mm.
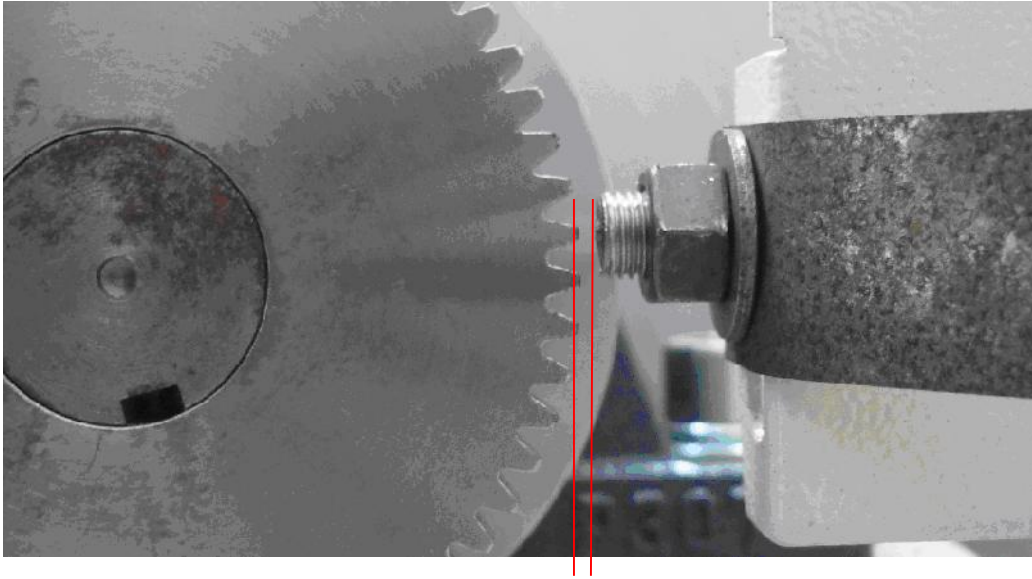
**Speed Sensor Gap:**   0.5 to 1.5mm for Variable Reluctance sensors
                               2 to 5 mm for Hall Effect sensors

To adjust the sensor gap, or adjust the height of the sensor, loosen the large nuts securing the sensor to the holding bracket, adjust the gap and height, and re-tighten the nuts. Do not over tighten as this can destroy the sensor.

The internal speed sensing circuit is a 2-level signal qualification type circuit to eliminate the influence of noise. In order to qualify as a pulse, the voltage of the signal must exceed the UPPER THRESHOLD (**UT**), and then go below the LOWER THRESHOLD (**LT**) before the subsequent pulse can be read. Both upper and lower thresholds are adjustable from potentiometers located on the main controller circuit board. RPM1 pots are labeled UT0 and LT0, RPM2 pots are labeled UT1 and LT1. A voltage sensing pad is provided adjacent to the pots to verify the threshold levels, as shown in the image below.

NOTE: The Lower Threshold voltage MUST be LESS than the Upper Threshold voltage to insure proper triggering of the circuit.

RPM1 Upper Threshold (UT0)   RPM1 Lower Threshold (LT0)
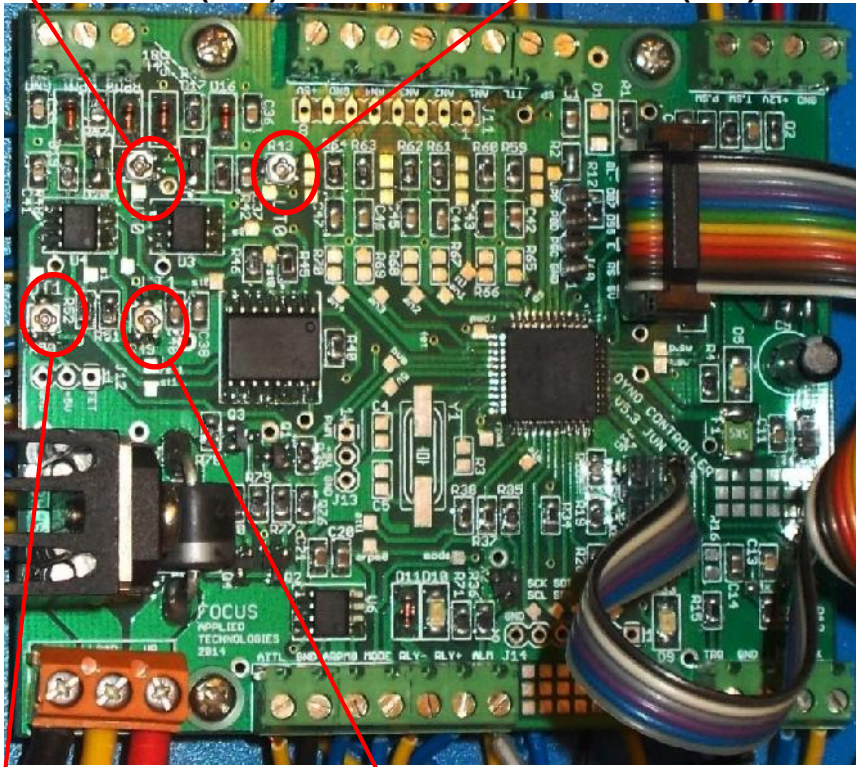
RPM2 Upper Threshold   RPM2 Lower Threshold

Typically we recommend a lower threshold voltage of 0.1V to 0.4V, and an upper threshold voltage of 0.5V to 1V for most VR sensors. For Hall Effect type sensors, the Lower Threshold Voltage should be ~0.5V above the low-voltage reading of the sensor, and the Upper Threshold Voltage should be greater than the Lower Threshold Voltage, and at least 0.5V below the upper voltage reading of the sensor. Hall effect sensors typically use a LT of 1V and UT of 1.5V.
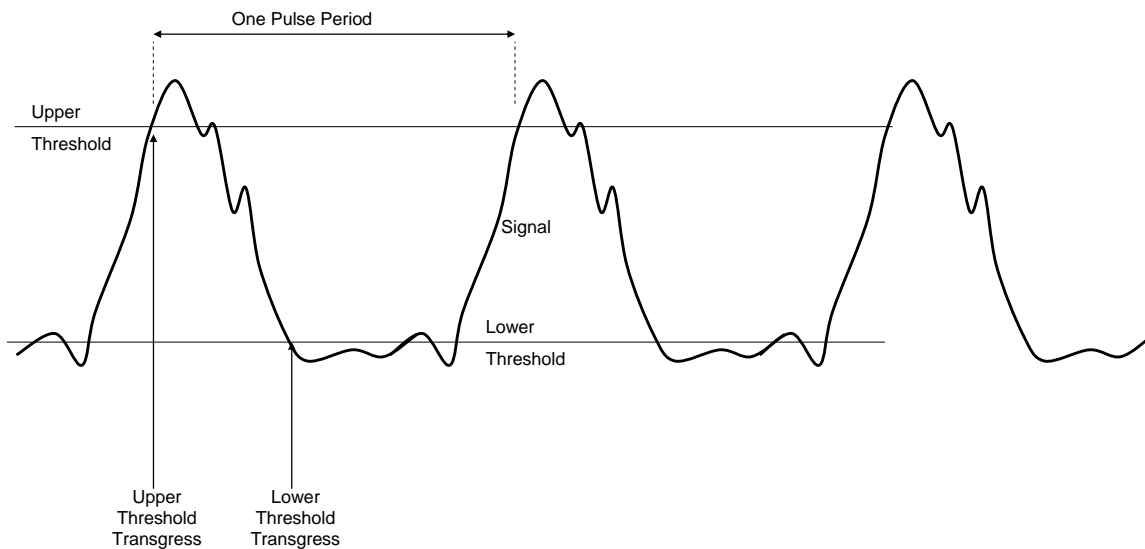
Torque Calibration

   To properly calibrate the torque, the torque calibration arm must be bolted to the appropriate location on the dynamometer load unit The dynamometer controller should be turned on and warmed up for 15 minutes prior to calibrating. Once the load arm is attached "Tare" the load (zero out the contribution from the laod arm) with the TARE button on the front panel of the dynamometer controller. Place the appropriate calibration weight on the calibration arm, aligning it over the loading mark (a pin or a hole in the arm as indicated by the arrow in the image below). In Torque Mode hit the right arrow until the torque calibration display is shown. The torque of the loaded mass M is:

Torque = 1 x 9.81 x R

Where: M is the weight of the mass in kg
            9.81 is standard gravitational acceleration
            R is the radius of the weights from the center of the dynamometer load in meters

If the front panel torque reading is different from this amount, then the calibration factor must be adjusted. To do this put the mode selector switch in TORQUE mode and go to the front panel menu by hitting the right arrow, and adjust the torque calibration factor up or down as required to get the torque (displayed on the top line) to agree with the actual torque. Re-zero and check the torque once the factor has been adjusted.
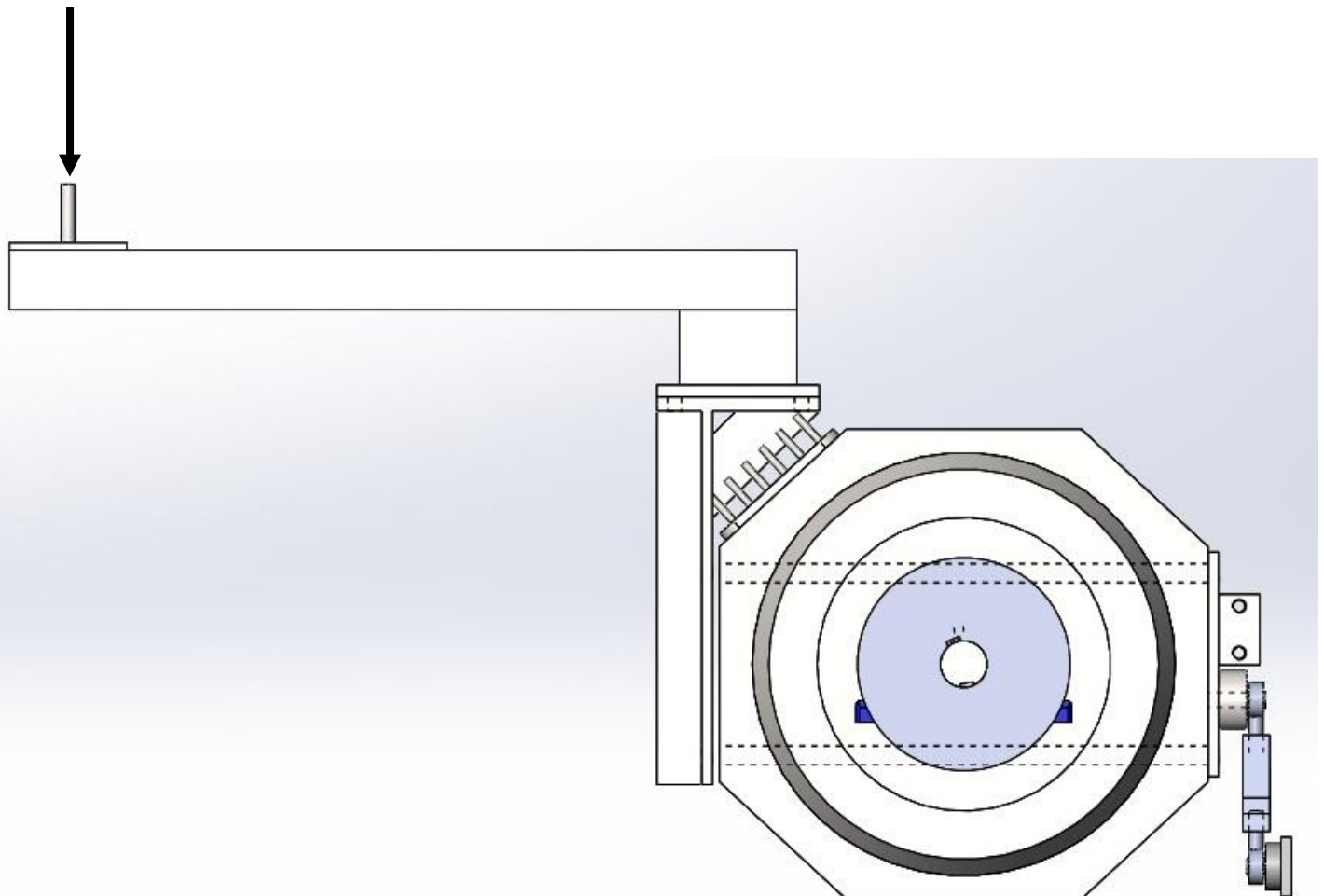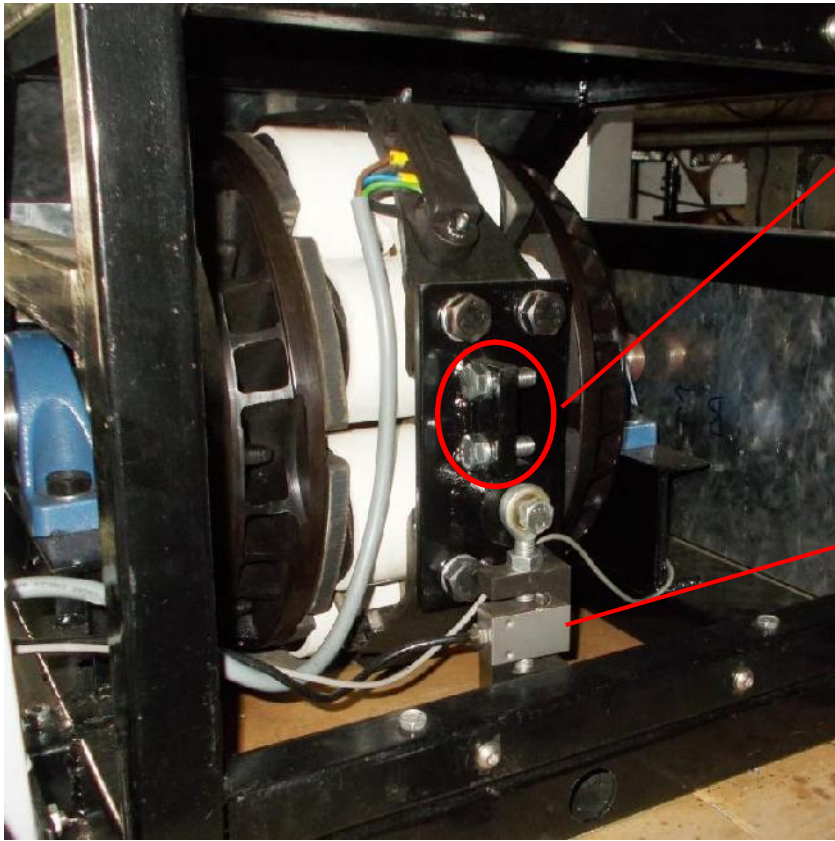
SCCD-200 Load Arm Mounting Bolts are located at the back of the Load Unit just above the load cell and are accessed by removing the rear safety grill.

Load Cell

Torque Amplifier Board

In some cases it may be necessary to adjust the Toque Amplifier Board inside the controller. This is generally only required when changing the load cell, or load cell amplifier, or applying a large offset torque. The amplifier will look similar to the image at right and will have potentiometer adjustments for Zero and Gain.

Generally the "Zero" pot is adjusted to give a small positive voltage (like 500mV) at no load. This allows us to measure slightly negative torques without saturating the DAQ at 0V. The GAIN pot adjusts the gain of the amplifier. If the Torque Amplifier Board is adjusted,

then the Torque must be re-calibrated as stated in the section above. Be sure to avoid increasing the gain so much that the output saturates, as this will cause non-linearity's, and inaccurate torque readings.

MAINTENANCE GUIDE

Most dynamometer are designed to require relatively little maintenance once properly setup, however there still are a few items that require periodic checking and maintenance. Roller bearings require greasing annually, and any belts require periodic tensioning, and may eventually require replacement. Each of these is described separately below.

Bearings

Roller bearings have a nipple at the top for addition of grease (red circle in foto below). Fresh grease needs to be applied periodically. This can be added with a grease gun by clipping the grease gun to the nipples and delivering a few pumps. This should be done once each year, or every 300 hours of operation.

Some versions of dynamometer also have grease fittings, for periodic greasing. Use a good quality wheel bearing or axel grease.

CAUTION: Do not add so much grease that it leaks from the bearings seals.
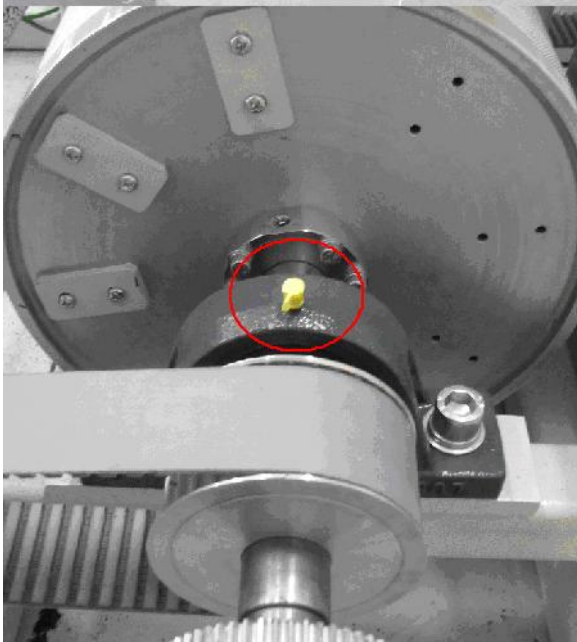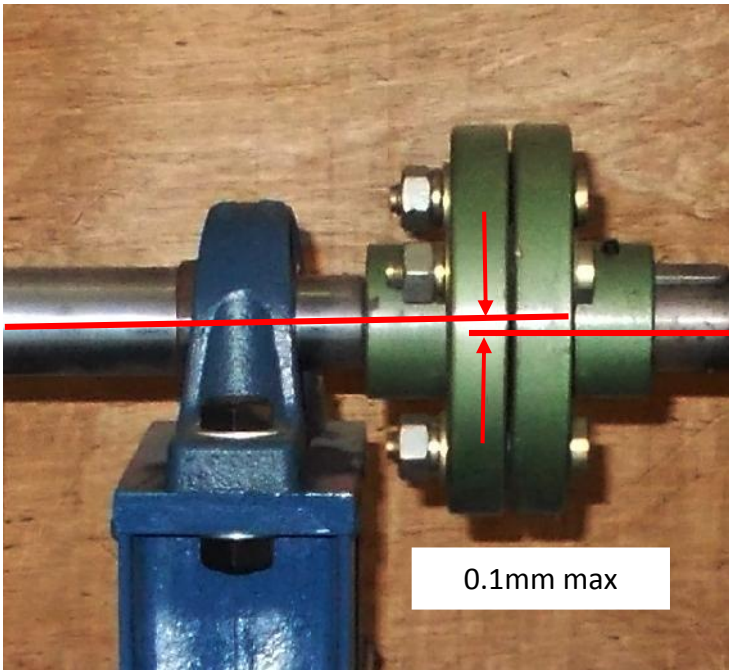
Shaft Couplers

Shaft couplers are used to compensate for the inherent misalignment between rotating shafts. Generally these couplers consist of a flange at the end of each shaft connected by a pliable or compressible medium, such as rubber bushings. These bushings compress when transferring torque between the shafts, and insure there is no metal-to-metal contact between the coupler halves. As the bushings wear, they become thin and must be replaced before metal-to-metal contact occurs as this will cause shock loading of the couplers, and may result in fatigue failure and/or wear of the couplers and shafts.
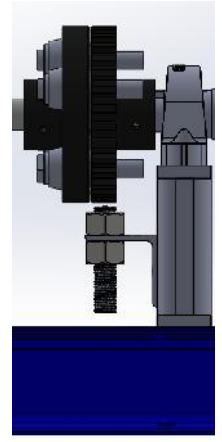
When connecting shafts, be sure that the shafts are well aligned to prevent premature wear of the bushings. The shafts should be aligned to within 0.1mm of each other radially. This can be checked with a micrometer mounted to one shaft and measuring the relative position of the 2nd shaft, while the 1st shaft is rotated.

0.1mm max

When properly aligned there should be slight free play between the two coupler halves as the shafts are rotated through 360 degrees. If the shafts or coupler binds, then it is probably misaligned and should be adjusted. Another simple check is to place a straight edge on the top of the two couplers to check their alignment in the vertical plane. This should be checked at 90 degrees as well to check the alignment in the horizontal plane.

The two coupler halves should be separated by a gap of 0.25 to 0.75mm in the axial direction. Finally insure that all the set screws and bolts are securely fastened so that the couplers do not move with respect to their shafts.

Belt Tension and Alignment

In some dynamometers a belt is used to couple two or more shafts which are not co-axial. When using a belt it is important that the sprockets are securely fastened to the shafts, and all set screws are tight.

The pulleys need to be aligned so that they are in the same plane, as any misalignment will stress the belt, and cause premature wear of the belt and pulleys. Additionally the two shafts must be as parallel as possible to eliminate "belt creep" to one side or the other.

Poor Pulley Alignment: Poor Shaft Parallelism:
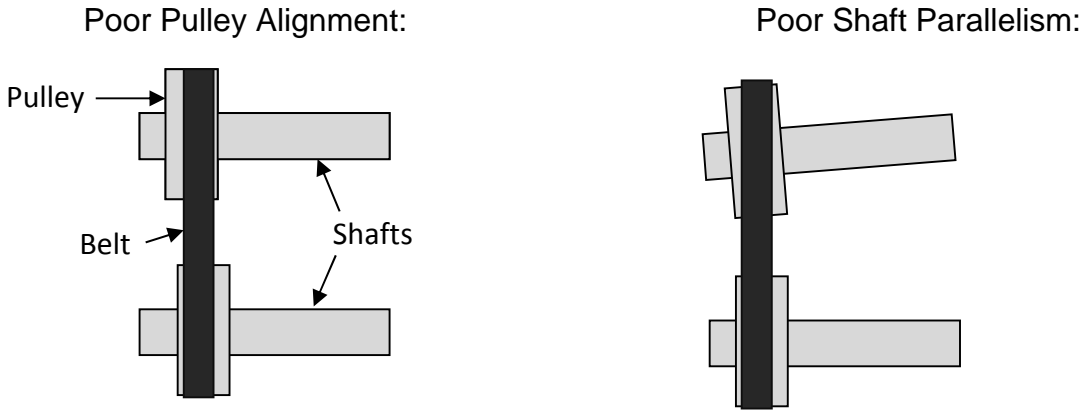
The belt should be tensioned so that a firm push at the center of the free section depressed the belt by no more than about 1mm per 10 centimeters of shaft separation.
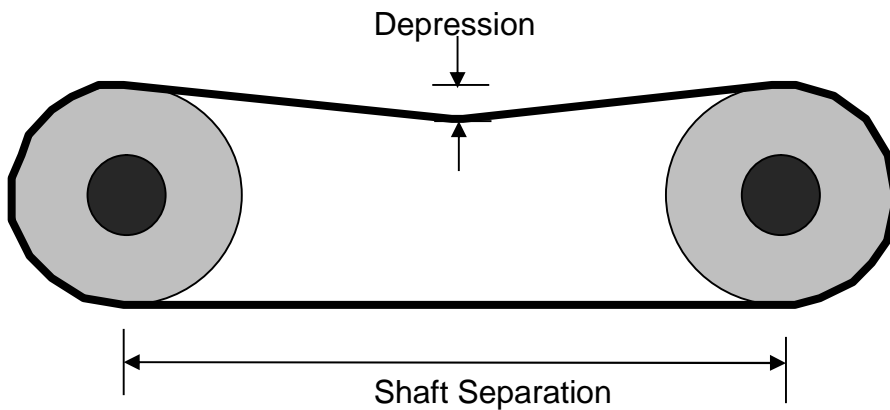
SCCD pulleys are accessed by removing the left side belt guard. Tension is adjusted with the bearing bias screws. Remember to loosen bearing hold-down bolts first, and re-tighten after tensioning belt.
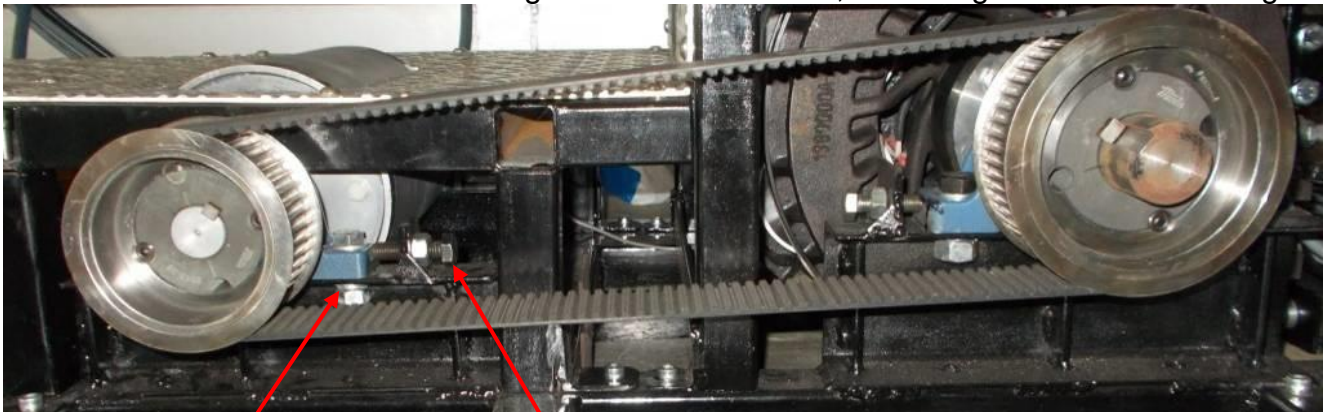
Bearing Hold Down Bolt   Tension Adjustment Screw

PID TUNING GUIDE

In Speed and Torque Control Mode the load on the dynamometer is adjusted using a "Proportional, Integral and Differential" (PID) gain controller. Tuning PID controllers for best operation can be difficult for the novice. For that reason we have included this simple PID tuning guide. It can be used with both the Speed and Torque control modes, although the examples below are for given speed mode.

Proportional Gain Tuning
To start with set the Integral and Differential (Ki and Kd) gains to zero.
Start with the Proportional gain (Kp) at some nominal value, for example 20.
Operate the system at a mid-range set point and throttle, eg. perhaps a set point of 1000 rpm and 25% throttle for a motorcycle engine.
In crease the proportional gain until the system goes unstable, ie. until it begins to oscillate beyond an acceptable range, eg. the engine may begin to oscillate from 800 rpm to 1200 rpm. This proportional is too high for use without differential gain to compensate, so reduce the proportional gain to half of it's unstable value. This should be a good value for the proportional gain. Proceed to tune the differential gain.

Differential Gain Tuning
Once proportional gain has been set, you can establish a reasonable value for the differential gain by performing "steps" and observing the over shoot. For example with a motorcycle operating at 25% throttle, you could get the system to run smoothly at 1000 rpm, then suddenly change the set point to 1250 rpm. It is likely that with higher values of proportional gain, the actual speed will over shoot the set point (eg. the dyno may operate at up to 1500 rpm before settling close to 1250). Increase the differential gain (Kd) until this overshoot is minimized. You may not want to completely eliminate over shoot, but Kd should be increased until the system does not oscillate more than one full cycle before stabilizing (ie. over shoots a bit, followed by less undershoot, then converges to the desired set point) as shown below
.

Kd too low

Kd Just Right

Speed

Time
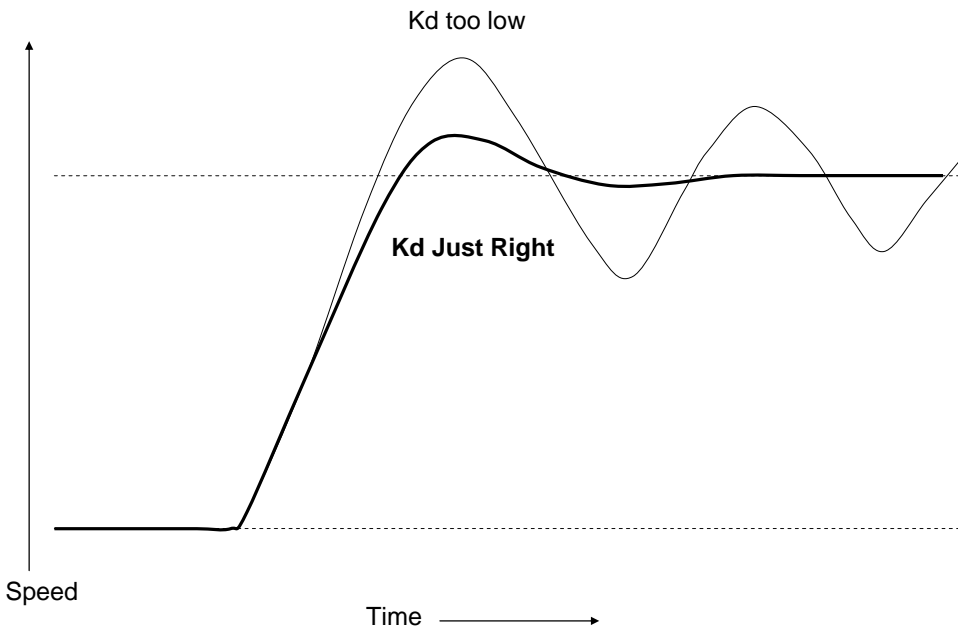
Integral Gain Tuning
Integral gain is used to eliminate the persistent steady state error, once a system has stabilized. In some systems, such as an internal combustion engine coupled with an eddy current dynamometers, integral gain may not be required at all. Integral gain should be used sparingly, as excessive integral

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gain will almost always make a system go unstable. Again operate the system at a nominal operating point, such as 1000rpm and 25% throttle. If the steady state error is consistent, eg. the system operates at 950rpm and won't converge to 1000 rpm even after a minute, then increase the integral gain (Ki) slowly, until the steady state error is reduced to an acceptable level. You should wait for say 30 seconds after each increment of Ki to make sure the system has time to stabilize with the new gain.

Final Checking
Once you have established a reasonable value for Kp, Ki and Kd, write them down. Now operate the system at various speeds and loads, performing large steps, to insure the system is still stable. If it exhibits instabilities, try reducing Ki, Kp, and perhaps increasing Kd (one factor at a time) until it performs acceptably under all conditions. When you have the final values, again write them down with a description of the system, and burn them to memory of the controller, by setting **SAVE CONFIG?** to **YES**.

Online PID Tuning Resources
For additional help in tuning PID systems you can refer to the following on-line resources:
http://en.wikipedia.org/wiki/PID_controller
http://www.eq.ufrj.br/links/h2cin/eqe768/AULA_3/Melhor%20Sintonia.pdf

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DYNO MONITOR PROGRAM

NOTE: This software is continually being updated with new features, and is always available on-line from: www.FocusAppliedTechnologies.com where you can also get the latest version of manual.

The purpose of this exercise is to gain familiarity with the Dynamometer Monitoring software.
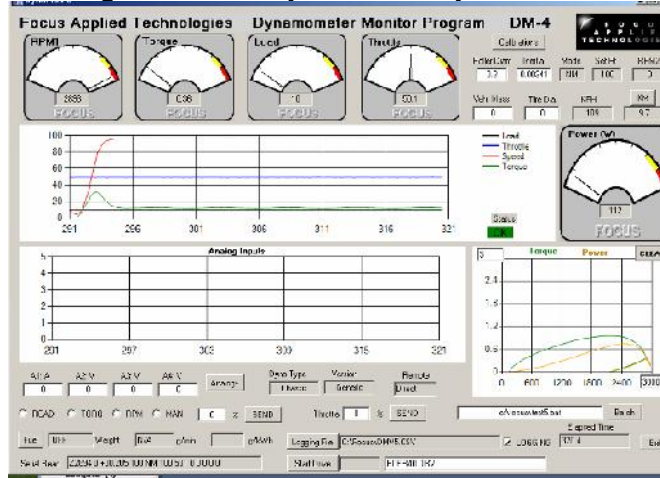
The Dyno Monitor software is supplied with out Gen-5 Dynamometer Controllers for display, data logging and Control of the Dynamometer. This document details the usage of the Dyno Monitor program.

To begin with the Dyno Monitor software should be "unzipped" and loaded into the **C:\Program Files\Focus** folder. If an older version exists, it should be Uninstalled first (From START menu, go to Control Panel, and then Add or Remove Programs, Click "DynoMonVx" and Uninstall).

Additionally a calibrations file **C:\Focus\DynoCal.CSV** should exist. If the folder does not exist, then create it. The Dyno Calibrations file contains important calibration factors relating to your dynamometer, and these should be recorded somewhere safe for reference (eg. in a notebook, or sticker on the dyno, or in a backup file for example DynoCal.Bak). If this file does not exist, it will be created, and can be modified by hand, or from the DynoMonitor program. As a "CSV" (Comma Separated Variables) it can be conveniently opened in Excell or other spreadsheet, and saved (make sure to save as a CSV format). Below is a typical DynoCal file:

Focus Applied Technologies Dynamometer Calibration File	DC5	
Version	Default	
Mass		120
Wheel Diameter		0.4
Pulses per Rev		20
RPMPV		0
MPSPV		0
Torque Offset		0
Torque Factor		1
Frict Offset		0
Frict Factor		0
Last Cal	Not Calibrated.	
Dyno Type	Unknown	
Roller Diam		0.3
Inertia		0
Controller Com Port		1
Fuel Scale Com Port		0
Emissions Com Port		0
AFR		3
V		1
V		1
V		1
Analog Offset 1		8.5
Analog Offset 2		0
Analog Offset 3		0
Analog Offset 4		0
T-Graph Max X		3000
T-Graph Max Y		20
Batch File		
Drive Cycle	ECER40.DRV	
Temp		25
Press		1000
RH		50
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0
Spare		0

The first 2 lines are headers, and do not effect operation of the DynoMonitor program.
Mass and Wheel Diameter are sometimes used on Chassis Dynamometers. The Pulses Per Revolution relates to the PPR in the dyno controller. It is not necessary to set this in the Dyno Monitor software in most cases. RPMPV and MPSPV are also only used in some systems.

Torque offset and Torque Factor can be used to modify the torque coming from the Dyno Controller. For example if you want to display different units on the screen of the computer (and save to a file) you can assign a torque offset (ie. constant) and Factor (ie. to be multiplied by the read torque) before display. Typically these are 0 and 1 respectively to display the same units as the Dyno Controller (ie. Nm).

The Friction Offset (in Nm) and Factor (in Nm/rpm) are used to compensate for any frictional loads which are unmeasured by the dynamometer. This is often the case in chassis dynamometers where the rollers and Dyno may have 4 or more large bearings applying friction to the roller which is not measured by the dyno. These factors are usually measured warm by allowing the dynamometer to spin to rest from a high speed. Analysis of the "spin down" velocity can be converted into Torque vs. Speed, and converted into the appropriate frictional compensation factors.
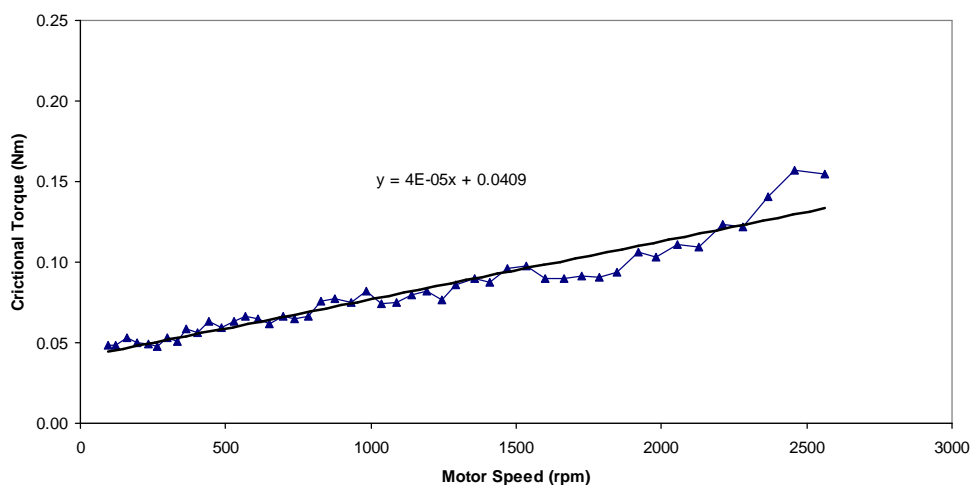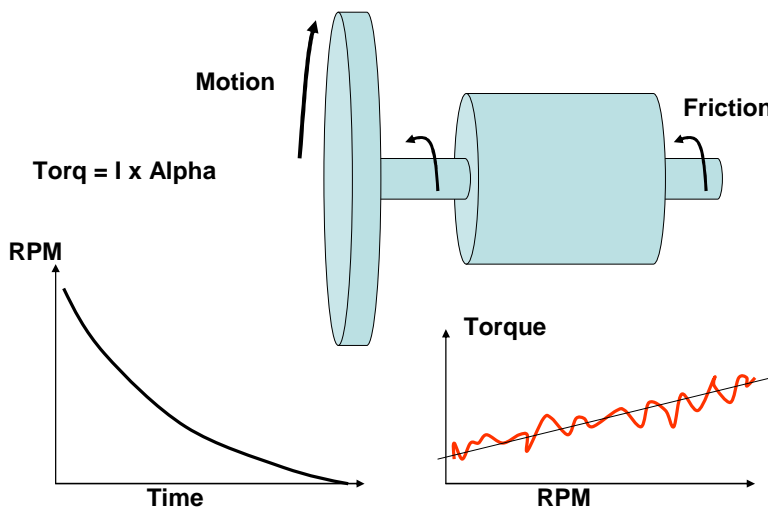
Last Cal is the numeric version of the last calibration date.
Dyno Type is usually either "Engine" or "Chassis".
Roller Diameter pertains to the roller size on chassis dynamometers.
Inertia is the total inertia of rotating components of the dynamometer. Note: This does not include the rotating inertia of the parts of the motor or vehicle which is spinning the dyno. In some cases the dynamometer is an "Inertia only" dynamometer, and does not have active loading, just a rotating mass accelerated by the power source. In this case the torque is calculated from the acceleration of the inertia via the following:

Torque = Frictional Offset + Frictional Factor x RPM + Inertia x Acceleration (rad/s/s)

In loading type dynamometers, Torque is calculated similarly, by the measured torque (usually the largest component) is added in. To eliminate inertia calculations, set the Inertia to zero. To eliminate frictional compensations, set the frictional factor and offset to zero.

The Communication Ports of the various dyno components are then listed. Typically each piece of equipment is connected to the computer via a USB-Serial com cable. These generally require a driver, and you can determine the address of each port from HyperTerminal or other serial communications program. If, when the Dyno Monitor program is started the selected serial port is not correct, it will open a message box, requesting the correct serial port number.

The next 4 factors (labeled A, V, V, V in this cal file) are the labels and factors of the Analog Channels 1, 2, 3 and 4 respectively, and the following 4 are the analog channels offsets. The Analog Inputs are 0-5V, and converted to Volts in the software. In this example we have a wide-band exhaust gas O2 sensor on Channel 1 (thus the label "AFR" for Air Fuel Ratio) where 8V is equal to 8.5AFR, and 5V is 23.5AFR. Using the proper labels and scaling factors (Unit/Volt) will result in a display of the proper value on the front screen and in the data file.

The various graphs are scaled to Speed and Torque (and Power = Speed x Torque) by the X and Y Scale Max Values. These can be reset from the main view of the Dyno Monitor program. Finally the last used Batch file (.BAT), and Drive Cycle (.DRV) are listed in the Dyno Calibrations file.

Major Display Areas

Speed, Torque, Load and Throttle Gages and History

Various Calibrations and Auxiliary Factors

Power Gage

Analog Inputs History

Speed and Torque Curves

Analog Inputs

Batch File

Fuel Scale Data

Data Logging File Name

Raw Controller Data

Drive Cycle File

Major Controls

Calibrations

This button clears the Torque/Power Graph

Analog Factors And Labels

Remote Commands: Mode Setpoint and Throttle

Drive Cycle On/Off

Logging on/off

The dyno controller receives one ping per 250ms in verbose mode. When Verbose mode is OFF, the controller software must "ping" the dyno controller with a "A" character to elicit the dyno's response. The dynamometer controller sends data as numerical characters at 9600 baud, 8bits, 1 stop bit, no parity. The raw data is shown in the lower left of the screen.

Speed (RPM1) Torque (in Nm), %Load and %Throttle are all sown in the dial gages at the top. Power is displayed in the dial gage on the far right. The top graph in the center of the screen is the history (last 30 sec) of Load, Throttle, Speed and Torque. The Maximum (ie. 100%) values of Speed and Torque are the "T-Graph Max X" and T-Graph Max Y" numbers set in the boxes on the Torque and Power graph on the lower right. The History of the Analog Inputs is displayed in the lower, central graph, on a 0-5V basis. The Analog labels and values are displayed in the 4 boxed just below the Analog History graph.
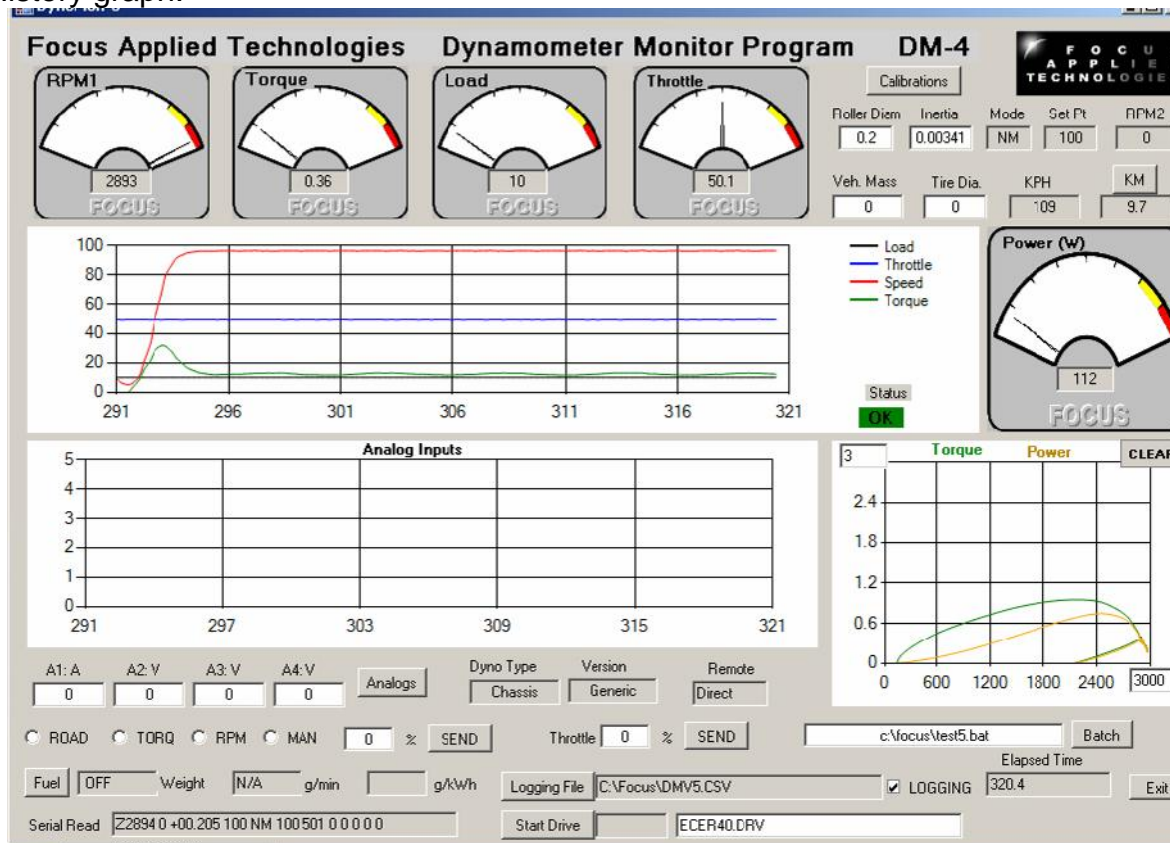
Various calibrations are displayed in the upper right corner of the display. Roller Diameter, Inertia, Vehicle Mass and Tire Diameter can be edited directly in these boxes. The MODE box displays the controllers Mode (M for Manual, S for Speed, T for Torque, and R for Road Load, the prefix "N" stands for "Normal" or dyno front panel control, and "C" is for "Computer" controlled mode, where you control the mode from the dyno monitor front panel, or from a batch file). The Set Point is the actual set point in the selected mode. Note: This may be scaled differently, ie Manual load of 12.5% appears as NM, 125. The 2nd speed input (RPM2) is also displayed, along with the speed (in km/hour) and an Odometer, which is resetable. The conversion to speed is done via the roller diameter.

Remote (controller must be in the COMputer control mode) Mode and Set Point are in the lower left, just below the Analog display. To send a 2800 rpm set point, click the RPM mode switch, and enter 2800 in the box (which will be labeled RPM) on the right. Hit the SEND button next to it to send. Throttle position is to the right of that.

Logging data file name is edited from the button below throttle, and logging can be turned on/off via the "switch" on the right of the data file name.

A Drive Cycle can be displayed for following. Select the file (a CSV type file with Time, Speed as columns) in the dialog box, and hit the "Start Drive" button to begin. Drive cycle can be halted and repeated as desired.

In COMputer control mode a "Batch" file of commands can be sent for automated testing. The file name can be edited in the Batch File dialog box, and execution begins by hitting the "Batch" button. Again this can be halted, and re-started (from the beginning) any time by hitting the Batch button. A batch file programming guide follows in the next section.

Calibrations

Hitting the "Calibrations" button (upper right) pulls up the Calibrations dialog box as shown right. Numbers can be entered in the appropriate boxes. Temperature, pressure and humidity are used in the SAE compensation for engine power (do not use for electric motors). Compensation can be clicked on by checking the box in the upper right of the power meter labeled "SAE". To close this hit the "Calibrations" button again. Inertia and Frictional values should not be changed from the factory settings unless compensating for abnormally large values from the driven wheels of the vehicle.

Standard Calibrations and Title

Roller Diameter (Chassis)	0.2	Torque Averaging (0-0.99)	0.8
Inertia (kg m²)	0.001	Torque Offset (Nm)	0
Friction Offset (Nm)	0	Torque Factor	1
Frict Factor (Nm/rpm)	0	Speed Averaging (0-0.99)	0.8
Dyno Max Torque (Nm)	2		
Power Correction Factors: ☑ AUTO Data		RPM2 Label	Engine
Ambient Temp (15-35 C)	30	RPM2 Factor	1
Pressure (90-105 kPa)	101	RPM2 Offset	0
% Rel. Humidity	60	RPM2 Averaging (0-0.99)	0

Speed/Distance/Power Units: ☑ Metric   Set Calibration Date to Now ☐

Overall Title: Dyno Type (BD10, CCD50...)

For More Information visit: WWW.FocusAppliedTechnologies.com   DC5 Demo

Open an existing Cal file, or Adjust factors then close or save.

[Load]   [Save]   [Close]

Analog Labels and Factors

The Analog Labels, Factors, Filtering and Display/Alarm Limits can be entered in the dialog box opened by hitting the "Analogs" button (lower left). Hit the button again to close.

Analog Input Calibrations

	Units	Units/V	Offset Units	Filter	MIN	MAX
Analog Input 1	Temp C	20	45	0	0	50
Analog Input 2	AFR	-3	8.5	0.5	8	25
Analog Input 3	V	1	2.5	0	0	5
Analog Input 4	V	1	3.5	0	0	5

Value = Volts * Units/V + Offset   Filter is 0 (none) to 0.99 (heavy)   Alarm Trigger Levels and Display Limits

Change labeles and calibration factor of the analog input channels.
Hit the "Analogs" Button again to accept the new values.   [Close]

Drive Cycle File

The first line of the drive cycle file is ignored as a header. The subsequent lines are in the format time, speed (usually in kph). The file is a ".CSV" comma separated variable format for easy editing. Below is the 1st "hump" of the ECE-R40 drive cycle pattern.

T	V
0.50,	0.0
1.00,	0.0
1.50,	0.0
2.00,	0.0
2.50,	0.0
3.00,	0.0
3.50,	0.0
4.00,	0.0
4.50,	0.0
5.00,	0.0
5.50,	0.0
6.00,	0.0
6.50,	0.0
7.00,	0.0
7.50,	0.0
8.00,	0.0
8.50,	0.0
9.00,	0.0
9.50,	0.0
10.00,	0.0
10.50,	0.0
11.00,	0.0
11.50,	1.9
12.00,	3.8
12.50,	5.6
13.00,	7.5
13.50,	9.4
14.00,	11.3
14.50,	13.1
15.00,	15.0
15.50,	15.0
16.00,	15.0
16.50,	15.0
17.00,	15.0
17.50,	15.0
18.00,	15.0
18.50,	15.0
19.00,	15.0
19.50,	15.0
20.00,	15.0
20.50,	15.0
21.00,	15.0
21.50,	15.0
22.00,	15.0
22.50,	15.0
23.00,	15.0
23.50,	15.0
24.00,	15.0
24.50,	13.5
25.00,	12.0
25.50,	10.5
26.00,	9.0
26.50,	7.5
27.00,	6.0
27.50,	4.5
28.00,	3.0
28.50,	1.5
29.00,	

FOCUS APPLIED TECHNOLOGIES

Focus Applied Technologies Dyno Monitor Batch Programming Language
Rev 2

Commands: M, S, T, R, P, L, C (T, S, 1, 2, 3, 4), E
Labels: 1, 2, 3, 4, 5, 6, 7, 8, 9

M: Manual Mode in 10 times % (eg. 33.3% is M333)
S: Speed Mode in RPM
T: Torque Mode in Nm
R: Road Load constant (0 to 255)
P: Throttle Position in 10 times % (eg. 12.3% is P123)
L: Loop back to label
C(T, S, 1, 2, 3, 4): Control Throttle (software servo) based on Speed, Torque, or Analog input #1, 2, 3 or 4
E: End

M, S, T, R, P command Syntax:
M#, $ where M is the mode (M, S, T, or R) # is the set point value, and $ is the duration in seconds.
The comma and seconds can be excluded if not required.

Control Command syntax:
C, Channel, Command, Set Point Value, Throttle Step Size, Duration (in sec)

Valid Command Examples:
M123   Manual Load 12.3%
M0,2   Manual Load 0%, then pause for 2 seconds
S3600   Speed Control Mode, 3600 rpm
S2400,1   Speed Control to 2400, pause 1 sec
T12.3   Torque Control Mode at 12.3Nm
R123   Road Load at 123% of nominal
R100,10   Road Load at 100%, pause for 10 sec
P0   Throttle Position to 0%
P500,6   Throttle Position to 50.0%, pause 6 sec
1   Label #1
L1,2   Loop back to label #1 2 times
C4,3,1.5,10   Control Throttle in (increments of 1.5%) so that Analog Input #4 becomes 3V for 10 sec
END   End. Stop batch execution and return to direct control from screen

Example Batch Program:
M0   Manual Mode, 0% Load
P500,5   Throttle Position to 50%, Dwell 5 sec
S3000,5   Speed Mode, 3000rpm, Dwell 5 sec
1   Label #1
S2900,5   Speed Mode, 2900rpm, Dwell 5 sec

```
S2800,5                 Speed Mode, 2800rpm, Dwell 5 sec
L1,2                    Loop to Label #1, run twice (total)
M0                      Manual Mode, 0% Load
P900,5                      Throttle Position 90%, Dwell 5 sec
2                       Label #2
M200,5                     Manual Mode, 20% Load, Dwell 5 sec
M300,5                     Manual Mode, 30% Load, Dwell 5 sec
L2,2                    Loop to Label #2, run twice (total)
P500                    Throttle Position to 50%
M0                      Manual Mode, 0% Load
CS,2800,1.5,10          Control Throttle to get Speed to 2800 rpm, increment throttle 1.5% for 10 sec
S3000                   Speed control at 3000rpm
M0                      Manual Mode, 0% Load
P0,5                    Throttle Position to 0, Dwell 5 sec
END                     Quit Batch Mode
```

Logging Data File

The data is continuously saved to the designated file as follows:
Time in seconds, Main Roller speed in rpm, Torque in Nm, % dynamometer load, Throttle position, Controller mode (described above in Computer Communications section), Set point (mode dependent), Friction in Nm (a function of speed), Acceleration in M/s^2, and the analog input voltages 1, 2, 3, and 4 respectively.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Focus Applied Technologies Dynamometer Data Log												
2	File Opened: 63475828548.14												
3	Time	RPM	Torq(Nm)	%Load	Throttle	Mode	SetPt	Frict(Nm)	Acell(m/s	Ch1	Ch2	Ch3	Ch4
4	5.296997	0	0	1.9	3.9	NM	19	2	0	5	5	5	5
5	5.563004	0	0	5.8	3.9	NM	57	2	0	5	5	5	5
6	6	0	0	8	3.9	NM	79	2	0	5	5	5	5
7	6.046997	0	0	10.7	3.9	NM	105	2	0	5	5	5	5
8	6.296997	0	0	16.8	3.9	NM	165	2	0	5	5	5	5
9	6.563004	0	0	19.8	3.9	NM	194	2	0	5	5	5	5
10	7.030998	0	0	23.4	3.9	NM	229	2	0	5	5	5	5
11	7.046997	382	0	29.8	3.9	NM	292	2.764	0	5	5	5	5
12	7.313004	882	13.58009	30	3.9	NM	294	3.382	3.590241	5	5	5	5
13	7.75	1286.5	27.34808	34.4	3.9	NM	337	3.691	7.230161	5	5	5	5
14	7.844002	1383.75	27.87659	37.3	3.9	NM	365	3.481	7.369884	5	5	5	5
15	8.046997	1073.875	80.82412	39.4	3.9	NM	386	2.764	21.36791	5	5	5	5
16	8.313004	729.9375	45.56084	44.2	3.9	NM	433	2.386	12.04517	5	5	5	5
17	8.765999	461.4688	19.66562	45.7	3.9	NM	447	2.193	5.199107	5	5	5	5
18	8.844002	278.7344	7.956489	48.4	3.9	NM	474	2.096	2.1035	5	5	5	5
19	9.046997	163.3672	-50.1613	52.9	3.9	NM	518	2.048	-13.2614	5	5	5	5
20	9.485001	93.68359	-39.2142	53.2	3.9	NM	521	2.024	-10.3673	5	5	5	5
21	9.546997	52.8418	-29.9272	56.9	3.9	NM	557	2.012	-7.91201	5	5	5	5
22	9.780998	29.4209	-22.4064	58.2	3.9	NM	569	2.006	-5.92371	5	5	5	5
23	10.047	16.21045	-16.1734	61.2	3.9	NM	599	2.003	-4.27585	5	5	5	5
24	10.5	8.605225	-13.9794	64.4	3.9	NM	630	2.001	-3.69582	5	5	5	5
25	10.547	4.302612	-10.0916	66.1	3.9	NM	647	2	-2.66798	5	5	5	5
26	10.781	2.151306	-7.2269	70.3	3.9	NM	688	2	-1.91061	5	5	5	5

This data can then be graphed and analyzed further.

Alternative Data Logging

An alternative option for data logging is via any serial communications program, such as Hyperterminal. Simply connect to the dyno controller, insure that the controller has Verbose mode ON, and save the resulting data to a text file. This text file can then be loaded into a spread sheet such as Excel and the various columns can be converted to data as mentioned above in the Computer Communications section above.

SAFETY PRECAUTIONS

GENERAL

All Focus Applied Technologies Dynamometers are designed to be an inherently safe machine via the use of heavy duty mountings and frame, wheel clamp, electrical fault protection, and ignition cutoff system. However as with any power equipment improper use can result in a hazardous situation.

With this in mind here are several tips to help keep the users safe:

- Always maintain the engine/motor fuel lines and power wires in good condition.
- Always make sure the test vehicle is firmly secured to the dyno
- NEVER TUCH on a moving roller!
- Avoid loose items including cloths, cables, belts and loose small times which might fall into the chain or gap between the roller and frame..
- The controller contains dangerous voltages and currents. Never operate the dynamometer with the controller opened.
- Disconnect all power to the dynamometer and auxiliary components before opening or servicing.
- Insure proper ventilation whenever operating a combustion engine.
- Always make sure a fire extinguisher is handy by.

NEVER allow personnel to access the inside of the dynamometer while in operation. Fingers and articles of clothing can be pulled into the moving rollers and/or belts potentially maiming the user.

ELECTRICAL HAZARDS

This equipment is powered by potentially dangerous AC and DC voltages, and normal precautions pertaining to electrical appliances apply. Do not operate the equipment if there is water present in, on, or around the equipment. Make sure all electrical wiring is properly installed and grounded, and has a fast-acting Ground Fault Interrupter in the circuit.

The power from the dynamometer to the dump load is to be considered a **HAZARDOUS VOLTAGE**, which may be as high as 240VAC. It is imperative that the dump load and wiring be routed in such a way at to prevent the possibility of contact with any conductive object or personnel. Additionally the load unit (dyno's rotor disks) may become **VERY HOT** in operation. Make sure it is mounted away from any flammable objects, or anything that could be damaged by elevated temperatures.

MECHANICAL HAZARDS

This equipment may be operating at high speeds, and rotating equipment is always a potential hazard. Keep hands, hair and cloths clear of the rotating shafts (especially the speed target

wheel). Inattention may allow a loose article of clothing (ie. a shirt sleeve, neck tie, or head scarf) to become entangled in the rotating shaft, potentially injuring **OR KILLING** the person.

Equipment featuring a spinning disk can be dangerous if imbalanced, or loose. Although the shaft selected may be operating within the designed specifications, it could possibly become damaged, or fail, resulting in an outward explosion of the disk, throwing heavy components outward at high speed. Insure the disk guard is in place during operation. **ALWAYS STAY WELL AWAY FROM THE DISK AREA WHEN IN OPERATION!**
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FIRE HAZARDS

As always, when operating engines high temperatures, sparks and fuel are present. Take all necessary precautions and **always** have a fire extinguisher on hand.

TROUBLE SHOOTING GUIDE

If you encounter problems with the dynamometer, there are some simple tests and checks you can perform to help you track down the source of the problem. A dynamometer and controller is a complex system, and very often problems are related to improper external wiring or usage of the controller. The following simple tests should help you diagnose what is wrong with the system and correct it.

DYNAMOMETER POWER TEST

Apply power to the Dynamometer Coils. This can be done by directly running power in (ie. connecting to a 12V battery or power supply) or by placing the dynamometer controller in manual mode and setting it to 20% load. The shaft of the dynamometer should have significant resistance to rotation. Remove the power from the dynamometer coil and the shaft should spin freely. If applying power to the dynamometer coils does not result in a loaded shaft than either the rotor (dyno coil lines in an eddy current dyno) or the stator (dump load lines in a generator type dynamometer) are open circuited. Disconnect the dynamometer and check the resistance across both sets of lines. The Dyno Coils should have a resistance of between 10 and 100 ohms. The dynamometers stator (the wires going to the Dump Load) lines should have a resistance below 20 ohms when disconnected from the dump load. The Dump Load should have a resistance of between 5 and 50 ohms. If any of these are out of specification the dynamometer will not be able to apply the appropriate load to the shaft.

DYNAMOMETER CONTROLLER POWER TEST

It is possible to measure the DC voltage of the dynamometer coil power with a DC Volt Meter. Alternatively you can see the voltage wave form with an Oscilloscope, however **BE VERY CAREFUL** as these lines can supply over 240V, and 15A, and **ARE NOT ISOLATED** from line voltage (ie. You must treat them as LIVE AC lines). When using an oscilloscope DO NOT directly connect the ground line to DYNO -, instead connect it to the ground line of the AC power system. Also it is advisable to use a 10k ohm resistor in series with the oscilloscopes probe to reduce the chance or drawing current through the oscilloscope to ground.

Apply a load to the Dynamometer Coil Output: a 1000 ohm, 10W power resistor can be used to simulate the coil load. In Manual Mode you should be able to see a signal on the **Dyno +** power linee. At low load the DC voltage across the load should be near zero, and should go up to the rated voltage at full load. This can be measured with either a volt meter, or on an oscilloscope. At 20% load you should see a wave form similar to that shown below on the **Dyno +** line.
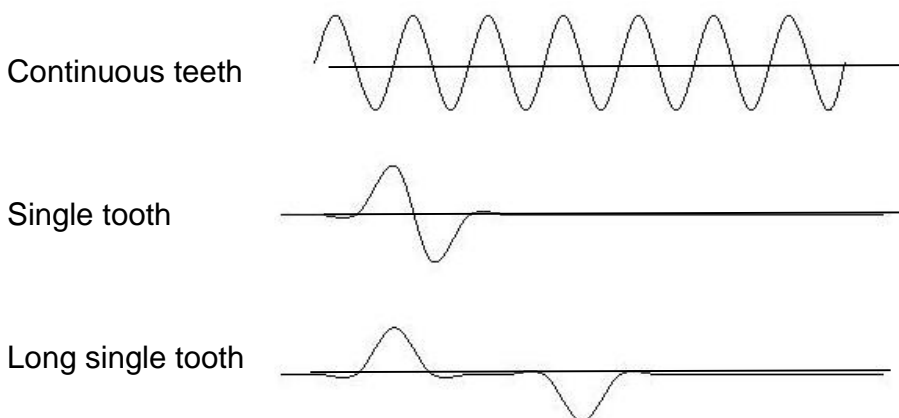
Voltage

100 – 200

0

8 to 10 ms between pulses
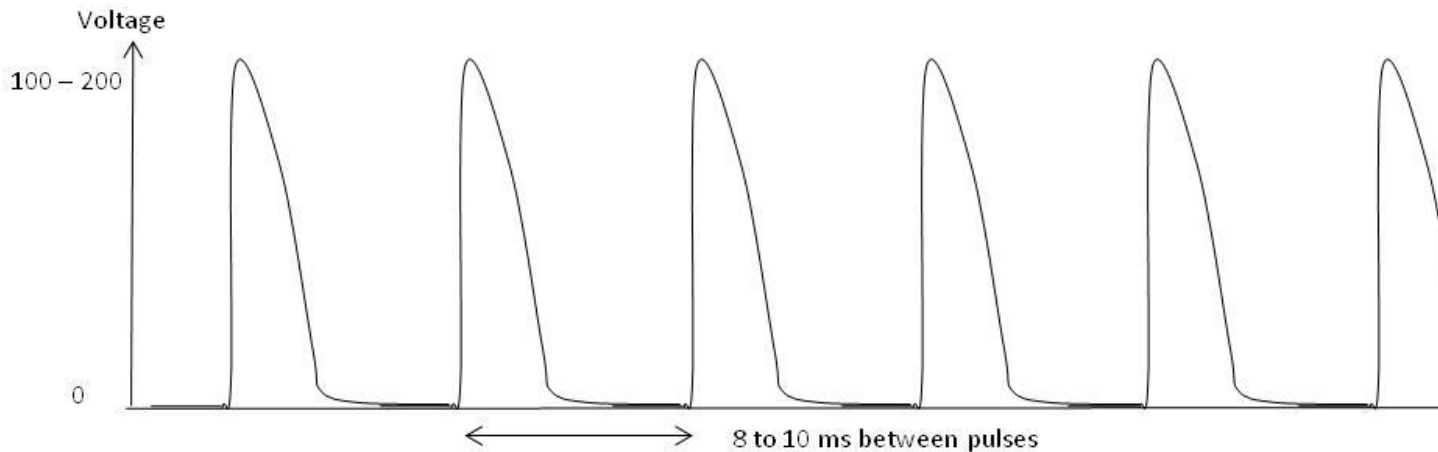
If you get this voltage, then the power supply, power switching transistor and controller are all working properly. If you do not, try resetting the circuit breakers, checking wire connections and trying again. If you get this signal but the dynamometer is not loading, then disconnect the dynamometer from the controller and check the continuity of the dynamometers power lines (ie. Dyno + to Dyno -). They should have a resistance of 4 to 30 ohms depending on the specs of the dynamometer. If the resistance is "open circuit" check for breaks in the wires or disconnected terminals. If the resistance is low, check for shorting in the lines.

SPEED SIGNAL TEST

The speed signal must have sufficient amplitude to trigger the speed sensing circuitry. Typically this will require a zero-to-peak amplitude of at least 0.5V, and a lower voltage of <0.1V. For accurate speed measurements, the signal should not have any noise exceeding this threshold. With the dynamometer spinning the speed pickup signal can be viewed on an oscilloscope. The signal should look like one of those shown below. If you have a good speed signal, but are not reading the RPM on the dynamometer controller, than either the sensor is not hooked up right to the controller, or the threshold levels have been set improperly.

These idealized signal waveforms are provided as a reference for trouble shooting purposes.
Variable Reluctance type Speed Signal

Continuous teeth

Single tooth

Long single tooth

45

Hall Effect type Speed Signal

Normal

Inverted
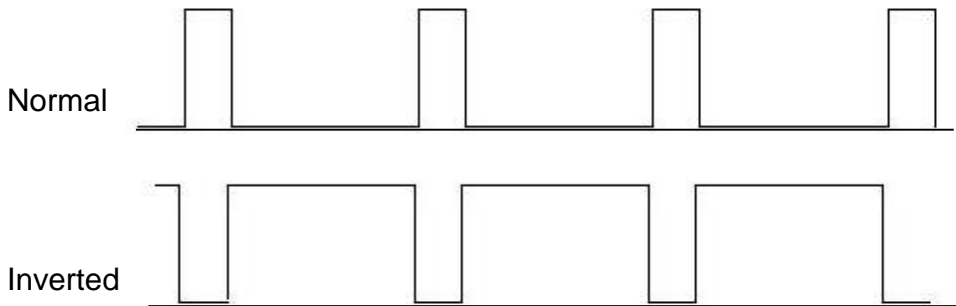
NOTE: Some Hall type sensors may not go all the way to 0 volts. This may require raising the Upper Threshold (UT) and Lower Threshold (LT) levels to properly read. Make sure that UT voltage is greater than the LT voltage.

LOAD CELL TEST

The load cell and amplifier can easily be tested together by observing the voltage (amplifier output which should be fed into Torque Input terminals on the back of the controller) while changing the load on the load cell. Unloaded the amplifier should have a small DC voltage (the "zero voltage"). As load is applied this voltage should increase linearly proportional to the applied load. If the voltage *decreases* when applying load in the nominal loading direction, reverse the **Sig +** and **Sig –** lines on the amplifier; this will cause the voltage to increase with applied load. When the load is removed the voltage should decrease back to the initial "zero voltage". If the assembly does not behave as indicated, it is likely that there is a problem with the load cell wiring, and you should proceed to the following "Load Cell Trouble Shooting" section.

LOAD CELL TROUBLE SHOOTING

The amplifier in this unit is designed to work with standard Wheatstone bridge configuration 4-wire load cells with resistance **R** between 100 and 450 ohms.
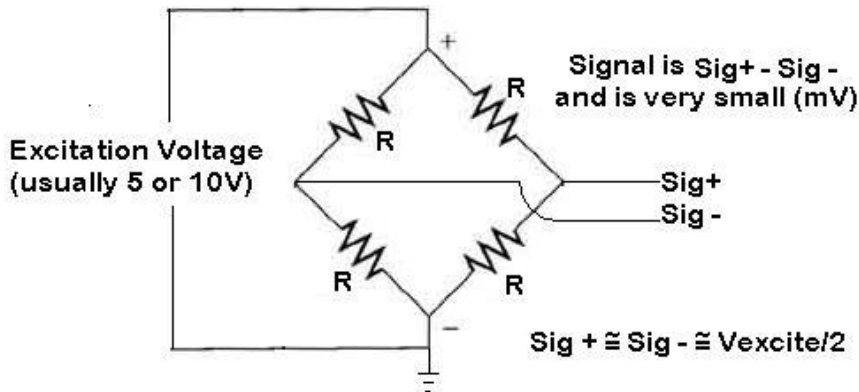
The excitation voltage (**Excite +** relative to **Excite -**) is either 5 or 10V depending on the amplifier. When functional the **Sig +** and **Sig –** lines should both be at approximately ½ the excitation voltage. Connecting a voltmeter (set to the DC mV scale) between **Sig +** and **Sig –** you should see a very small voltage (a few mV) which changes linearly with load. If the excitation voltage is properly applied, and you do not get a repeatable and linear change in the **Sig +** to **Sig –** voltage, it is likely that your load cell is either improperly hooked up, one of the leads is broken, or the load cell itself is damaged.

The most common problems associated with strain gages are:

1) Disconnected Leads – One of the wires is not properly connected
2) Shorted Leads – One or more of the leads is shorted together or to a shield ground
3) Internal Connection Breakage – One of the wire bonds to the actual strain element is broken

Any one of these faults may lead to signal drift, noise, no signal or signal pegged high or low. If your system is exhibiting these faults, you should check the resistance of between the leads and compare them to the table below.

LOAD CELL RESISTANCE MEASUREMENTS

Leads	Resistance
Excite + to Excite -	R
Sig + to Sig -	R
Excite (+ or -) to Sig (+ or -)	3R/4
Shield to any other lead	Infinite

If you do not get a consistent R, 3R/4 reading than the load cell may be damaged.

EXTERNAL WIRING DIAGRAM
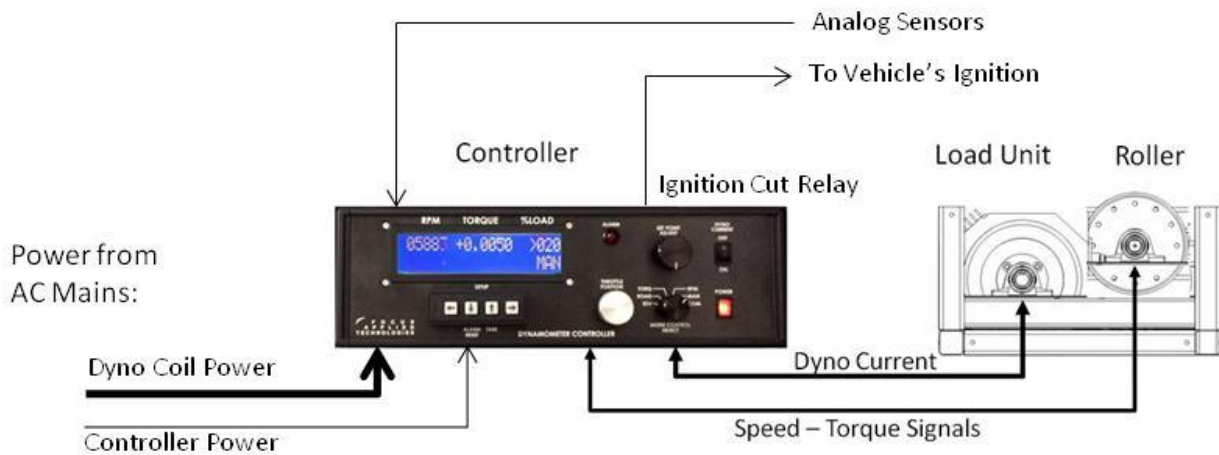
The Controller and any computer or sensor power should be is powered from a clean AC line power source with a lower current breaker (eg. 10A)

The Dynamometer Coil power lines are connected to a higher current breaker using heavy (30A capable) wires. Insure appropriate gage wires are used.

WARNING: Both the Dyno +/- control lines may have high voltages on them and can cause shocks if handled improperly! Always use appropriate cautions when using/installing the dynamometer.

The controller reads the Torque from the dynamometer via four wires connected to the load cell input at the back of the controller. These wires are RED (Excite +), Black (Excite -), White (Signal +) and Green (Signal -). In case the torque signal is reversed, simply reverse the positions of the WHITE and GREEN wires. Excite+ is a 5V reference voltage, so make sure not to short it to ground.

Speed of the roller is read from the Hall Effect sensor. The Speed Target Wheel at the hub of the roller, should be located approximately 2mm from the tip on the sensor. The sensor is wired to the RPM1 input at the back of the controller (YELLOW wire), Ground (GREY wire) and Excite+ (BROWN wire).

The vehicles ignition power can be routed through the Ignition cutoff relay (at the back of the dynamometer controller) to cut off engine power in an alarm state. Also the analog inputs are acessable at the back of the controller.

Serial port communications are via RS232: 9600 baud, No parity, 1 Stop bit. The cable should be a "straight through" cable connecting pins 2, 3, and 5 at both ends. The data from the controller will be decimal coded ACSII number for the speed, torque and other data separated by a space and terminated by a linefeed/carriage return. The controller will send data 4 times a second in Verbose mode, or respond to a "A" character ping when Verbose mode is OFF.

SPECIFICATIONS

DIMENSIONS
LxWxH:	2170 x 900 x 450 mm (SCD excluding ramp, nose clamp)
LxWxH:	2710 x 680 x 23 (deck) 47 (Load) SCCD excl. Ramp, Nose
Weight:	Approximately 500kg (SCD), 450 kg (SCCD)

POWER IN
Voltage:	120 VAC +/- 10%, or 220+/- 10%	
Frequency:	60Hz	50Hz
Current Draw:	18A max	

CONTROLLER OUTPUT
Resistance:	10 ohms minimum
Power:	2000W maximum
Voltage:	200V nominal
Current:	10A nominal

DYNAMOMETER
Mechanical Power:	200kW nominal maximum
Roller Diameter:	320 mm (SCD) 165 mm (SCCD)

INPUTS
Speed:	Hall Effect type, 5V excitation
	30 pulse per revolution
	5V Zero-peak
	4,500 rpm maximum
Load Cell:	1000Nm maximum Loading
	200 to 500 ohm
	4-wire Wheatstone bridge
	5 or 10V excitation

SERIAL COMMUNICATIONS
Baud, Bits, Parity, Stop:	9600, 8, N, 1

ENVIRONMENT
Temperature:	10 to 40°C Operational
	0 to 50°C Non-Operational
Humidity:	5 to 90% Non-condensing
Shock/Vibe:	<10g

CONTACT INFORMATION

As there are so many factors outside of our direct control, Focus Applied Technologies does not assume any liability for accidents caused by the use of this equipment. Use of this equipment is at the users own risk. If any problems or accidents occur, we wish to be informed so that we may improve our products, and fix any issues they may have. Please send us any feed back you have regarding the use of this equipment.

F O C U S
A P P L I E D
T E C H N O L O G I E S

INPUT POWER   220VAC 50/60HZ
                     18A MAX

DYNO OUTPUT   200VDC Nominal
                     10A Nominal
                     2000 VA MAX

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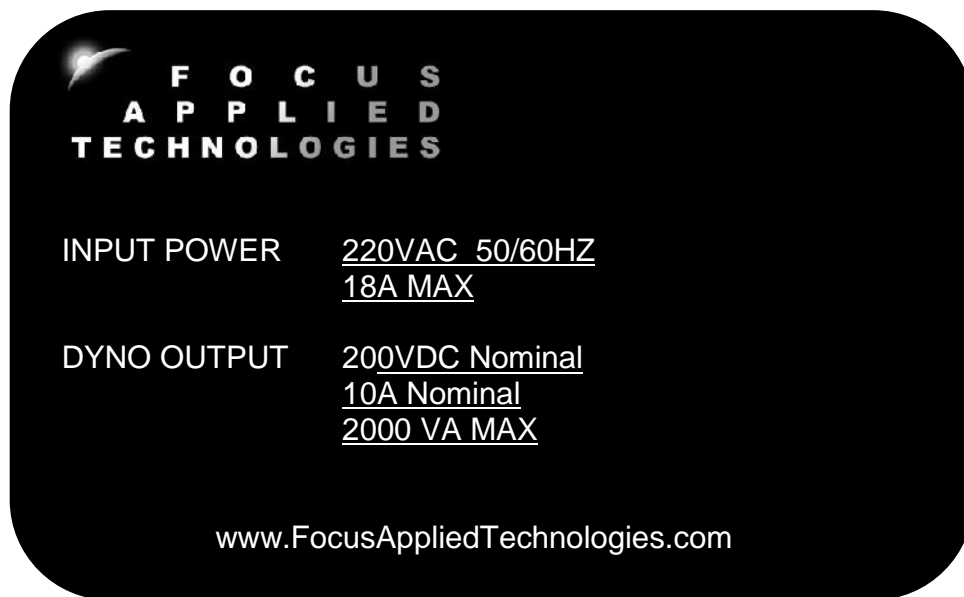
For further information on this or other products please contact us via the following:

Web site: www.FocusAppliedTechnologies.com

Email: Sales@FocusAppliedTechnologies.com

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              Nibong Tebal 14300
              PENANG, MALAYSIA