FOCUS APPLIED TECHNOLOGIES
CONTROLLER MODEL DC5

Manual Rev. 7-0313

5th GENERATION EDDY CURRENT
DYNAMOMETER CONTROLLER

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INTRODUCTION

The Focus Applied Technologies DC5 Dynamometer Controller is a universal dynamometer controller designed for eddy current and generator type dynamometers. With the optional H-bridge Valve Driver, it can also control hydraulic and water break dynamometers.

The dynamometer controller comes in 3 different packages:
- Compact
- Bench Mount
- Rack Mount

The output power rating is from 50V 3A to 100V 10A depending on the transformer supplied. The transformer may be internal, or external depending on the controller package and transformer supplied.

Output power is provided as a Pulse Width Modulated (PWM) DC output from the back of the controller via the **Dyno +** and **Dyno –** lines. **Dyno +** is always held at the maximum positive voltage (with respect to the internal ground of the dynamometer controller), where as the **Dyno –** line is pulled down with respect to the **Dyno +** line to provide the required voltage difference for current induction into the dynamometers coils. The PWM frequency is typically 2kHz. Output power to the dyno runs through a circuit breaker located at the back of the controller.

WARNING: Both Dyno + and Dyno – lines may have hazardous voltages, which persist for some time after being unplugged! Use appropriate caution when servicing the dynamometer or controller.

The dynamometer controller measures speed from a time-based signal, such as pulses generated by a Variable Reluctance or Hall Effect type sensor, or a tachometer signal. The signal trigger levels may be set by adjusting potentiometers on the controller's main board, and the number of pulses per revolution can be programmed from the front panel display.
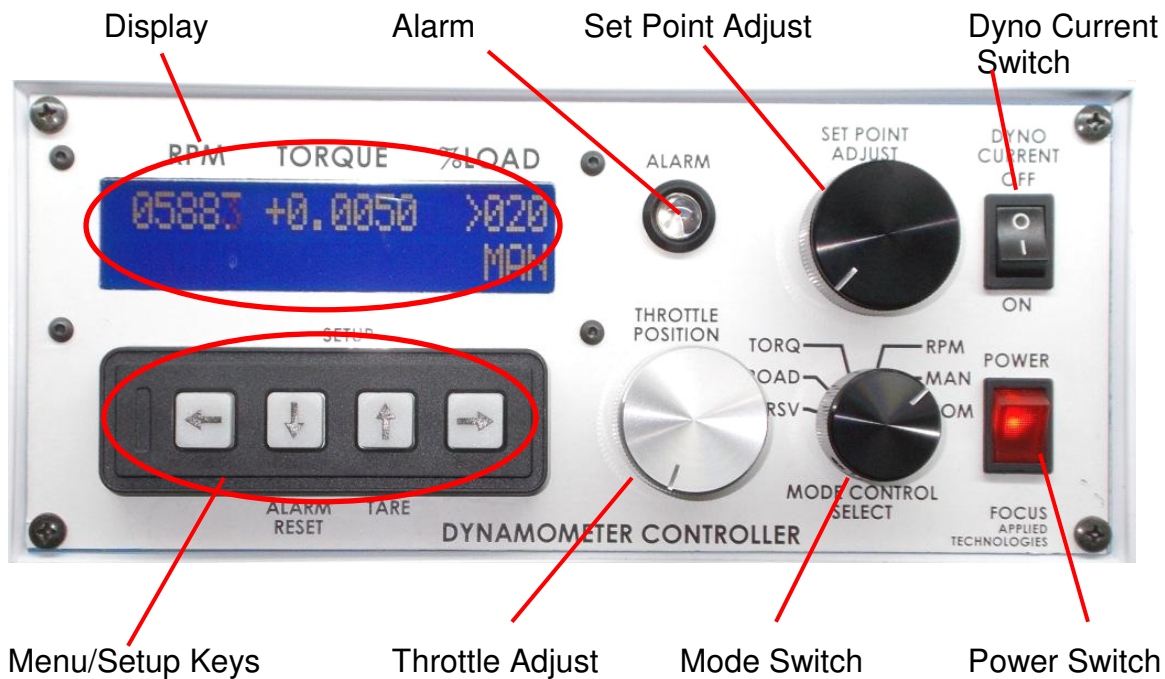
Torque is measured from a Wheatstone bridge configuration load cell. Generally the load cell amplifier has already been matched to the dynamometer's load cell, but can be adjusted for a wide range of different load cells via potentiometers on the load cell amplifier board inside the controller. The Torque calibration is adjustable via the front panel configuration.

NOTE: Changing the load cell amplifier gain will change the calibration factor, thus necessitating re-calibration.
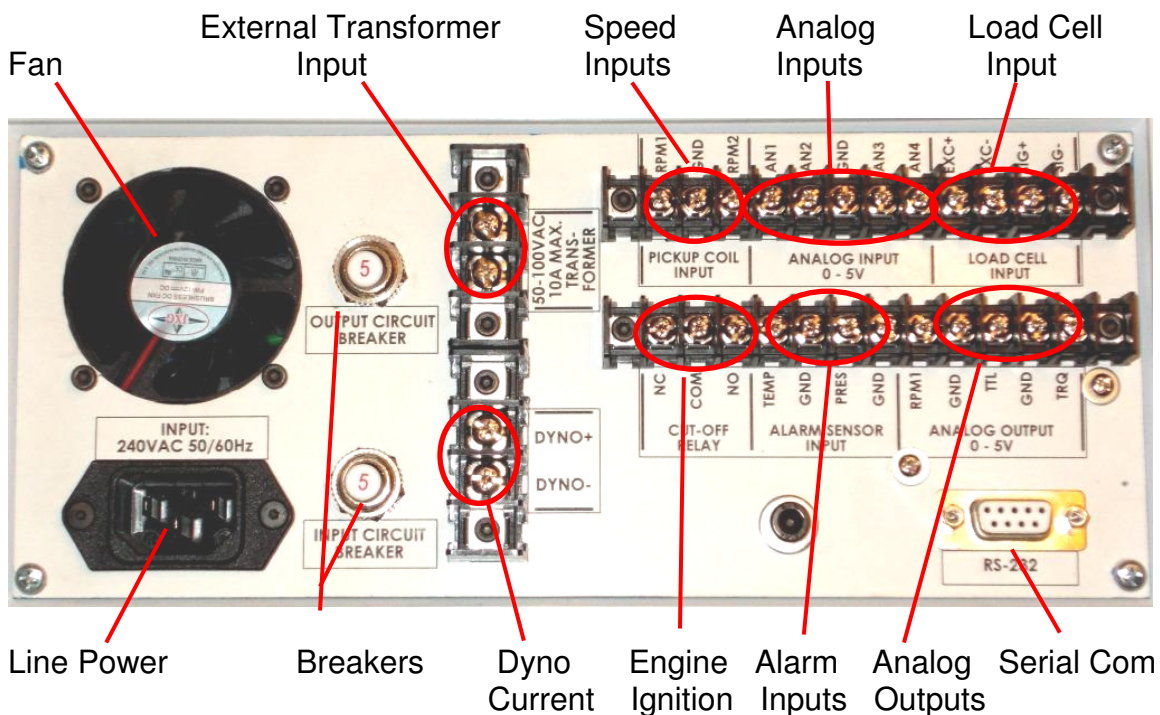
An analog throttle position control signal is provided at the rear of the controller. Using an optional Throttle Servo Motor this can directly drive the throttle of an engine.

Serial communications for control and data logging are also provided at the back.

CONTROLLER FRONT VIEW

Display   Alarm   Set Point Adjust   Dyno Current Switch

Menu/Setup Keys   Throttle Adjust   Mode Switch   Power Switch

CONTROLLER REAR VIEW

Fan   External Transformer Input   Speed Inputs   Analog Inputs   Load Cell Input

Line Power   Breakers   Dyno Current   Engine Ignition   Alarm Inputs   Analog Outputs   Serial Com

FEATURES

Dynamometer Controller

A dynamometer applies a load to a mechanical power source, or "prime mover". The dynamometer controller is responsible for controlling the load, as well as measuring the speed and torque of the prime mover.

This dynamometer controller allows the user to control the dynamometer load in several different modes: Manual, Speed, Torque, Road Load (RPM²) and Computer (remote) mode as selected via the **Mode Control Select** switch on the front panel. In each mode (except computer control mode) the set point is adjusted by rotating the **Set Point Adjustment** knob. Which of these modes to use depends on the specifics of your 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 constant torque, use the Torque Control more (Speed will vary). Road Load mode is commonly used to simulate the aerodynamic, acceleration and rolling resistance of a vehicle when operated on the road. Note that inertia/mass is not matched unless this dynamometer specifically has an inertial load, however this can be compensated for in the road load mode. Computer control mode is used for automated testing (eg. drive cycle testing, automatic loading of dyno "pulls"), 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 data logging, display, and remote operation via the Serial Port. If serial ports are unavailable on your computer then an optional USB-Serial Port converter may be used, which requires an appropriate Device Driver for operation. Typically the most common device driver is included in the compressed file package with the DynoMonitor software. 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, preferable with a shield grounded to the frame ground 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, RealTerm and similar. Alternatively Focus provides a variety of "Dyno Monitor" programs, and users can also develop their own data logging and display applications using the information provided below. 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 ASCII character "A" from the computer will cause the controller to respond with the data. The controller should not be pinged with the "A" more than once every 250ms. Additionally the alarm state can be set or cleared by sending an "X" or "x" respectively.

In general the data is output in the following format:

ZSSSS1_SSSS2_TT.TTT_LLL_Mode_SP_TTL_Alarm_A1_A2_A3_A4 [CR]

Where:

4

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 12.345 213 NS 2500 53 0 123 345 678 1023

Speed 1 is 2510 RPM

Speed 2 is 6500 rpm

Torque is 12.345Nm

Load is 21.3%

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*123/1024)

Analog Input 2 is 1.686V

Analog Input 3 is 3.314V

Analog Input 4 is 5.00V

NOTE: Load is in the % duty cycle of the power supply which is Pulse Width Modulated at 2kHz. Thus a 100V, 6A power supply would provide approximately 50V at 50% load, and at full load (ie. 100%) should be able to supply 100V at a maximum of 6 amps, depending on the dyno's resistance.

Data Acquisition System

This dynamometer controller includes a basic internal Data Acquisition System (DAQ). This system is for reading 0 to 5V analog 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.

The alarm is triggered when the speed or torque exceeds the maximum set point, or when the external Alarm inputs are sent either high or low, depending on their configuration. The alarm can also be triggered by any one of the analog input channels going above or below a maximum or minimum value.

NOTE: Some sensors, such as thermocouples, must have an amplifier (not provided) in order to generate a useable signal. Additionally some conversion may be required to convert the voltage back into a useful measurement.

A Note on ElectroMagnetic Interference (EMI)

Engines can make a lot of spark noise (electromagnetic interference, or EMI), which interferes with some Serial communications converters. This can cause "hesitation" or seizing of the serial communications from the controller. Reducing electronic noise is the best way to combat this. One common fix is to run a ground line from the chassis of the computer to the GND on the back of the controller. If your system is having intermittent communications problems when running, try running a grounding wire as described. Some brands of USB-Serial converters are more subject to electromagnetic interference. "Prolific" "Sparkfun" brand units are relatively more resistant to EMI.

To reduce spark noise a resister type spark plug cap, or resistor type high-voltage spark wires with a resistance of 5k to 20k ohms can be also be used. Also it is good practice to keep all wires and cables away from the high voltage lines of any spark system to reduce EMI in the connected systems.

SPECIFICATIONS

DIMENSIONS

HxWxD:	120 x 246 x 230 mm (Compact)
HxWxD:	133 x 320 x 248 mm (Benchtop)
HxWxD:	133 x 483 x 298 mm (Rack Mount)
Weight:	Approximately 4kg with 50V, 3A transformer

POWER IN

Voltage:	120 VAC +/- 10%, or 220+/- 10%
Frequency:	50 to 60Hz
Current Draw:	13A max (with 100V, 10A output)

CONTROLLER OUTPUT

Resistance:	10 ohms minimum
Power:	1000W maximum (electrical)
Voltage:	50 or 100V nominal
Current:	3A to 10A maximum

INPUTS

Speed:	Variable Reluctance or Hall type input
	1 to 120 pulse per revolution
	20V pk-pk maximum
	24,000 rpm maximum at 60 ppr
Load Cell:	100 to 500 ohm
	4-wire Wheatstone bridge
	5 to 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

CONTROLLE MODES

Modes of Control

This dynamometer controller allows the user to control the dynamometer in several different modes: Manual, Speed, Torque, Road 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 constant torque, use the Torque Mode (speed will vary). For automated testing, use the COMputer control 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.

MAN: 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 speed) as Dyno load is increased to keep the engine just at redline speed. Once the throttle is full 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 say 500 rpm allows the wide open throttle (WOT) torque curve to be determined.

NOTE: Some engines are not tolerant of continuous operation at WOT. It is the duty of the operator to prevent damage to the engine being tested.

Using the right and left arrow keys in Manual mode allows you to adjust various parameters such as the alarm trigger points for speed and torque, and the number of pulses per revolution on the RPM1 and RPM2 input channels.

RPM: 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. 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 Proportional, Integral and Differential control gains (PID) must be carefully adjusted as described later in this manual.

The right and left arrow keys in RPM mode allow you to set the maximum control speed and the Proportional, Integral and Differential gains for the speed control mode.

8

TORQ: 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. 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.

The right and left arrows in Torque mode allow you to adjust the maximum torque control value, as well as the Proportional, Integral and Differential gains for the torque control mode.

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 and 100% load at the designated "saturation" 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.

The right and left arrows allow you to adjust the frictional load, aerodynamic saturation RPM, and the acellerational load (proportional to vehicle mass).

COM: Computer Control

In Computer control mode the operating control mode, set point, throttle position and Verbose Mode are set from the computer via the serial port. The mode and set point 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:

M123   Manually Sets Load to 12.3%
S12250   Sets Speed control mode to 12250 rpm (Limited to maximum speed @ controller)
T12.34   Set Torque control mode to 12.34Nm
R250   Set Road Load with factor of 250%

For throttle Position control send the following sequence:

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

For Example the following sequence sets the throttle output voltage to 50% (ie. 2.5V):
P500

Verbose mode can be activated from the computer by sending a capital V, and deactivated by sending a lower case v:

V Turns Verbose mode ON
v Turns Verbose Mode OFF

The Alarm mode can be activated from the computer by sending a capital X, and deactivated by sending a lower case x:

X Turns Alarm mode ON
x Turns Alarm Mode OFF

The torque measurement can be Tared (zeroed) by sending a capital Z:

Z Tare the load measurement

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. The zero point, and gain of the amplifier can be adjusted by trim potentiometers on the amplifier board inside the controller. In general these will not require adjustment. If they are adjusted, the Torque calibration will require re-calibration.

Internal/External Dynamometer Power Supply

This dynamometer controller features either an internal power supply providing DC current to the dynamometer coils, or an external transformer supplying AC voltage to the rear of the controller, which is internally converted to DC. Make sure not to exceed the power supply ratings. In general the dynamometer coil resistance should be greater than 10 ohms. In case of an over current situation the Dynamometer Coil circuit breaker should trip, stopping dynamometer current. This can be reset by pushing the breaker button back in.

Serial Port Data Logging

Along with the controller a serial port data logging and display "DynoMonitor" program 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). It may require the installation of a USB-Serial device driver if using a USB-Serial port converter. The simple serial port communications protocol can also be reproduced in user defined programs for customization. The latest version of DynoMonitor can be down loaded from the Focus web site: www.FocusAppliedTechnologies.com.

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.

In Torque mode you can adjust the Torque Maximum Set Point and the Proportional, Integral and Differential gain values for the Torque PID Control.

In Road Mode you can adjust the Friction, Aerodynamic and Acceleration (mass) values.

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 ($\rightarrow$) 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 ($\rightarrow$) 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 (friction)
Ka: Speed at which Aerodynamic Resistance becomes 100%
Km: Acellerational Drag (mass)

Load% at a given speed (RPM) is then calculated (approximately) as:

13

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 (20 kph) steady state cruise throttle setting, the high speed steady-state cruise throttle setting (60kph or higher) and the time required to reach 60kph from a stand still.
First, zero out the Ka (by setting Ka very high, say 20,000rpm) and Km (Km = 0) settings. 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 throttle setting. Next set the Aerodynamic Resistance (Ka) to get the appropriate throttle setting at the "high speed" cruise speed. Note that a lower Ka value gives a higher load.
Finally increase the Acellerational Drag (Km) to get the appropriate zero to 60kph acceleration time.
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								

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)

|	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
P	L	E	A	S	E		S	E	L	E	C	T		M	O	D	E		!

The reserved mode is not available for adjustments.

CALIBRATION

Speed Calibration and Adjustment

This dynamometer controller accepts speed signals from most "pulsed" types of speed sensors, including Hall Effect (HE) and Variable Reluctance (VR) sensors. 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, but each dynamometer may have a different number of teeth, so this should be measured. The Pulses Per Revolution (PPR) can be set from the front panel by hitting the right arrow in Speed mode, and following the prompts on the screen. If the speed target wheel is not on the main shaft (engine/motor input shaft, or rollers for chassis dynos) then the number of teeth needs to be multiplied by the gear ratio such that the number of PPR refers to the number of pulses received in one revolution of the *input* shaft. For example if the dyno spins at 2x the input shaft speed, and has 4 teeth, then there will be 8 pulses per revolution of the input shaft, and thus PPR = 8.

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 1mm for VR sensors, and approximately 4mm for HE sensors.
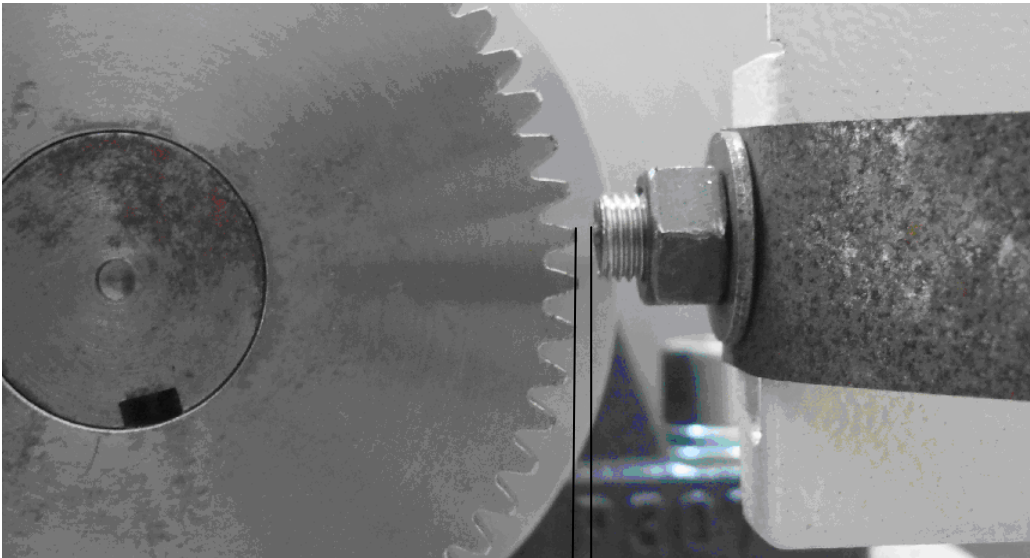
Gap: 0.5mm to 1.5mm for VR type sensors
3 to 6 mm for Hall Effect type sensors

The 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 with a volt meter.

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)
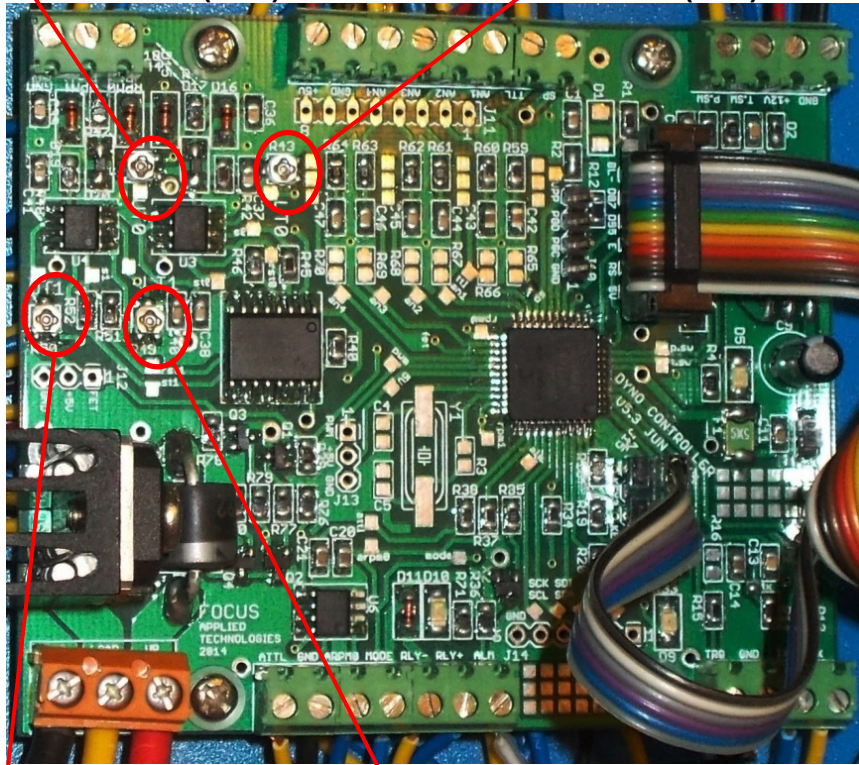
RPM2 Upper Threshold   RPM2 Lower Threshold

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 (eg. about 1V), 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 (eg. about 4V).
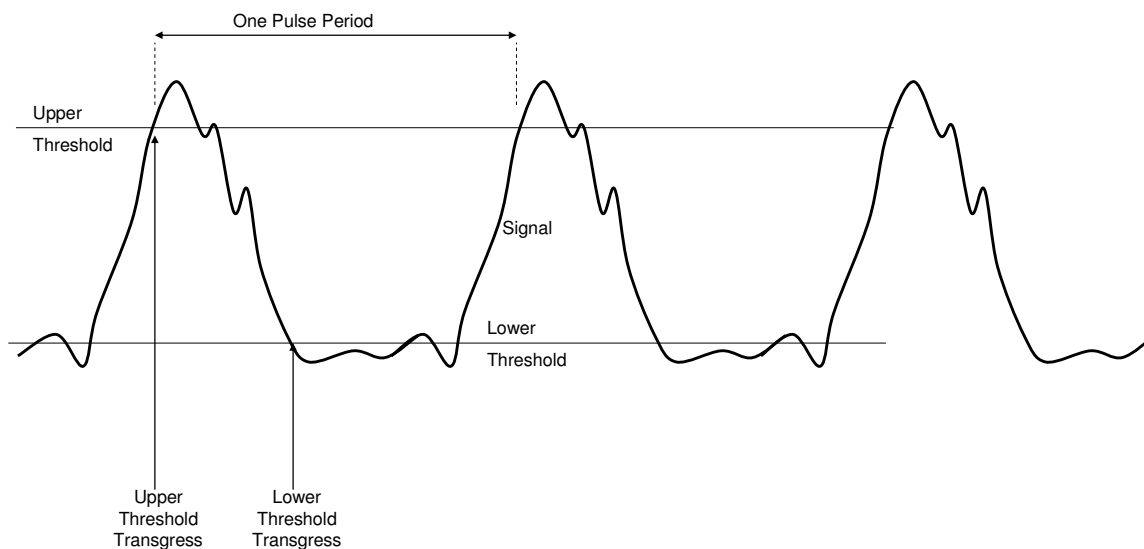
Torque Calibration

Before calibration the dynamometer should be warmed up, and loaded with a typical load for a few minutes. A calibration arm is provided with most dynamometers. This needs to be mounted to the dynamometer appropriately. Once the arm is loaded the load should be zeroed at the dynamometer controller. Simply hit the TARE button on the front panel to zero the torque. Calibration weights can now be added to the cal-arm at the indicated location. This places the weights at a defined radius (**R**) from the centerline of the dynamometer. The torque reading is the torque resulting from a mass **M** is:

Torque = M x 9.81 x R

Where:
M is the weight of the mass in kg
9.81 is standard gravitational acceleration (m/s^2)
R is the radius of the weights from the center of the dynamometers shaft in meters

*NOTE: if measuring the torque on a dynamometer which has a gearing ratio, this needs to be included in the calculation. If the dyno spins at **G** times the input shaft rpm then the torque at the main shaft should be:*

Torque = M x 9.81 x R x G

If the front panel torque reading is different from this amount, then the calibration factor must be adjusted. To do this, temporarily turn the dyno current off to avoid overheating) 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. Generally the calibration only requires small changes, ~1% of the nominal value. If your system requires very large changes after the initial calibration, it may be a sign that the load cell is damaged.

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.

Place Calibration
Weights Here
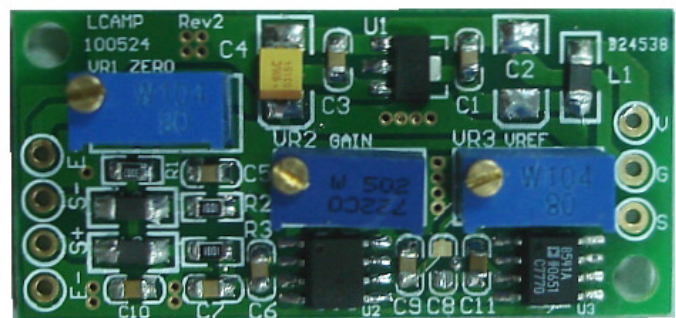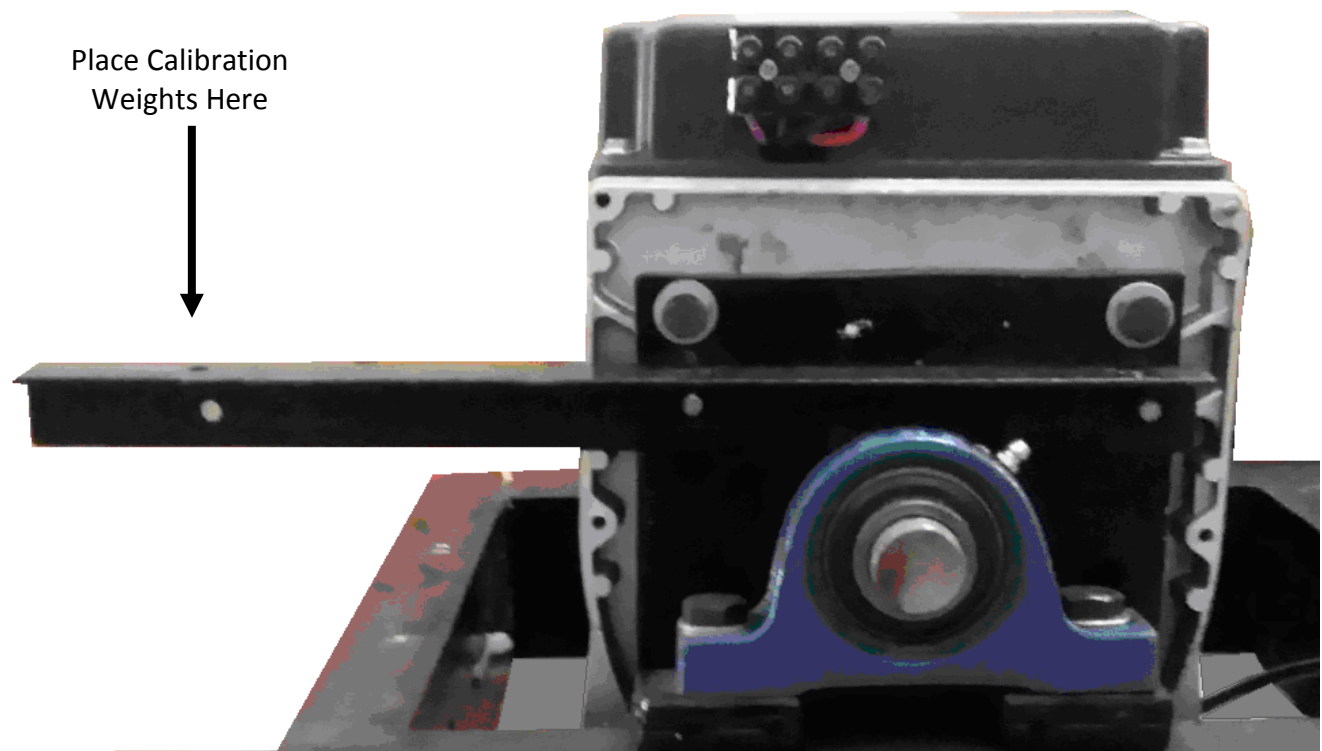
Each dynamometer should have a designated calibration weight loading point, or calibration "arm" as shown here. The radius **R** from the centerline of the dynamometer to the loading point is a critical dimension.

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.

Roller 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.

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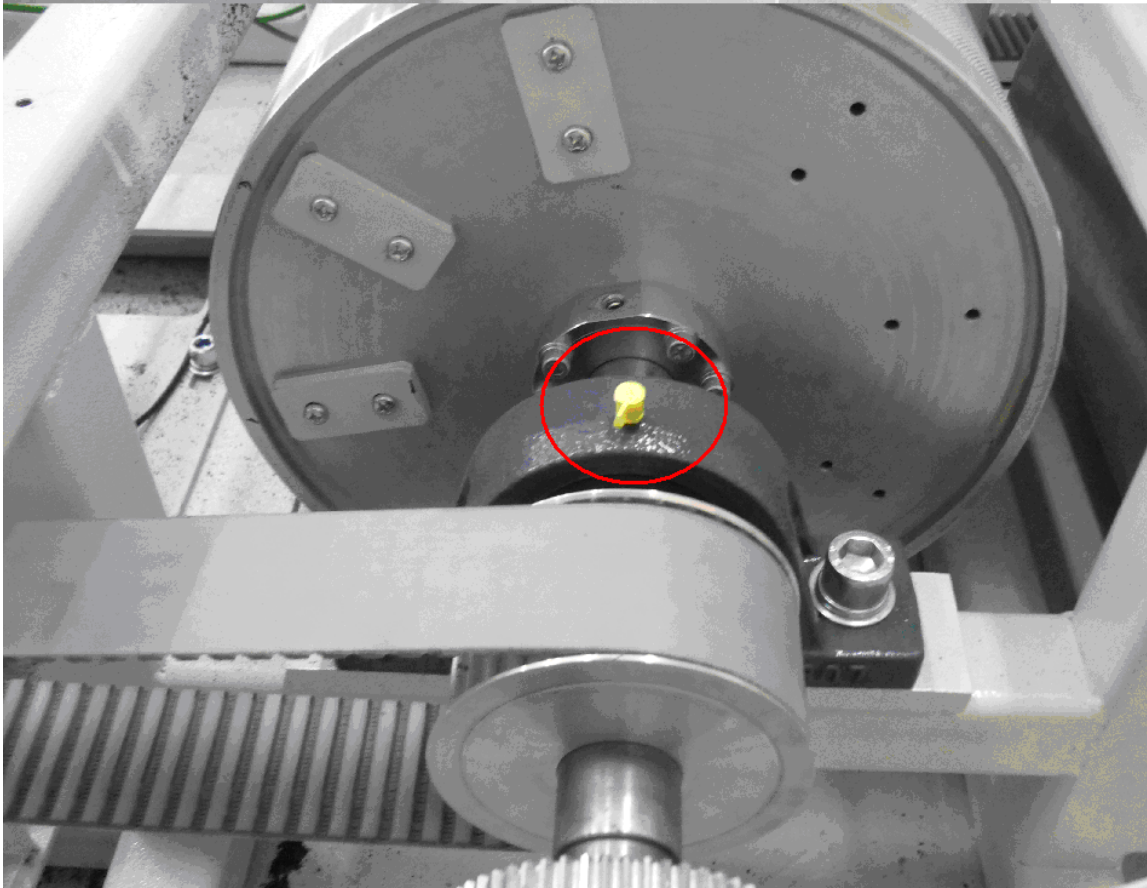
Shaft Couplers

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.
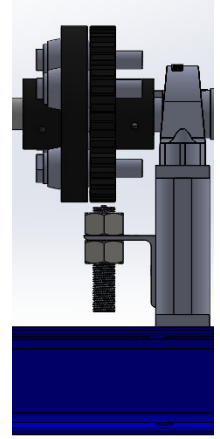
When connecting shafts, be sure that the shafts are well aligned to prevent premature wear of the bushings. The shafts should be aligned to within 0.1mm of each other radially. This can be checked with a micrometer mounted to one shaft and measuring the relative position of the 2nd shaft, while the 1st shaft is rotated.

0.1mm max
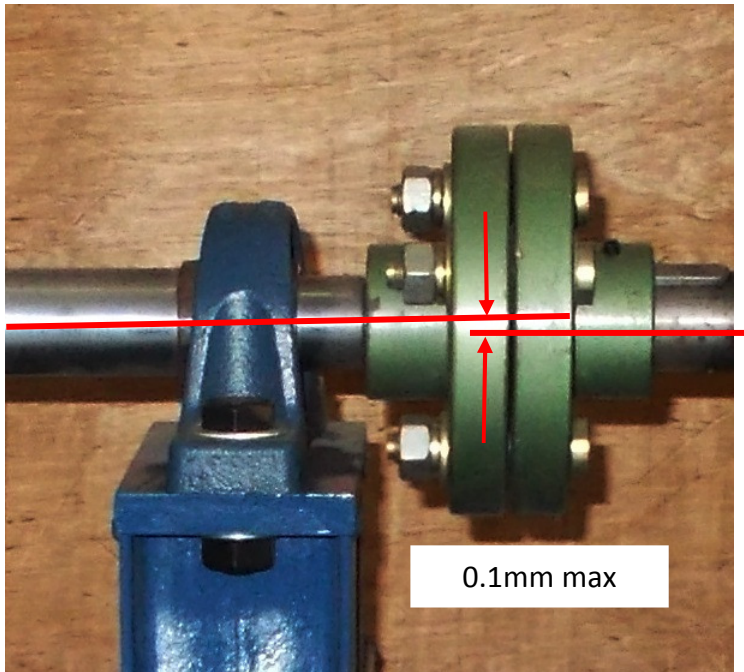
When properly aligned there should be slight free play between the two coupler halves as the shafts are rotated through 360 degrees. If the shafts or coupler binds, then it is probably misaligned and should be adjusted. Another simple check is to place a straight edge on the top of the two couplers to check their alignment in the vertical plane. This should be checked at 90 degrees as well to check the alignment in the horizontal plane.
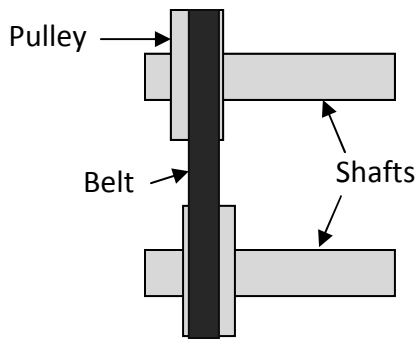
The two coupler halves should be separated by a gap of 0.25 to 0.75mm in the axial direction. Finally insure that all the set screws and bolts are securely fastened so that the couplers do not move with respect to their shafts.

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.
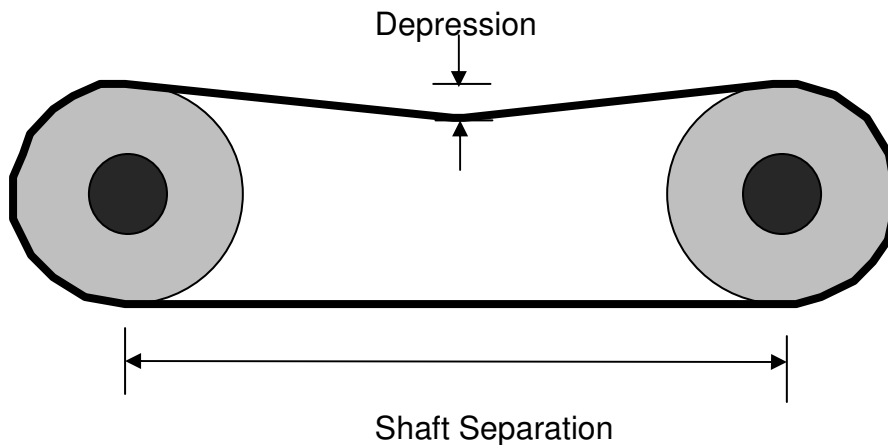
Poor Pulley Alignment: Poor Shaft Parallelism:

Pulley
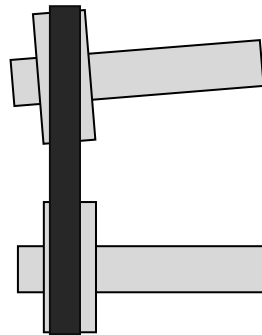
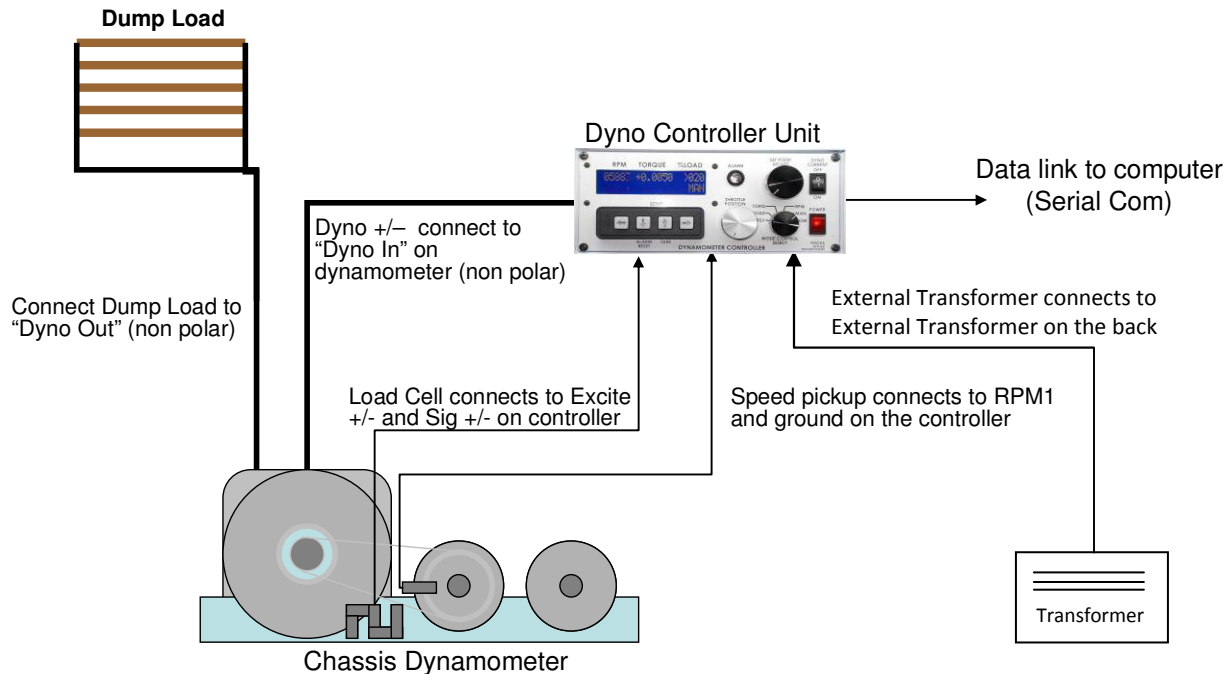Belt   Shafts

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.

Depression

Shaft Separation

EXTERNAL WIRING DIAGRAM

Dump Load

Dyno Controller Unit

Data link to computer
(Serial Com)

Dyno +/– connect to
"Dyno In" on
dynamometer (non polar)

Connect Dump Load to
"Dyno Out" (non polar)

External Transformer connects to
External Transformer on the back

Load Cell connects to Excite
+/- and Sig +/- on controller

Speed pickup connects to RPM1
and ground on the controller

Transformer

Chassis Dynamometer

NOTE:

1) Not all dynamometers have an external dump load. Generator type dynos usually do, but many air-cooled eddy current dynamometers do not. Water cooled dynos obviously require an external source of cooled water.

2) Not all dynamometers require an external transformer. Depending on the type of controller and dynamometer the power supply may be internal to the controller. Generally if the dyno requires 100V at 3A or less the power is inside the controller.

The Controller should be powered from a clean AC line power source.

The Dynamometer +/- power lines are connected to the "Dyno In" lines on the dynamometer with power cables rated for twice the maximum dyno current. Dump load are typically large air-cooled resistors, and thus non-polar, and may have power up to 400V AC, and 20A. Insure appropriate gage wires are used. There should be one meter long heater resistor for every 2kW of dyno power rating. Dump load resistors can get very hit, and should be mounted high on a non-combustible wall, and away from any burnable materials.

WARNING: Both the Dyno+/- control lines and the Dump Load lines (if existent on your dyno) may have high voltages on them and can cause shocks or electrocution if handled improperly! Always use appropriate cautions when using/installing the dynamometer.

WARNING: The Dyno +/- control lines will stay energized for some time after the power is shut off. Allow the controller 10 minutes to discharge the internal capacitor and check the voltage levels before contacting these wires.

The speed pickup is connected to the appropriate inputs via a shielded co-axial cable. This signal is non-polar and should be approximately 2 to 30V AC depending on the speed and proximity of the sensor to the speed target wheel.

Variable Reluctance Speed sensors connect between ground and RPM1. Hall Effect sensors require +5V from Excite+ as well. Colors may vary, but are typically one of the following:

Connection	Loose HE Sensor	HE Sensor in Harness
RPM1	Black	Yellow
Ground	Blue	Grey
Excite+	Brown	Brown

The load cell amplifier is connected to the appropriate connections on the dyno controller, typically the wire colors will be as follows:

RED	Excite+ (either 5 or 10V DC)
BLACK	Excite – (Ground)
YELLOW or WHITE	Signal +
ORNGE or GREEN	Signal -

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 noisy environments a grounding line may be required between the controllers ground, and the computers frame ground. 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.

PID TUNING GUIDE

Tuning PID controllers for best operation can be difficult to 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 3000 rpm and 25% throttle for an automotive 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 2500 rpm to 3500 rpm. This proportional is too high for use without differential gain to compensate, so reduce the proportional gain to half of its 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 an automotive engine operating at 25% throttle, you could get the system to run smoothly at 2500 rpm, then suddenly change the set point to 3500 rpm. It is likely that with higher values of proportional gain, the actual speed will over shoot the set point (eg. the engine may operate at up to 4000 rpm before settling close to 3500rpm). 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
.
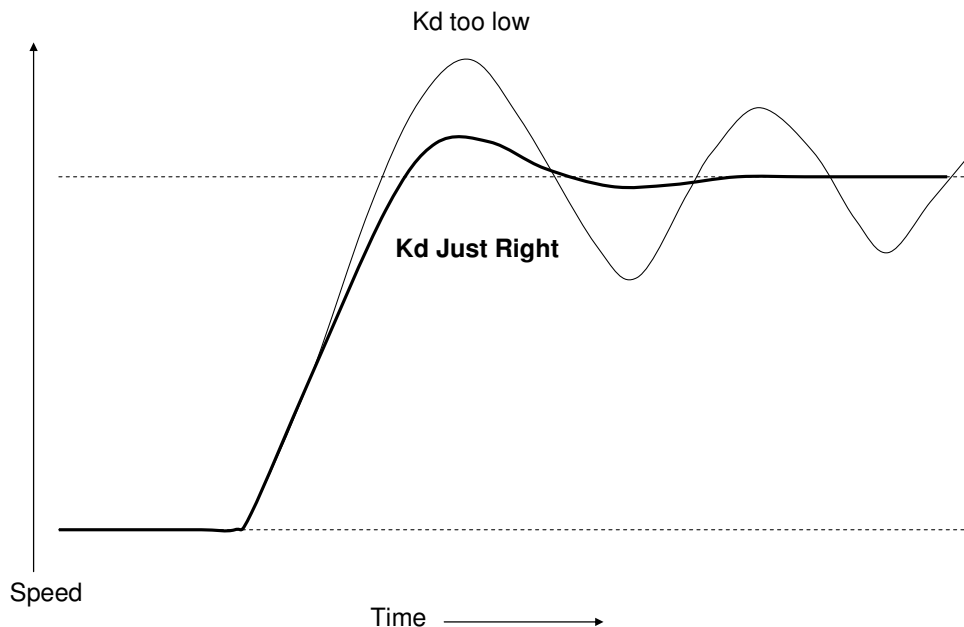
Integral Gain Tuning
Integral gain is used to eliminate the persistent steady state error, once a system has stabilized. In some systems, such as an internal combustion engine coupled with an eddy current dynamometers, integral gain may not be required at all. Integral gain should be used sparingly, as

excessive integral gain will almost always make a system go unstable. Again operate the system at a nominal operating point, such as 3000rpm and 25% throttle. If the steady state error is consistent, eg. the system operates at 2950rpm and won't converge to 3000 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.

If the rate of convergence to a new set speed is too slow, you may want to increase the Kp. Kd may also require adjusting to achieve an acceptable rate of convergence with minimal overshoot.

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

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

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 Dynamometer Coil Output lines. At low load the DC voltage across the load should be near zero, and should go up to the rated transformer 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.

WARNING: The voltages on the Dyno+ and Dyno- lines can be dangerously high, make sure to wear appropriate protective equipment, and do not contact the lines with your fingers.

**Voltage of Dyno – (with reference to ground)**
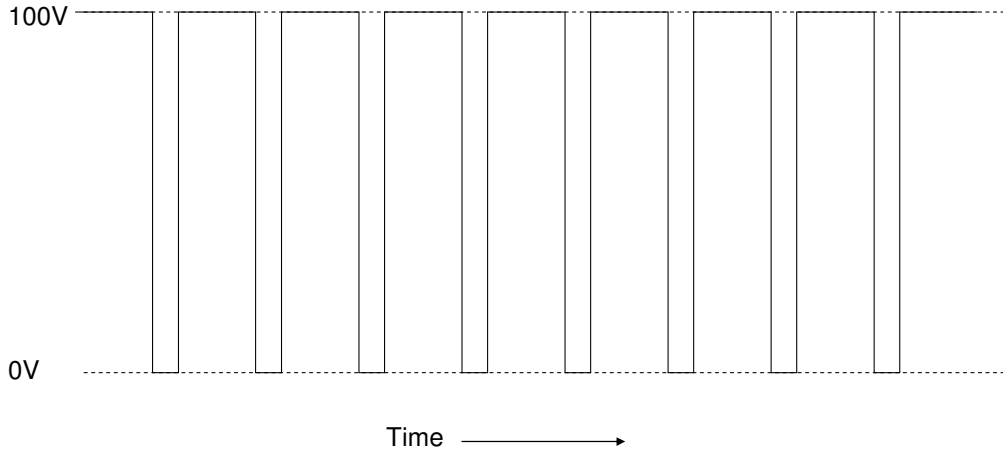
The diagram above depicts a 100V power supply. The actual upper voltage of your system may be different, but is typically 50 to 100V. If you get this DC voltage, then the power supply, power switching transistor and controller are all working properly. If you do not, try resetting the circuit breakers, checking wire connections, making sure the external transformer (if present) is powered on and try again. If everything else is in order, but the dnyo lines still have no power, than the power circuit may be damaged. Contact Focus for appropriate action or guidance.

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
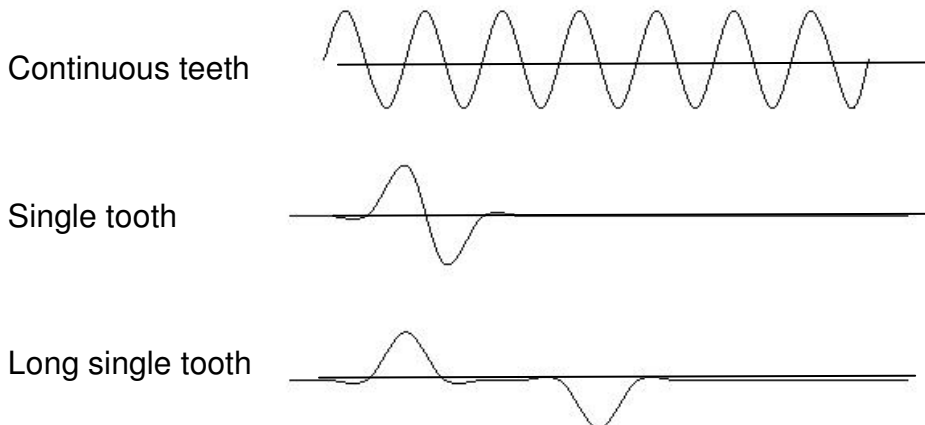
Hall Effect type Speed Signal

Normal

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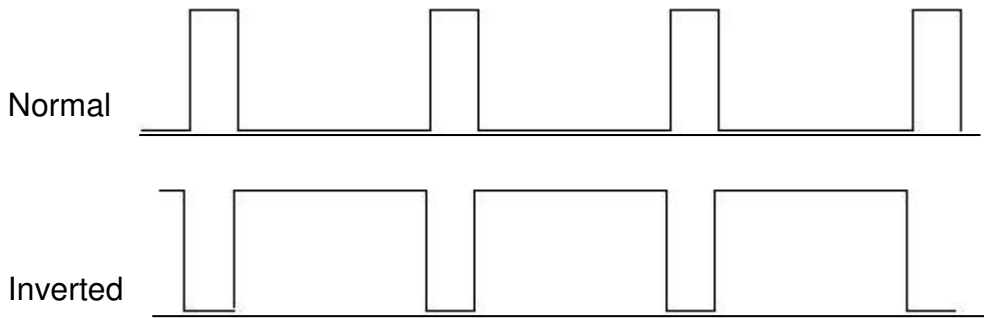
NOTE: Some Hall type sensors may not go all the way to 0 volts. This may require raising the Upper Threshold (UT) and Lower Threshold (LT) levels to properly read. Make sure that UT voltage is greater than the LT voltage.

LOAD CELL TEST

The load cell and amplifier can easily be tested together by observing the voltage (amplifier output present at the Torque output 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.

The maximum Torque voltage at the back of the controller is about 5V. Above this load the amplifier is saturated, and will no longer respond to increasing torque. If you wish to read higher torques, then the load cell amplifier gain must be decreased, and the torque will have to be re-calibrated. See the above section on torque calibration for more information.

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 500 ohms.
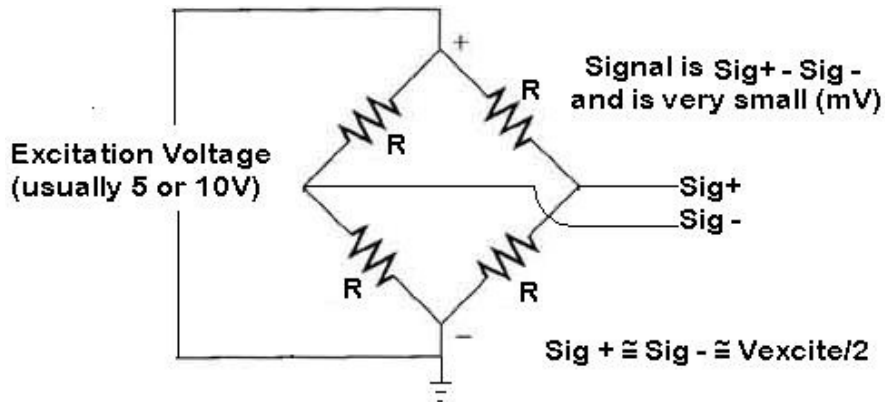
The excitation voltage (**Excite +** relative to **Excite -**) is either 5 or 10V depending on the amplifier. When functional the **Sig +** and **Sig –** lines should both be at approximately ½ the excitation voltage. Connecting a voltmeter (set to the DC mV scale) between **Sig +** and **Sig –** you 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.

COMMUNICATIONS TROUBLE SHOOTING

Engines and electric motors can make a lot of electronic noise. This noise interferes with some Serial communications converters. This may cause "hesitation" or seizing of the serial communications from the controller. Reducing electronic noise (use of resistive type spark plug wires or spark cap, proper grounding of the vehicle, keeping signal wires away from the "noisy" wires and etc.) is the best way to combat this.

If you continue to experience serial communications problems despite proper noise reduction, one common fix is to run a ground line from the chassis of the computer to the GND on the back of the controller. This causes electronic noise to be grounded via this wire, instead of traveling through the serial communications cable.

NOTE: The cable is supposed to be "shielded, and grounded at both ends, but often the cables shields are not actually connected.

 If your system is having intermittent communications problems when running, try running a grounding wire as described.

DYNO MONITOR PROGRAM
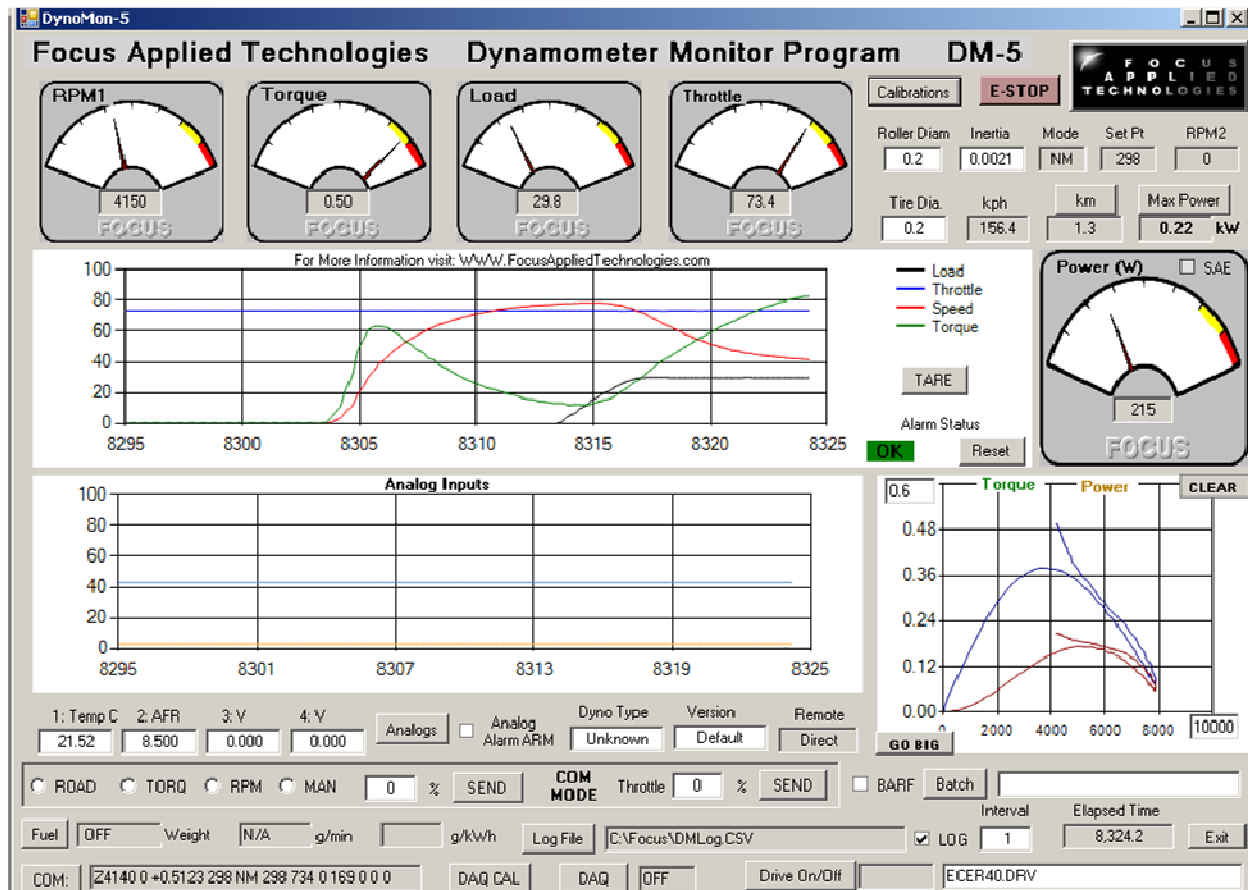
The Dyno Monitor software is supplied with our Gen-5 Dynamometer Controllers for display, data logging and Control of the Dynamometer. This document details the usage of the Dyno Monitor program.

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). You can install the Dyno Monitor software by running the setup.EXE file and following the prompts. If using a USB-Serial adapter cable, you may need to install the appropriate device driver. For Focus provided USB-Serial com cables the Prolific PL2303 driver is provided in the zip file and you should run the setup program to install it.

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. If there is a miss match between the DynoCal file version and the DynoMonitor program (eg. When updating to a newer version of Dyno Monitor) you can save the old version of DynoCal, allow Dyno Monitor to create a new one, then copy over the old values to the new file.

Focus Applied Technologies Dynamometer Calibration File	DC5
Version	Default
Mass	120
Wheel Diameter	0
Pulses per Rev	20
RPMPV	0
Torque Averaging	0.5
Torque Offset	0
Torque Factor	1
Frict Offset	0
Frict Factor	0
Last Cal	Not Calibrated.
Dyno Type	Unknown
Roller Diam	0.2
Inertia	0.0025
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
Analog Filter 1	0
Analog Filter 2	0
Analog Filter 3	0
Analog Filter 4	0
Analog Lower Alarm 1	10
Analog Lower Alarm 2	0
Analog Lower Alarm 3	0
Analog Lower Alarm 4	0
Analog Upper Alarm 1	19
Analog Upper Alarm 2	999
Analog Upper Alarm 3	999
Analog Upper Alarm 4	999
Analog Alarm ARM	TRUE
T-Graph Max X	8000
T-Graph Max Y	1
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

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.

Frictional Compensation

During "spin down" the inertia is decelerated by friction from bearing, windage. We can measure the speed profile, and calculate the deceleration to determine the friction.
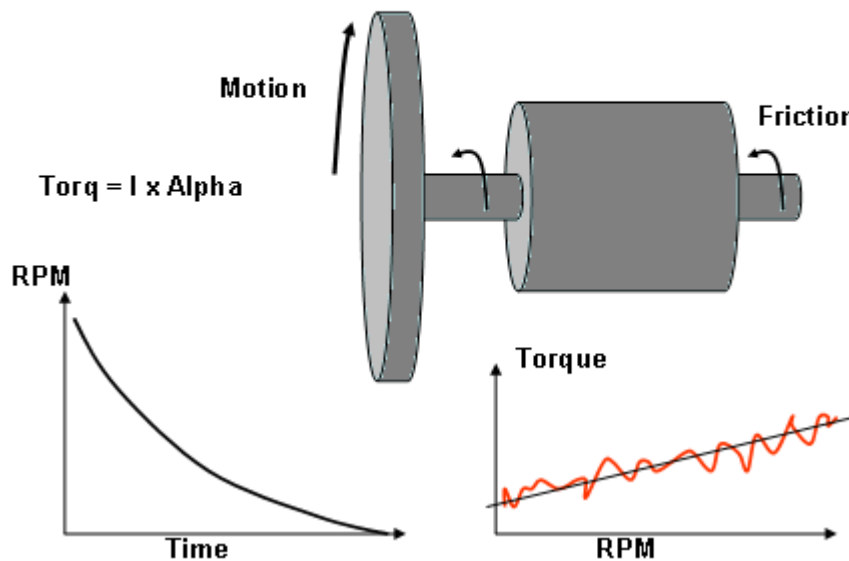
NOTE: Be sure to fully warm up the dyno (and bearings) before measuring the bearing friction! It is strongly affected by temperature (cold bearings giving 2 or 3 x higher friction).

$y = 4E\text{-}05x + 0.0409$

34
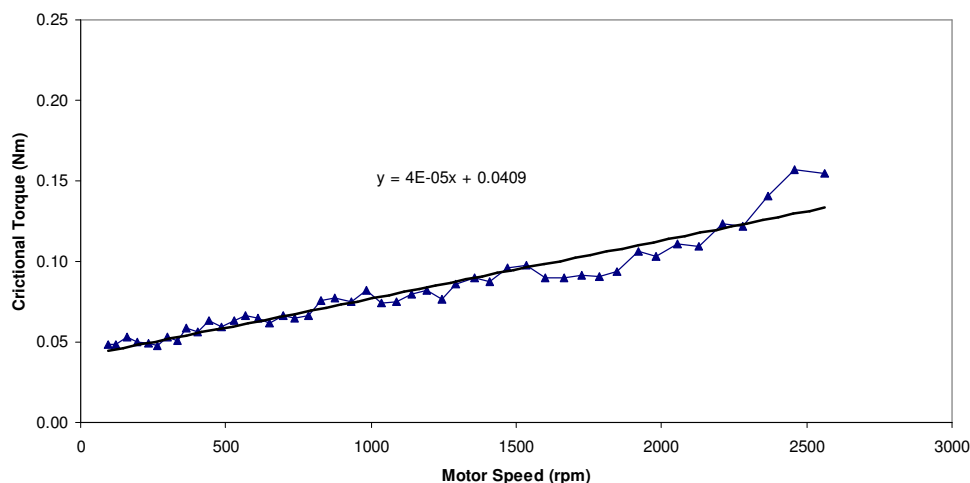
Last Cal is the numeric version of the last calibration date.

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:

$$\textbf{Torque = Frictional Offset + Frictional Factor x RPM + Inertia x Acceleration (rad/s}^2\textbf{)}$$

In loading type dynamometers, Torque is calculated similarly, but the measured torque (usually the largest component) is also 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.
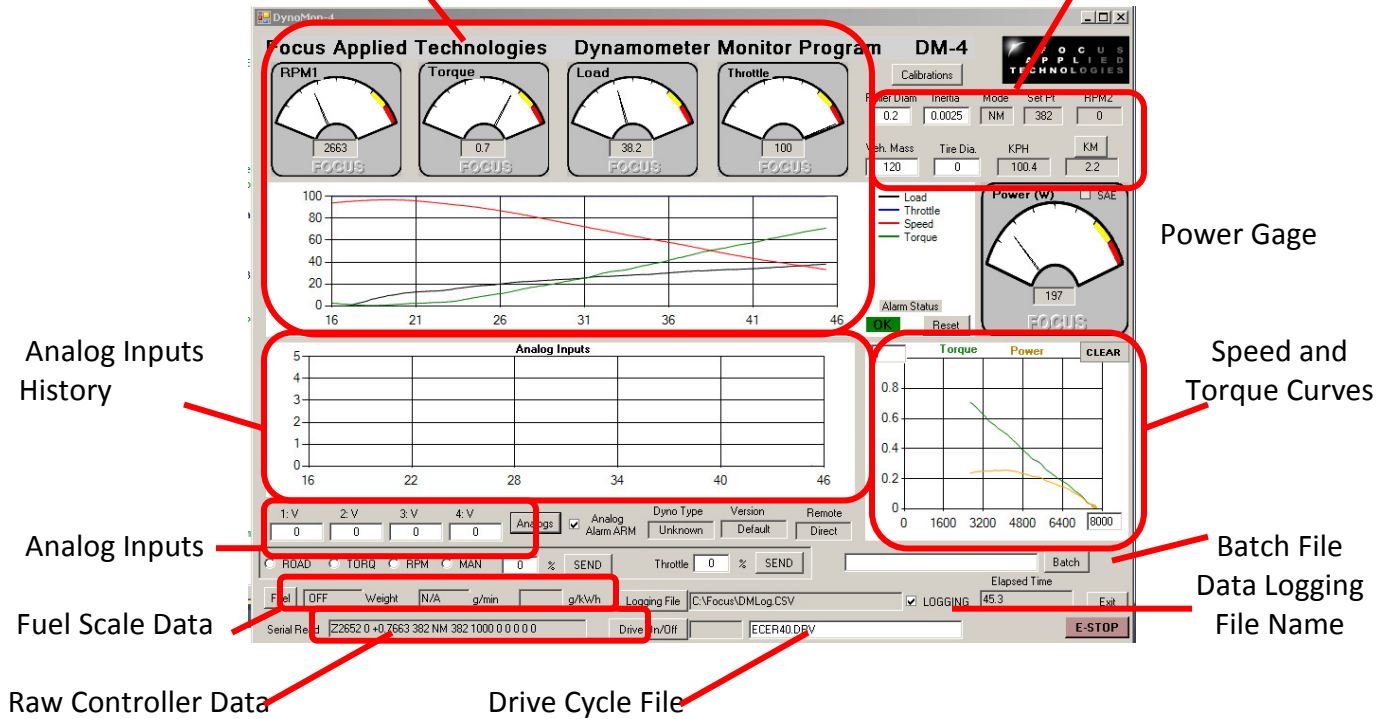
The next 4 factors (labeled AFR, V, V, V in this cal file) are the labels and factors of the Analog Channels 1, 2, 3 and 4 respectively, and the following 4 are the analog channels offsets. The Analog Inputs are 0-5V, and converted to Volts in the software. In this example we have a wide-band exhaust gas O2 sensor on Channel 1 (thus the label "AFR" for Air Fuel Ratio) where 0V 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 next 4 items are the individual analog channel filtering factors (0 = no filtering, 0.99=heavy filtering). The next 4 lines are the lower limits for triggering the alarm from the Analog Inputs, and following that are the upper limits for triggering the alarm from the analog inputs. The next line gives the value of the Analog Alarm ARM: True if the alarm is to be triggered from Analog out-of-range values, and FALSE if not.

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.
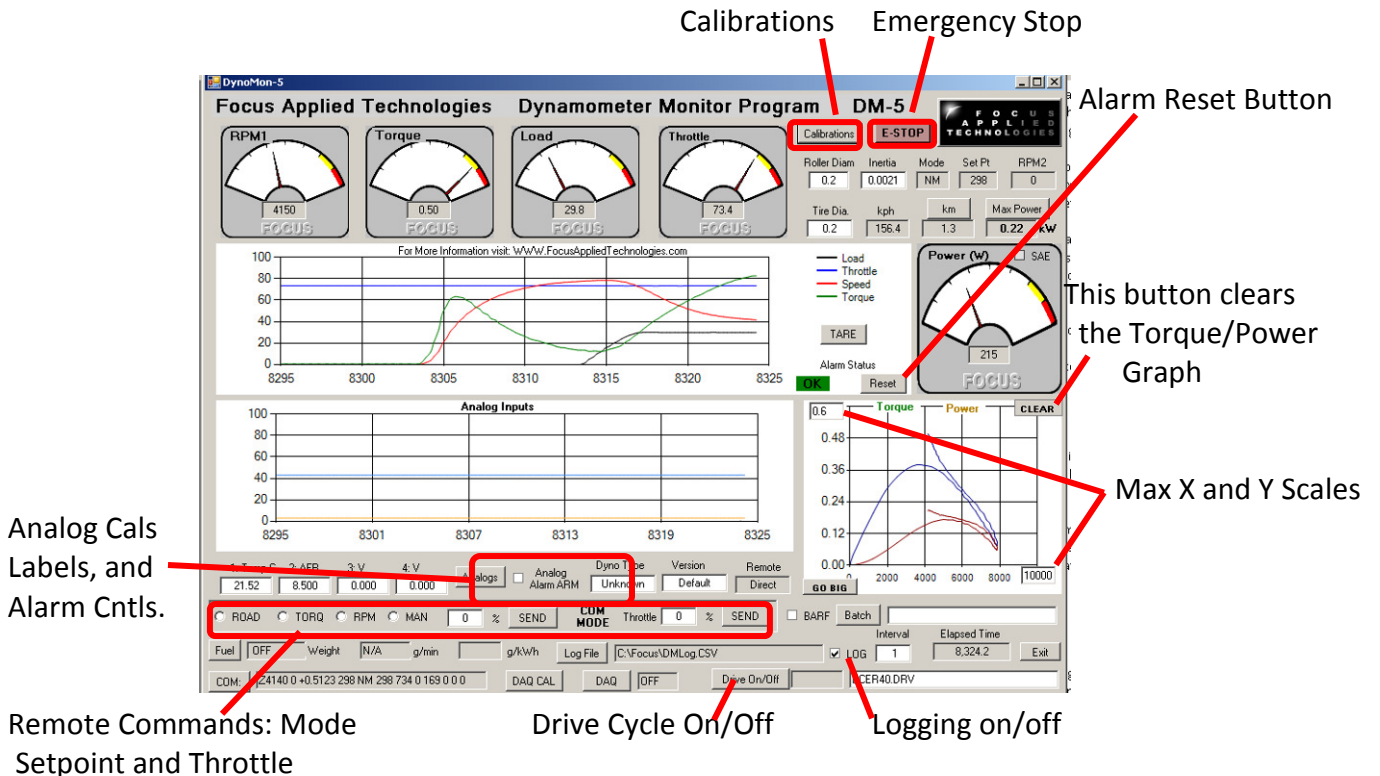
Major Display Areas

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 Data Logging File Name

Fuel Scale Data

Raw Controller Data

Drive Cycle File

Major Controls

Calibrations

Emergency Stop

Alarm Reset Button

This button clears the Torque/Power Graph

Max X and Y Scales

Analog Cals Labels, and Alarm Cntls.

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 0-100% of maximum value basis. The Analog labels and values are displayed in the 4 boxed just below the Analog History graph.
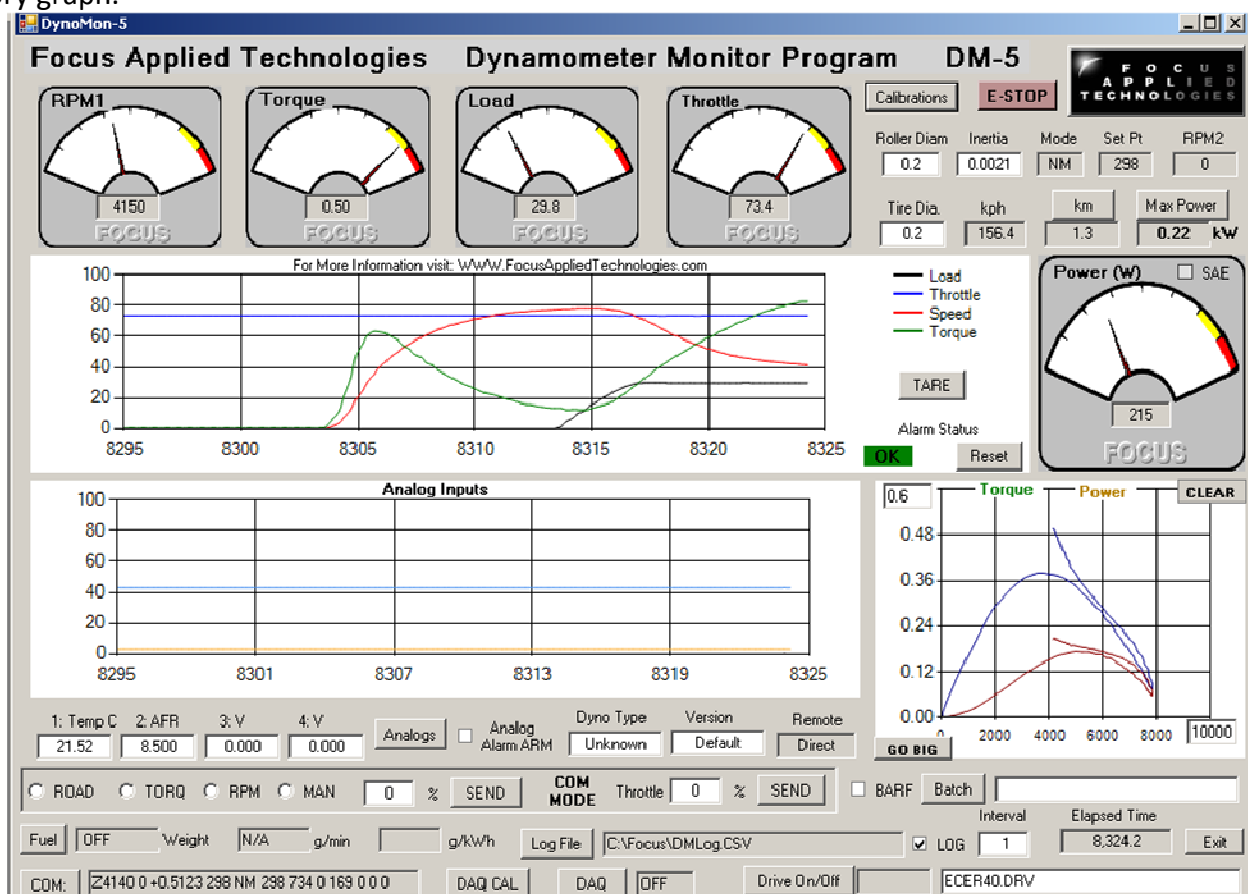
Various calibrations are displayed in the upper right corner of the display. Roller Diameter, Inertia, and Tire Diameter can be edited directly in these boxes. The MODE box displays the controllers Mode (M for Manual, S for Speed, T for Torque, and R for Road Load, the prefix "N" stands for "Normal" 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 the command to the controller. Throttle position is to the right of the mode.

Logging data file name is edited from the button below the remote 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 "DRIVE ON/OFF" 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 below. 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, or CLOSE. The title above the main history graph can be entered at the bottom of the calibration window. In general the Torque offset will be 0, and torque factor will be 1. Frictional factors can be adjusted so that an unpowered spin down of the fully warmed dynamometers reads approximately zero power during the cost down to stop. When the Inertia and friction are correctly calibrated, they cancel each other during an unpowered spin down of the dyno.

Analog Labels and Factors

The Analog Labels, Factors, Offset, Filter and Alarm Limit values can be entered in the dialog box opened by hitting the "Analogs" button (lower left). Hi the button again to close. The analog history graph is scaled from 0 to 100% between the minimum and maximum values, for example is the min is 8 and the max is 23, then the graphical display 0 to 100% will represent 8 to 23 in the units of that channel.

Drive Cycle File

The first line of the drive cycle file is ignored as a header. The subsequent lines are in the format time followed by a comma, then 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. Generally the controller will be set to Road Load with the appropriate factors for the vehicle being tested during drive cycle testing.

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,	0.0

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 % (eg. 10% is M10)
S: Speed Mode in RPM
T: Torque Mode in Nm
R: Road Load constant (0 to 255)
P: Throttle Position in % (eg. 10% is P10)
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, Set Point Value, Throttle Step Size, Duration (in sec)

Valid Command Examples:
M12.3   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%
P50,6   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
P50,5   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

P90,5	Throttle Position 90%, Dwell 5 sec
2	Label #2
M20,5	Manual Mode, 20% Load, Dwell 5 sec
M30,5	Manual Mode, 30% Load, Dwell 5 sec
L2,2	Loop to Label #2, run twice (total)
P50	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 shaft speed (rpm1) in rpm, rpm2 in rpm, Measured (raw) Torque in Nm, Total Torque (measured + Friction + Inertial) in Nm, Power in Watts, % dynamometer load, Mode, Set point, Throttle position, Alarm, and the analog input values 1, 2, 3, and 4 respectively.

Focus Applied Technologies Dyno Controller Log Version: Default   Opened: 10-Mar-17 1:49:47 PM

Time (s)	RPM1	RPM2	Torque Raw	Total Torq	Power (W)	Load	Mode	SetPoint	Throttle	Alarm	1:Temp C	2:AFR	3:I (A)	4:V	Fuel (g)	
0.1	0	0	0	0.00E+00	0	0	CM	0	1000	0	5	8.5	0	0	0
0.3	0	0	0	0.00E+00	0	0	CM	0	1000	0	5	8.5	0	0	0
0.6	36	0	0	0.015334	0	0	CM	0	1000	0	5	8.5	0	0	0
0.8	199	0	0	0.083215	1.7	0	CM	0	1000	0	5	8.5	0	0	0
1.1	531	0	0	0.207251	11.5	0	CM	0	1000	0	5	8.5	0	0	0
1.3	922	0	0	0.327519	31.6	0	CM	0	1000	0	5	8.5	0	0	0
1.6	1468	0	0	0.475293	73	0	CM	0	1000	0	5	8.5	0	0	0
1.8	2117	0	0	0.62865	139.4	0	CM	0	1000	0	5	8.5	0	0	0
2.1	2667	0	0	0.689023	192.4	0	CM	0	1000	0	5	8.5	0	0	0
2.3	2909	0	0	0.589387	179.5	0	CM	0	1000	0	5	8.5	0	0	0
2.6	2957	0	-0.029	0.402631	124.7	0	CM	0	1000	0	5	8.5	0	0	0
2.8	2979	0	0	0.267766	83.5	0	CM	0	1000	0	5	8.5	0	0	0
3.1	2971	0	0	0.161985	50.4	0	CM	0	1000	0	5	8.5	0	0	0
3.3	2982	0	0	0.100276	31.3	0	CM	0	1000	0	5	8.5	0	0	0
3.6	2972	0	0	0.054655	17	0	CM	0	1000	0	5	8.5	0	0	0
3.8	2970	0	-0.029	0.015086	4.6	0	CM	0	1000	0	5	8.5	0	0	0
4.1	2982	0	0	0.013798	4.3	0	CM	0	1000	0	5	8.5	0	0	0
4.3	2972	0	0	0.004792	1.4	0	CM	0	1000	0	5	8.5	0	0	0
4.6	2982	0	0	0.006468	2	0	CM	0	1000	0	5	8.5	0	0	0
4.8	2972	0	0	3.48E-05	0	0	CM	0	1000	0	5	8.5	0	0	0
5.1	2970	0	-0.029	-0.01608	-5.1	10	CM	100	1000	0	5	8.5	0	0	0

This data can then be graphed and analyzed further. To read the data in Excell, open the file and specify that it is using a comma delimited format.

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.

MORE INFORMATION
For More Information on vehicle Drive Cycles please visit the US EPA website:
https://www.epa.gov/vehicle-and-fuel-emissions-testing/dynamometer-drive-schedules

SAFETY PRECAUTIONS

Focus Applied Technologies Dynamometers are designed to be an inherently safe machine via the use of heavy duty bearings and frame, electrical fault protection, and ignition cutoff system. However as with any large 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 belts, pulleys and wires in good condition and at the proper tension.

- NEVER STEP on a moving roller!

- Avoid loose items including cloths, cables, belts and loose small times which might fall into the gap between the roller and the dynamometers kick plate.

- The control boxes contain dangerous voltages and currents. Never operate the dynamometer with the control boxes opened.

- Make sure the dynamometer is firmly bolted to the floor, and the test vehicle is strapped to the dyno so that it can not accidentally slip out.

- Disconnect all power to the dynamometer and auxiliary components before opening or servicing.

- Insure proper ventilation whenever operating a combustion engine.

- Insure proper cooling of the motor or engine to avoid overheating.

- Always make sure a fire extinguisher is available in case of a fire.

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 400VAC. 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 dump load 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 Universal Joint shaft can be dangerous if overloaded. 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 shaft, throwing heavy components outward at high speed. **ALWAYS STAY WELL AWAY FROM THE UNIVERSAL JOINT/COUPELER/BELT/PULLY AREA WHEN IN OPERATION!**
If this unit is intended for intense usage with personnel in close proximity, then a universal joint explosion cover should be affixed.

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.

TYPICAL DYNAMOMETER STARTUP PROCEDURE

This controller is equipped with several safety features to avoid damage to the dynamometer and engine. Theses must be correctly wired to insure safe operation. This section is provided as typical examples of how the dynamometer can safely be used. .

Dynamometer Startup Procedure

1. VMI: Visually inspect all components of the dynamometer system, engine and fueling system for make sure there are no missing or broken components, leaks or loose items which may cause damage. Make sure that the engine's ignition system power is routed through the Engine Ignition Cutoff Relay.
2. Check Dump Load (Generator type dynos only)
3. Turn Computer ON for logging
4. Turn Dynamometer Current to the OFF position
5. Switch the Mode selector switch to MANUAL mode
6. Set the Set Point Adjust to 0%
7. Turn the Dynamometer Controller Power Unit ON
8. Turn the external transformer power ON (if present)
9. TARE the load cell (this may be repeated after unit has warmed up for best results)
10. Set the Throttle Set Point to IDLE

Engine Startup Procedure

1. Check the Engine Oil and Coolant levels
2. Check Vehicle – Insure it is strapped securely to the dynamometer
3. Insure that the engine's ignition system power is routed through the Ignition Cutoff Relay on the dynamometer controller
4. Place the transmission in Neutral Gear
5. Power ON the Cooling System (Fan or water pump)
6. Power on the exhaust ventilation system
7. Open the Fuel Valve
8. Turn ON the Engine Ignition
9. Place Throttle to the START position (IDLE)
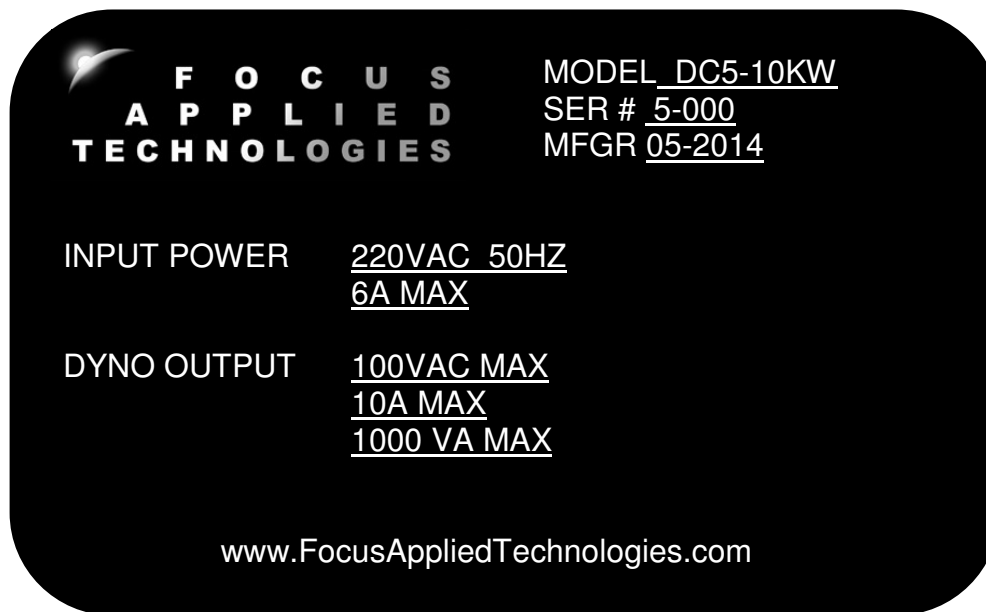10. Start the engine and IDLE

Engine Testing Procedure

1. Place engine in required gear
2. Switch Dyno Current ON
3. Switch Controller to appropriate Mode
4. Adjust Set Point to desired set point
5. Open Throttle to Desired Operating Condition
6. Commence Measurements, adjusting either Set Point of Throttle as required

Shut Down Procedure

1. Reduce Throttle to Idle
2. Place the transmission in Neutral Gear
3. Save all data on the computer
4. Place Dynamometer in Manual Mode
5. Reduce Dynamometer load to 0%
6. Switch Dyno Current OFF
7. Switch OFF the external transformer (if present)
8. Allow the engine some time to cool at IDLE if hot
9. Shut OFF the Engine Ignition
10. Turn OFF the Fuel Valve
11. Turn OFF the cooling system (Fan of Pump)
12. Turn OFF Exhaust fan
13. Stop the Computer Data Acquisition Program
14. Shut OFF The Dynamometer Controller

CONTACT INFORMATION

As there are so many factors outside of our direct control, Focus Applied Technologies can 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 procedures, 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

MODEL DC5-10KW
SER # 5-000
MFGR 05-2014

INPUT POWER   220VAC 50HZ
                 6A MAX

DYNO OUTPUT   100VAC MAX
                 10A MAX
                 1000 VA MAX

www.FocusAppliedTechnologies.com

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

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