

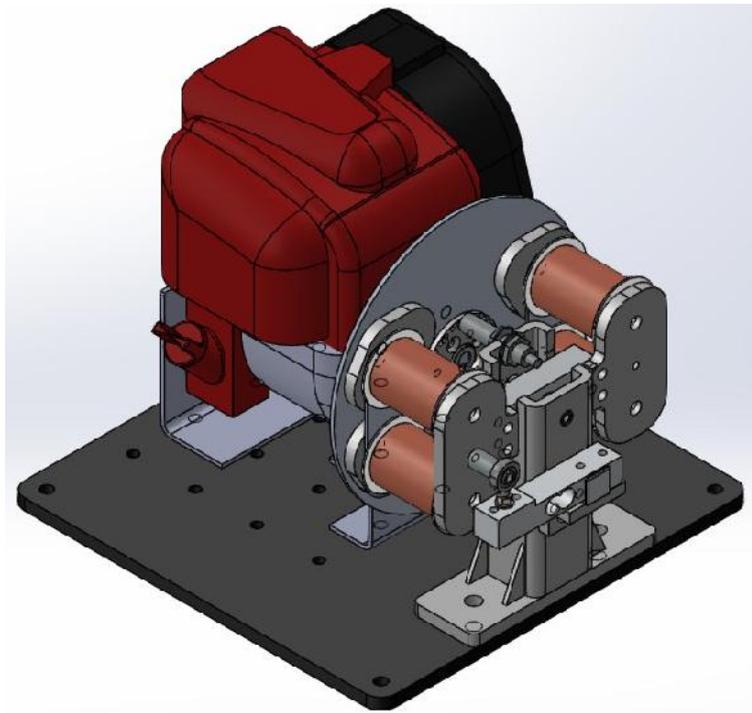


# FOCUS APPLIED TECHNOLOGIES DYNAMOMETER SYSTEM DESKTOP DYNO MODEL DTD1 CONTROLLER MODEL DC5

Manual Rev. 2-0816

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## 2kW EDDY CURRENT DYNAMOMETER WITH CONTROLLER



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*This product was developed in  
collaboration with the Malaysian Ministry  
of Science and Technology and Innovation*

# CONTENTS

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| <u>SECTION</u>                     | <u>PAGE</u> |
|------------------------------------|-------------|
| 1. Introduction                    | 2           |
| 2. Controller                      | 3           |
| 3. Dynamometer                     | 6           |
| 4. Internal Combustion Engine      | 8           |
| 5. AC Motor                        | 11          |
| 6. DC Motor                        | 13          |
| 7. Dynamometer Controller Features | 15          |
| 8. Control Modes                   | 18          |
| 9. Speed Calibration               | 25          |
| 10. Torque Calibration             | 28          |
| 11. PID Tuning Guide               | 30          |
| 12. Dyno Monitor Software Guide    | 32          |
| 13. Safety Precautions             | 43          |
| 14. Trouble Shooting Guide         | 45          |
| 15. External Wiring Diagram        | 49          |
| 16. Specifications                 | 51          |

# 1. INTRODUCTION

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In today's technological environment it is becoming more important for students to have a good grasp of fundamental engineering principals associated with powered machinery. The most valuable, and effective education comes from hand-on learning using real-world scenarios. To that end the Desk-Top Dynamometer was developed. The Desktop Dynamometer is an innovative educational system consisting of a dynamometer and controller, Alternating Current Motor (ACM), Direct Current Motor (DCM), and Internal Combustion Engine (ICE). The Desk-Top Dynamometer is provided with a number of easy to understand laboratory exercises, including procedure, discussion of the phenomenon being investigated, and question and answers, as well as teaching material for the various related classes.

This manual is intended for servicing and maintenance of the Desk-Top Dynamometer as a whole system. Each of the prime movers (AC Motor, DC Motor, or ICE) can be quickly changed out by unbolting them from the dynamometers base plate, and replacing them with a different unit. The only critical alignment consists of making sure the speed target wheel on the hub of the prime mover is close enough to the hall effect speed sensor to be reliably read.

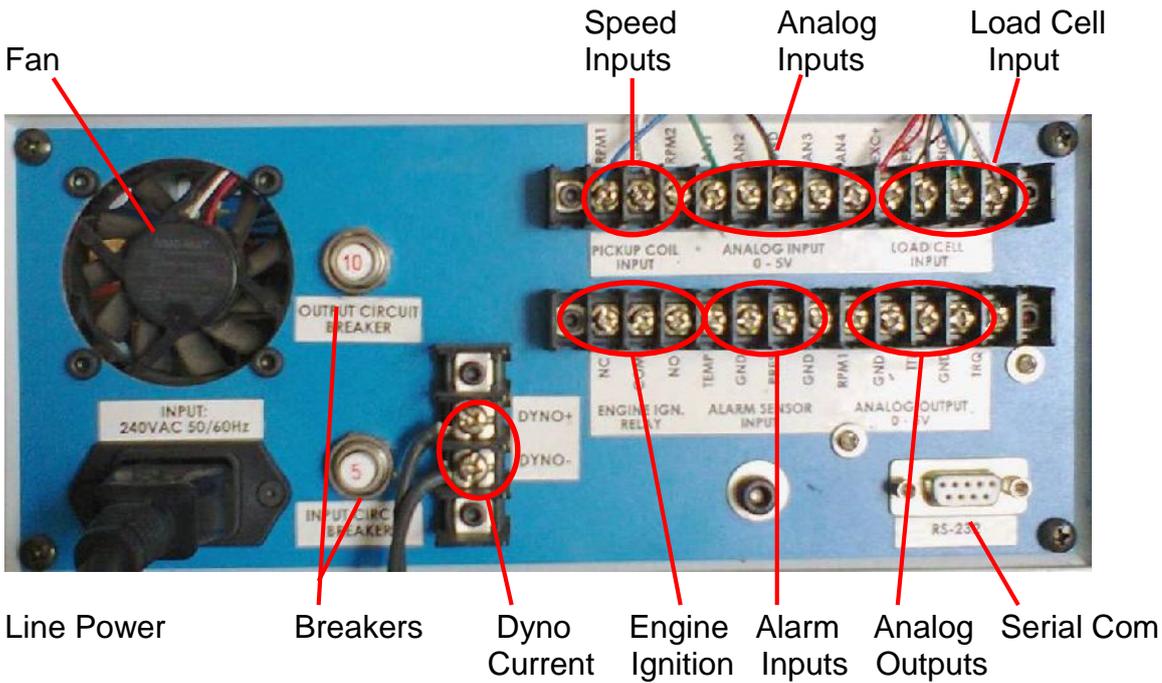
- The ICE engine is a 1kW Honda GX35 gasoline utility engine. Peak torque on this engine (at the output shaft) is approximately 2Nm at 4500 rpm, and peak power occurs at 9000rpm.
- The AC motor is a 375W AC induction motor with a peak mechanical power of approximately 550W, and a peak torque of 2Nm at 2500rpm.
- The DC motor is a 120W, 48V Permanent Magnet Direct Current (PMDC) Brush-type motor. It has a no-load speed of over 8000 rpm, and peak power of 160W at 4000 rpm.

# 2. CONTROLLER

## CONTROLLER FRONT VIEW



## CONTROLLER REAR VIEW



## 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 prime mover (AC Motor, DC Motor or ICE) is read from the Hall Effect sensor. The Speed Target Wheel at the hub of the prim mover, 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 dynamometer controls the load on the prime mover 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 heavy gage blue wires going to the dynamometer. In operation DYNO+ will always have 50V DC. As load is applied the DYNO- line will be pulled to ground, resulting in a current in the coils. The DYNO- line is Pulse Width Modulated (PWM) at 2kHz. At no-load it will have 50V DC, the same as the DYNO+ line, thus no current will flow. At 50% load it will have a 50% duty cycle (50V 250us, and 0V for 250us), allowing an average current of approximately 1.5amps to flow through the coils. At full load the DYNO- line is pulled to ground, resulting in 50V across the coils, for a current draw of about 3A.

As the Eddy Disk connected to the prime mover rotates in the magnetic field, eddy currents are induced in the Eddy 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 rotating Load Arm, the force on the coils is transmitted to the load cell retaining the load arm. This results in compression of 2 of the strain gages, and extension of the other 2 strain gages, yielding a small signal on the Signal+ and Signal- lines.

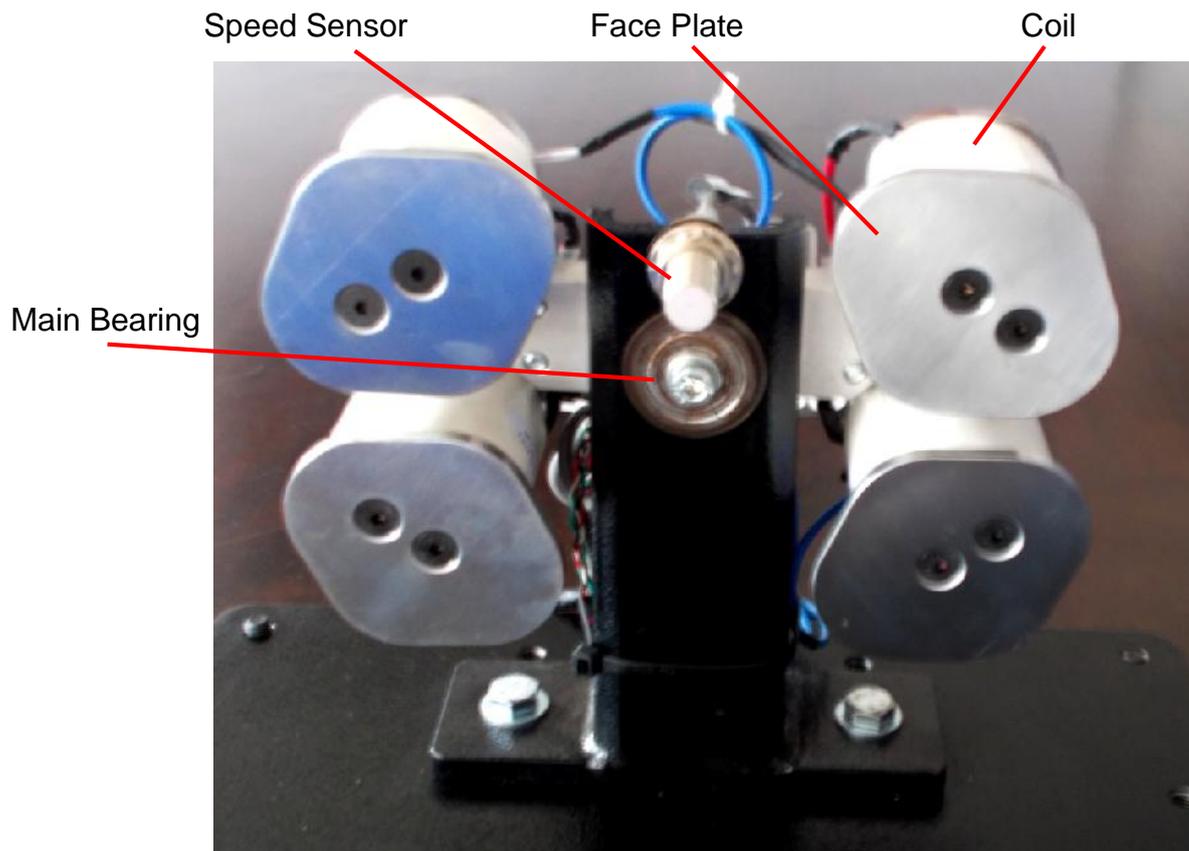
The speed, torque and Load are displayed on the screen on the front of the dynamometer, and sent via the serial communications link to a computer (optional) for display and recording.

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 engine or motors input 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.

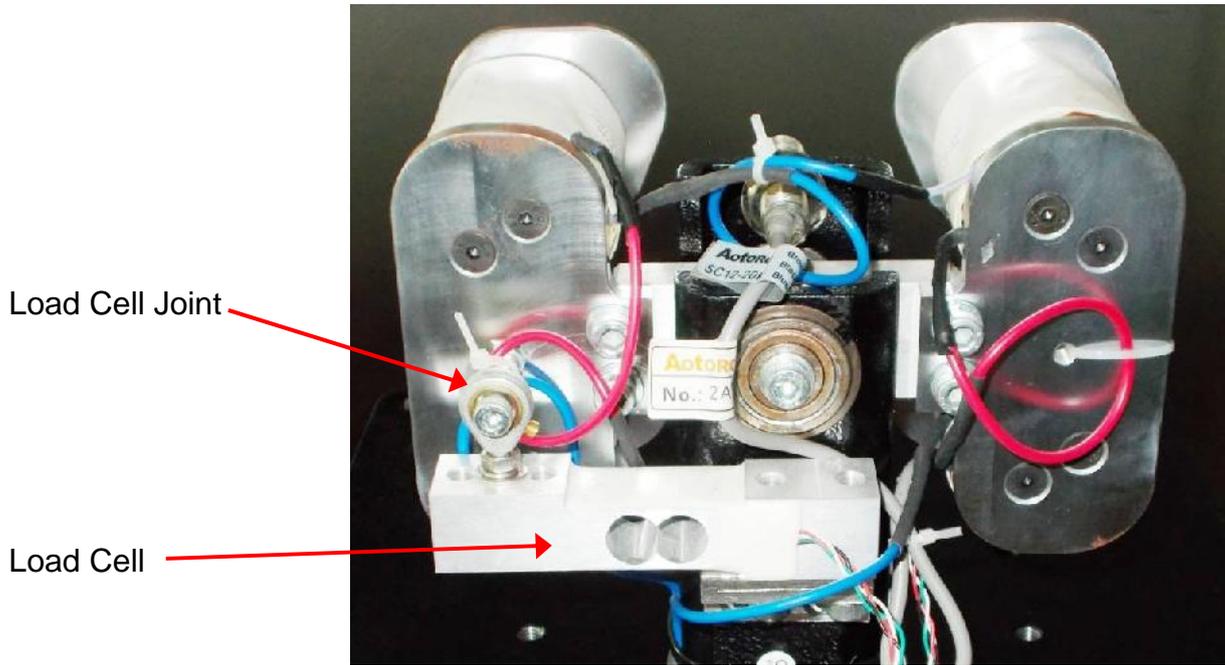
# 3. DYNAMOMETER

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## DYNAMOMETER FACE VIEW



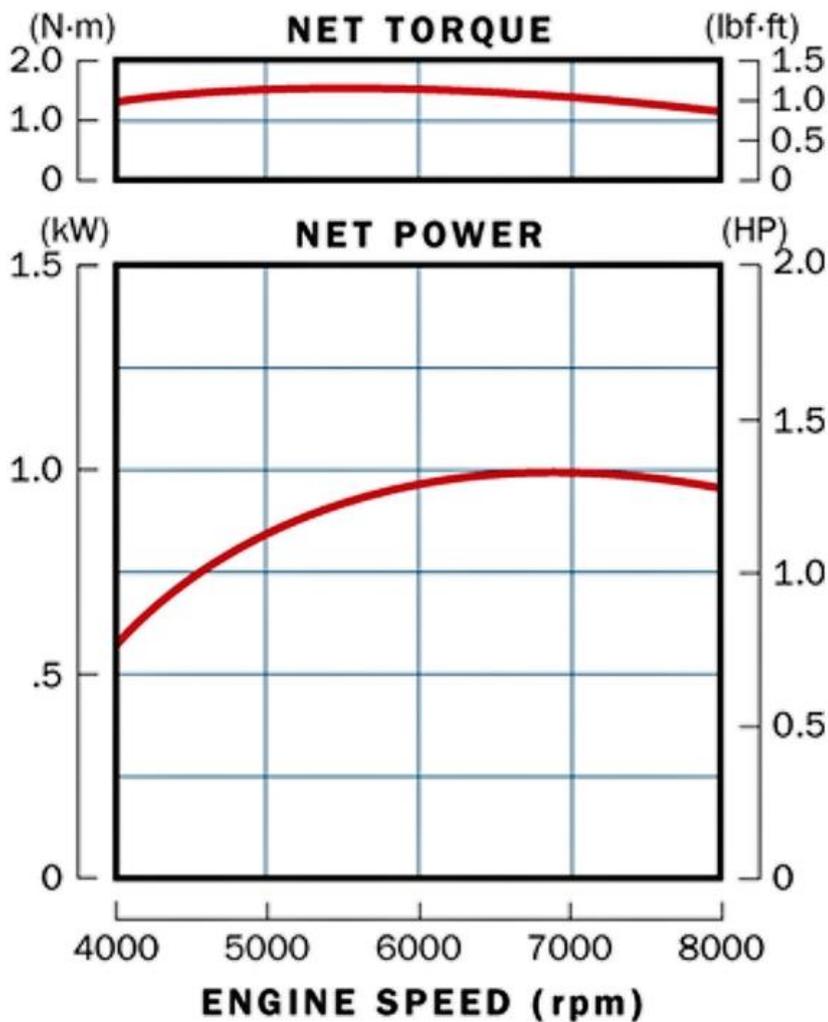
## DYNAMOMETER BACK VIEW



# 4. INTERNAL COMBUSTION ENGINE

This shows the Internal Combustion Engine (ICE) mounted on the Desk-Top Dyno





The standard GX50 has a peak torque of about 1.5N·m at 5500 rpm, and a peak power of 1kW at 7000 rpm.

### ENGINE STARTING

Before starting check and refill the fuel and oil if required. Also check the engine mounting bolts, and eddy disk clamp screws to insure they are tight. To start the engine, pump the fuel pump bulb located at the bottom of the carburetor 3 times, or until fuel smoothly flows through the carburetor. Lift the Choke control lever if starting a dead cold engine, and slightly open the throttle. Pull the pull starter handle in short, quick strokes 2 to 3 times. The engine should start easily. Once started, allow the engine to warm up for a minute, and move the choke lever to the lower position to prevent excessive fuel flow.

### ENGINE STOPPING

To stop the engine, return the throttle to the idle position, and hit the KILL button until the engine has stopped.

## **CONNECTIONS FOR USING FUEL SCALE**

There are 2 fuel lines entering the bottom of the carburetor: one with a black hose, and one with a clear hose. When using the Fuel Scale a fuel tank needs to be placed on the fuel scale, and fuel is then gravity fed into the carburetor via the black hose connection. The clear hose must be disconnected from the carburetor to avoid pumping fuel out of the engine mounted fuel tank. Make sure the fuel supply tank is at least 20cm above the engine, but not more than 1.2 meters. Also insure that the fuel supply is clean, and always use a fuel filter as small particles will clog the carburetor, and cause operational problems.

## **PERIODIC MAINTENANCE**

The engine should be checked and maintained every few months. Check the following:

Engine Oil Level. Change or refill with 10W30 motor oil as required.

Air Filter. In dusty conditions this will require occasional cleaning and re-oiling.

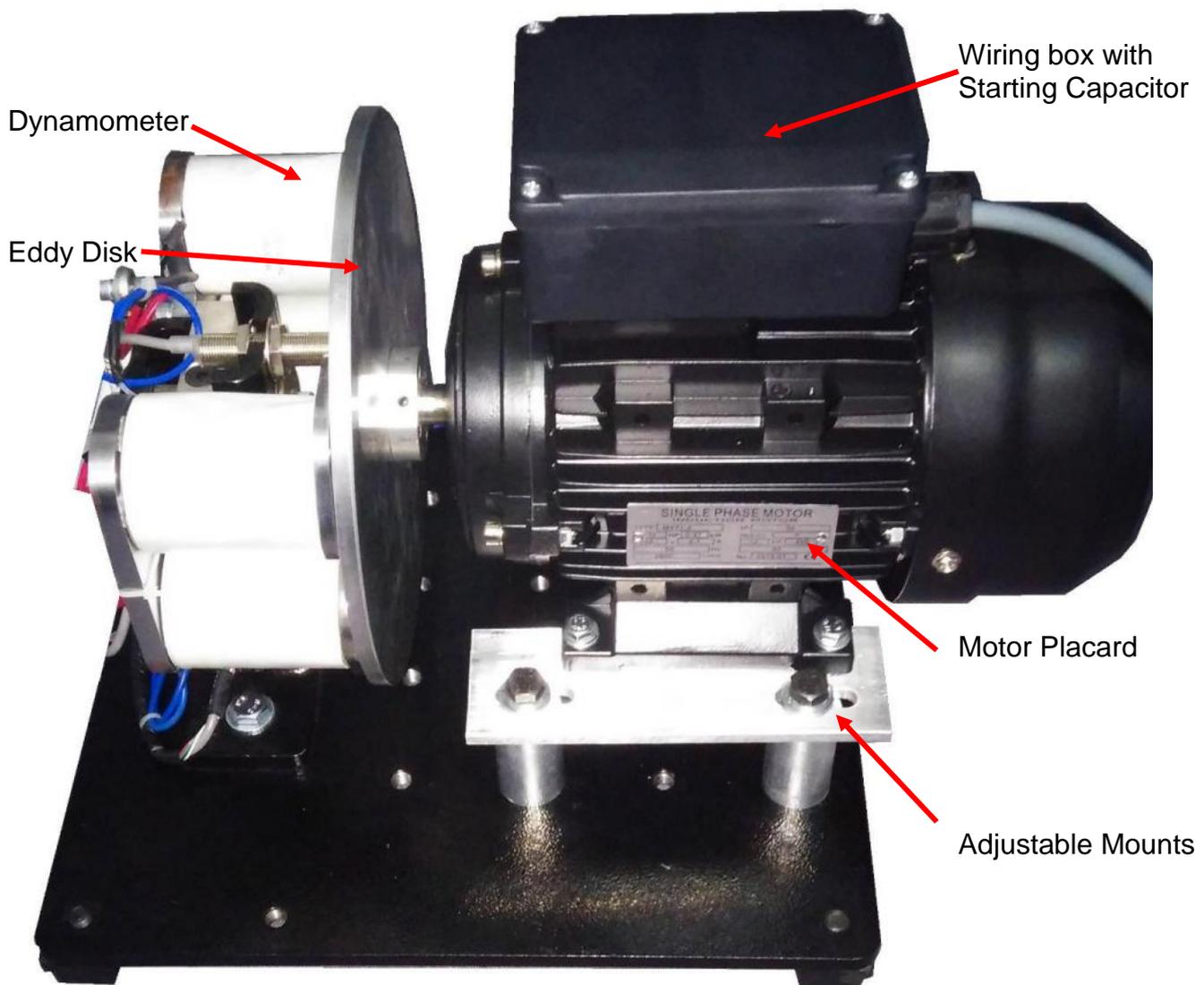
Check and tighten all mounting bolts as required.

# 5. AC MOTOR

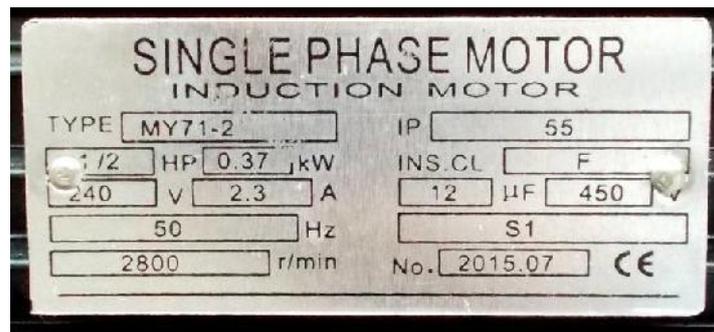
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## ALTERNATING CURRENT INDUCTION MOTOR

This shows the Alternating Current Induction Motor (ACM) mounted on the Desk-Top Dyno



Most large motors have a placard declaring their designated voltages, powers and speeds. These are often referred to when sizing, testing or maintaining motors. In some of the following laboratory exercises we will be investigating the actual specifications of the motor and comparing them to the placard.



This placard states that it is a ½ hp (nominal power rating), 370W 50Hz single phase AC induction motor designed to operate at 2800 rpm. Synchronous operation would be at 3000 rpm, so the unloaded speed will be near 3000 rpm. The current draw is listed as 2.3A at 240V. Electrical power is current times voltage:

$$P_e = V \times I$$

Where:

$P_e$  is the electrical power (W)

$V$  is the AC RMS Voltage (V)

$I$  is the AC RMS Current (A)

$$P_m = \text{torq} \times w$$

$P_m$  is the mechanical power (W)

torq is the torque of the motor (Nm)

$w$  is the rotational speed (rad/sec)

This gives an electrical power rating of 552W.

### CONNECTIONS FOR USING CURRENT CLAMP METER

The current clamp meter should be in AC mode, and clamped around only one of the wires in the wiring box. Be careful to avoid contact with any conductors inside the box as they may have lethal voltages.

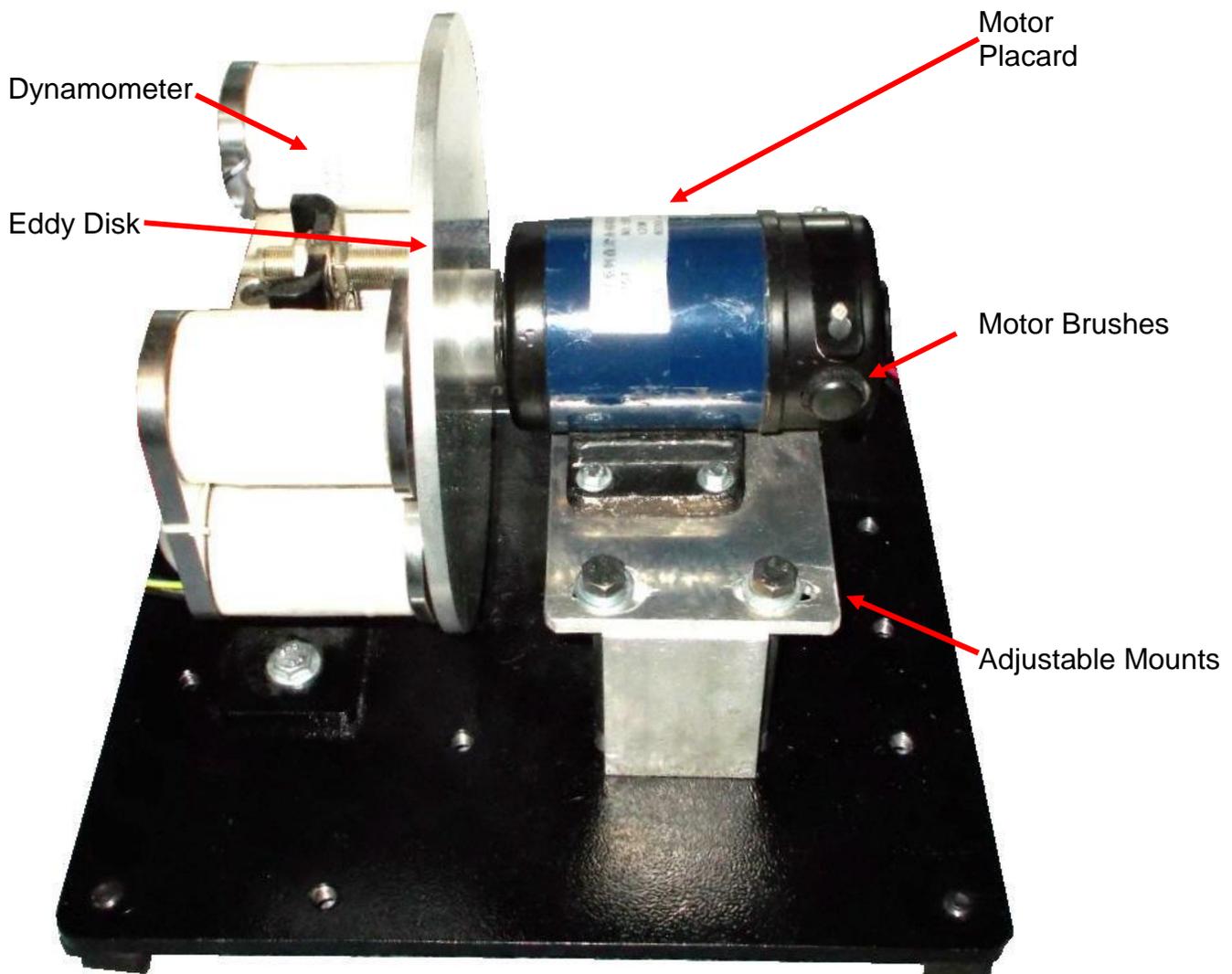
### PERIODIC MAINTENANCE

This induction motor is basically maintenance free, although the bearings may require lubrication or replacement at very long intervals.

# 6. DC MOTOR

## DIRECT CURRENT PERMANENT MAGNET MOTOR

This shows the Direct Current Motor (DCM) mounted on the Desk-Top Dyno



Most large motors have a placard declaring their designated voltages, powers and speeds. These are often referred to when sizing, testing or maintaining motors. In some of the following laboratory exercises we will be investigating the actual specifications of the motor and comparing them to the placard.



This placard states that it is a 120W (nominal power rating), 48V motor designed to operate at 6000 rpm. The current draw is listed as 3.8A at 48V. Electrical power is current times voltage:

$$P_e = V \times I$$

Where:

$P_e$  is the electrical power (W)

$V$  is the DC Voltage (V)

$I$  is the DC Current (A)

$$P_m = \text{torq} \times w$$

$P_m$  is the mechanical power (W)

torq is the torque of the motor (Nm)

$w$  is the rotational speed (rad/sec)

This gives an electrical power rating of 182W.

### CONNECTIONS FOR USING CURRENT CLAMP METER

The current clamp meter should be in DC mode, and clamped around only one of the wires going to the motor from the wiring box. Be careful to avoid contact with any conductors inside the box as they may have lethal voltages.

### PERIODIC MAINTENANCE

This DC motor will require replacement of the commutator brushes and may require occasional lubrication of the bearings.

# 7. DYNAMOMETER CONTROLLER FEATURES

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## Dynamometer

The dynamometer is an eddy current dynamometer especially designed for easy replacement of the prime mover, including an Internal Combustion Engine, AC or DC motor. Power from the engine or motor rotates the Eddy Disk in front of the dynamometers coils. The dynamometers axial magnetic field is controlled by the dynamometer current. More current gives a stronger stator magnetic field, inducing more eddy current in the rotating disk. The resulting magnetic field produced in the disk opposes the direction of motion, creating drag on the disk, and a torque on the dynamometer which is measured by a load cell. Power from the prime mover 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 is 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.  $5 \cdot 123 / 1023$ )

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 Ratio (AFR) when combined with an air flow sensor.

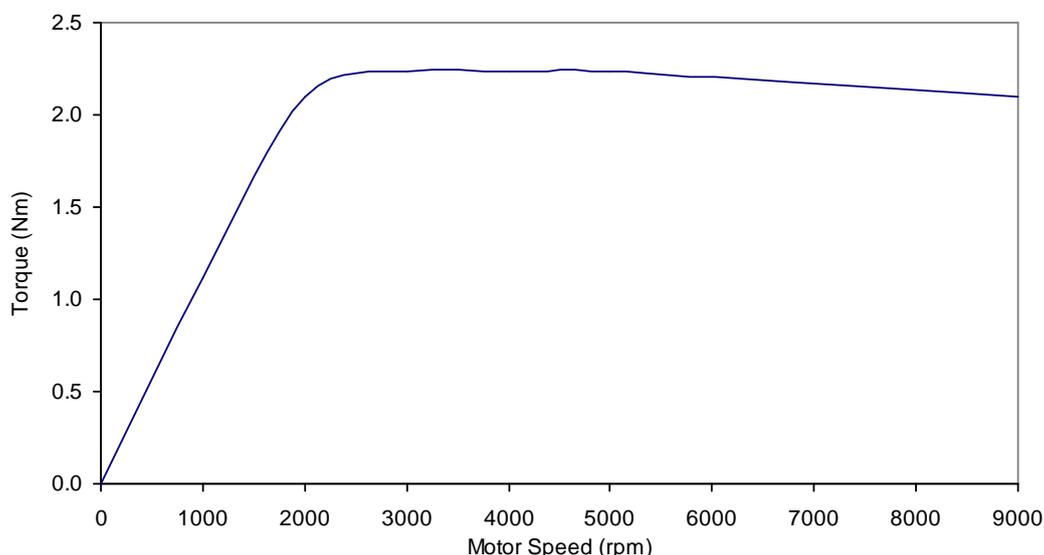
## Dynamometer Operating Range

The dynamometer is designed to operate at over 10,000 rpm, however the prime mover's speed should be limited to 10,000 rpm max. One advantage of having the prime mover drive the eddy disk directly, is that all dynamometer friction is eliminated. There is a slight "wind load" on the disk, and some bearing losses in the motor or engine, which can be compensated for using the following Torque Friction Correction equation (numbers used are for the AC Motor):

$$\text{Compensated Torque} = \text{Measured Torque} + (0.04 + \text{RPM} \times 2 \times 10^{-5})$$

For example, if you are measuring 1Nm of torque at 6000rpm, the compensated torque is about 1.16 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 datalogging file, along with the compensated torque (which includes friction and accelerational torque based on the declared inertia).

The maximum torque rating of the dynamometer is approximately 2Nm. This gives a maximum mechanical power of approximately 2kW at 10,000rpm.



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.

# 8. CONTROL MODES

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## Modes of Control

This dynamometer controller allows the user to control the dynamometer in several different modes: Manual, Speed, Torque, Road (RPM<sup>2</sup>) 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 is 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.

## 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. When operating loads requiring more power, it will be necessary to provide an external power switching device (ie. transistor), which may be triggered from the controller's dynamometer output by running it through an appropriate voltage divider.

## **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 every 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 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 | i | m | t         | : | > | 0 | 5 | 0 | 0 | 0 |
| o     | v | e | r | t | r           | q | l | i | 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 | ? |  |  |  |  |
|       |  |  |   |   |             |   |   |   |   |           |   |   |   |  |  |  |  |

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 |   |   |           |   |   |   |  |   |   |   |
| 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 |   |   |   |   |  |  |  |
|-------|---|---|---|---|-------------|---|---|---|---|-----------|---|---|---|---|--|--|--|
| 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 |   |   |           |   |   |   |  |   |   |   |
| 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 |

| 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: Accelerational Drag

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

$$\text{Load\%} = Kf + 100 \times (\text{RPM}/Ka)^2 + Km \times (\text{RPM}')^2$$

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 and Km 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.

Next set the Aerodynamic Resistance (Ka) to get the appropriate throttle setting at the “high speed” cruise speed.

Finally increase the Accelerational Drag (Km) to get the appropriate zero to 60kph 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):** As the name implies, this mode is not made available to customers.

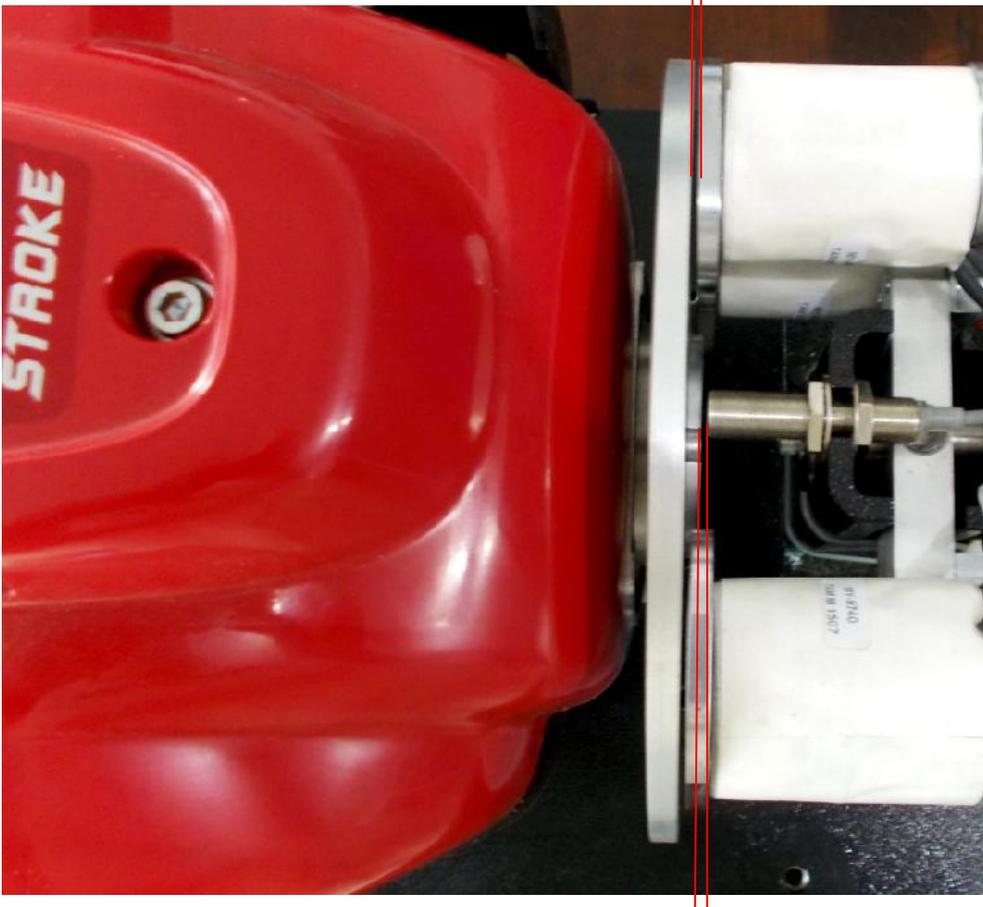
# 9. SPEED CALIBRATION

## 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 4 teeth and is mounted on the Dynamometer (as shown below), thus the controller should be set up for **4 pulses per revolution (PPR)** to give the appropriate disk 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 it is important that the speed pickup be clean, and in close proximity to the disk clamp target wheel. The gap between the speed pickup tip and the target wheel should be approximately 2mm. The acceptable range is 1mm to 3mm. Additionally the Eddy Disk should be close to the Dynamometers Face Plates to insure good flux transfer. The recommended gap is 3mm.

**Disk Gap: 3 to 4mm**



**Speed Sensor Gap:**

**1mm to 3mm**

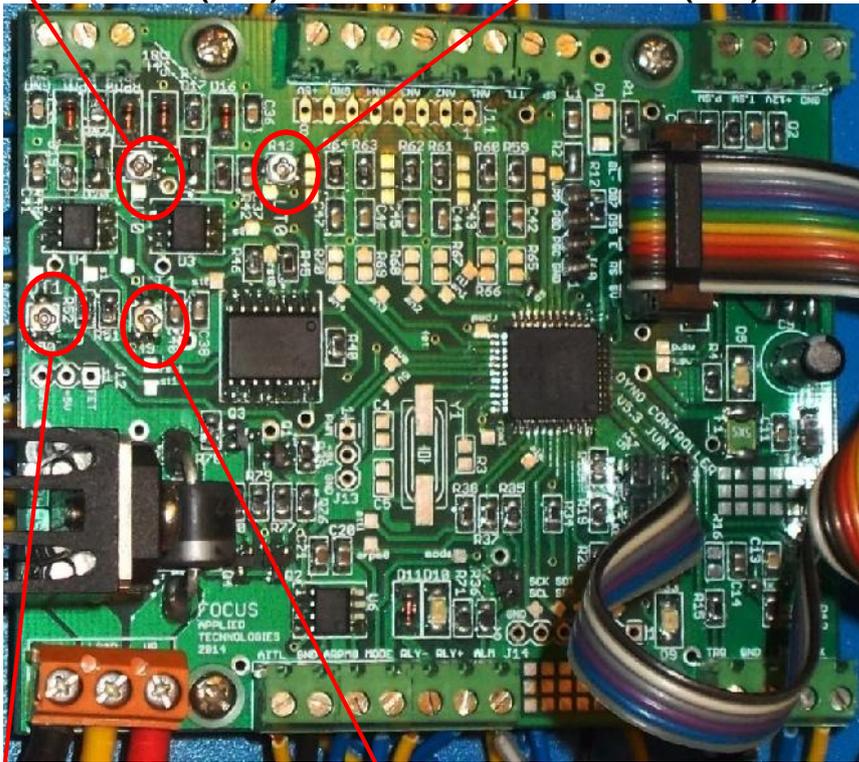
First adjust the Disk to Face Plate gap by loosening the Engine Mounting Block bolts, and moving the engine to give an even gap distance right and left. If the gap is not consistent top to bottom the engine may be shimmed by inserting a thin metal shim below the mounting blocks as required. Once the disk has a uniform gap of approximately 3mm, tighten the engine mounting bolts down and confirm the proper gap.

Finally, 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.

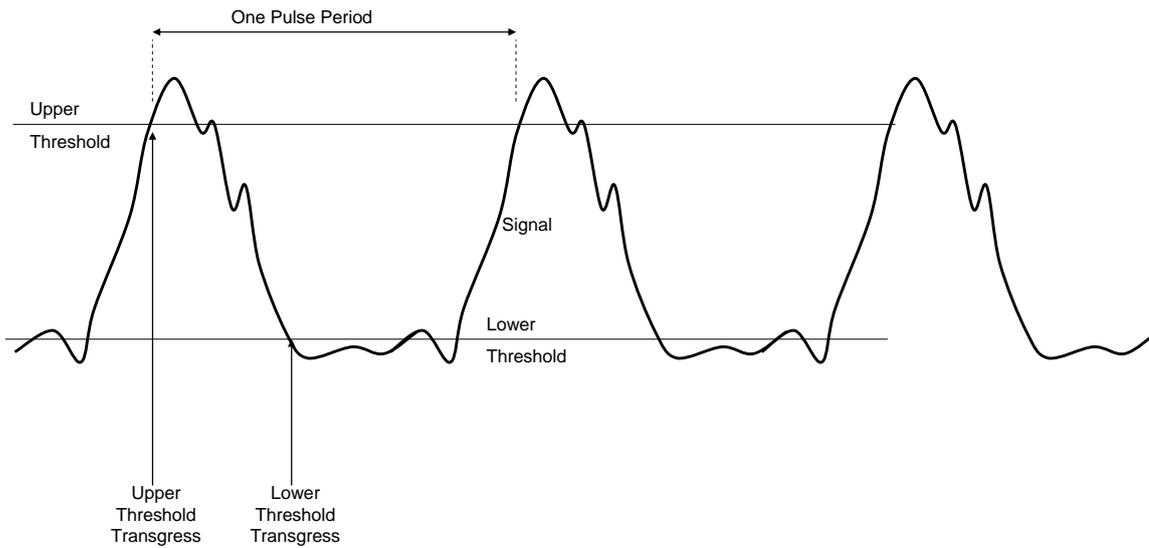
*NOTE: The Lower Threshold voltage MUST be LESS than the Upper Threshold voltage to insure proper triggering of the circuit.*

**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.



# 10. TORQUE CALIBRATION

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A calibration weight with a small aligning pin is provided with the dynamometer. This needs to be placed in the calibration weight mounting hole as shown below to calibrate the system. First remove the back cover if present, exposing the load cell and coils. Power on the dynamometer controller. Load the dynamometer by pushing down lightly on the load cell, and release. Zero the torque reading by hitting the **TARE** button. A standard 1kg weight is supplied with a mass of 1kg. There is a mounting hole on the top of the load arm above the load cell at a radius of 0.065m from the center of rotation of the load arm. The torque resulting from a mass M is:

$$\text{Torque} = 1 \times 9.81 \times 0.065$$

Where:            M is the weight of the mass in kg  
                      9.81 is standard gravitational acceleration  
                      0.065 is the radius of the weights in meters

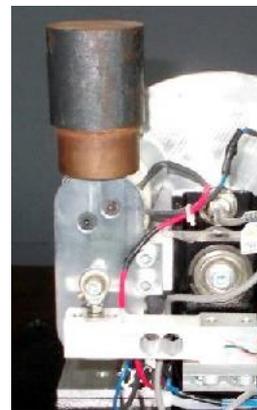
For the 1 kg mass this should give a reading of **0.638Nm**. If the front panel torque reading is different from this amount, then the calibration factor must be adjusted. To do this put the mode selector switch in TORQUE mode and go to the front panel menu by hitting the right arrow, and adjust the 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.



Calibration Weight



Cal Weight Mounting Hole



Mounted Cal Weight

## Torque Amplifier Board

In some cases, it may be necessary to adjust the Torque 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.



# 11. PID TUNING GUIDE

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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 ( $K_i$  and  $K_d$ ) gains to zero.

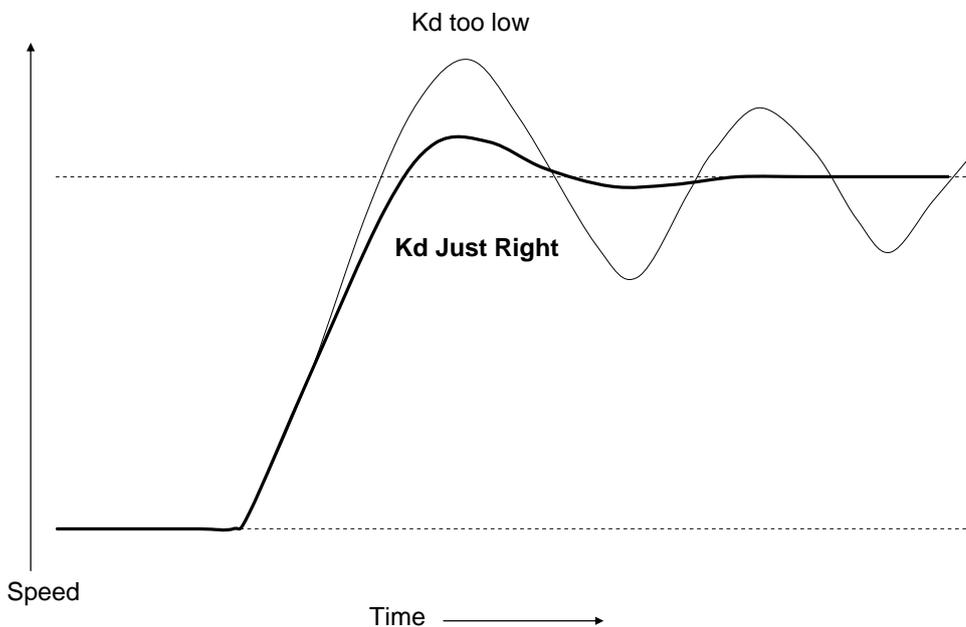
Start with the Proportional gain ( $K_p$ ) at some nominal value, for example 20.

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.

Increase 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 overshoot. 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 overshoot the set point (eg. the engine may operate at up to 4000 rpm before settling close to 3500rpm). Increase the differential gain ( $K_d$ ) until this overshoot is minimized. You may not want to completely eliminate overshoot, but  $K_d$  should be increased until the system does not oscillate more than one full cycle before stabilizing (ie. overshoots 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 ( $K_i$ ) slowly, until the steady state error is reduced to an acceptable level. You should wait for say 30 seconds after each increment of  $K_i$  to make sure the system has time to stabilize with the new gain.

### Final Checking

Once you have established a reasonable value for  $K_p$ ,  $K_i$  and  $K_d$ , 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  $K_i$ ,  $K_p$ , and perhaps increasing  $K_d$  (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

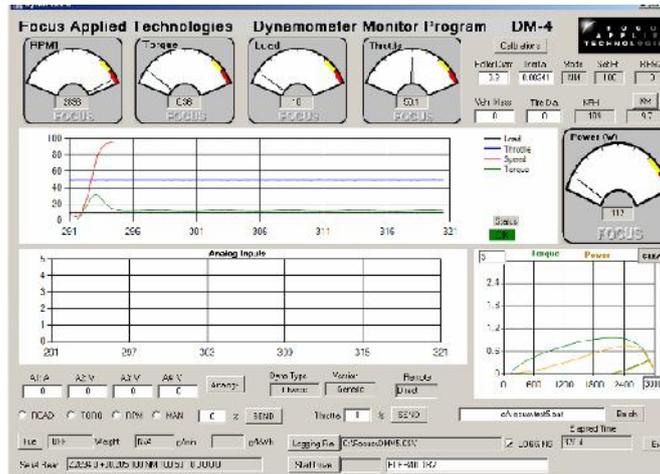
For additional help in tuning PID systems you can refer to the following on-line resources:

[http://en.wikipedia.org/wiki/PID\\_controller](http://en.wikipedia.org/wiki/PID_controller)

[http://www.eq.ufrj.br/links/h2cin/eqe768/AULA\\_3/Melhor%20Sintonia.pdf](http://www.eq.ufrj.br/links/h2cin/eqe768/AULA_3/Melhor%20Sintonia.pdf)

# 12. DYNO MONITOR SOFTWARE GUIDE

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.

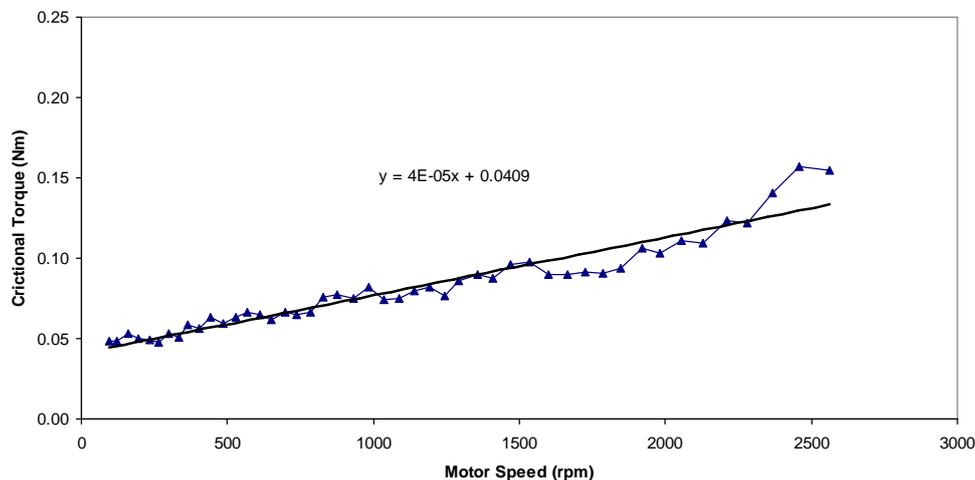
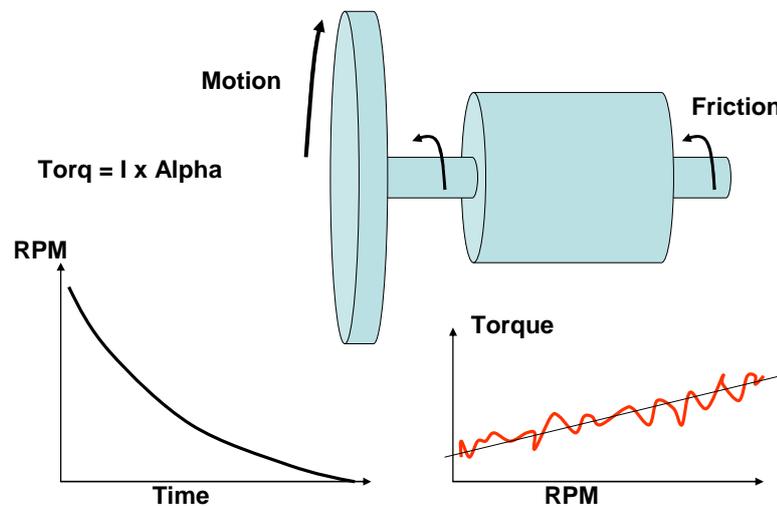
To begin with the Dyno Monitor software should be “unzipped” and loaded into the **C:\Program Files\Focus** folder. If an older version exists, it should be Uninstalled first (From START menu, go to Control Panel, and then Add or Remove Programs, Click “DynoMonVx” and Uninstall).

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:



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:

$$\text{Torque} = \text{Frictional Offset} + \text{Frictional Factor} \times \text{RPM} + \text{Inertia} \times \text{Acceleration (rad/s/s)}$$

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.

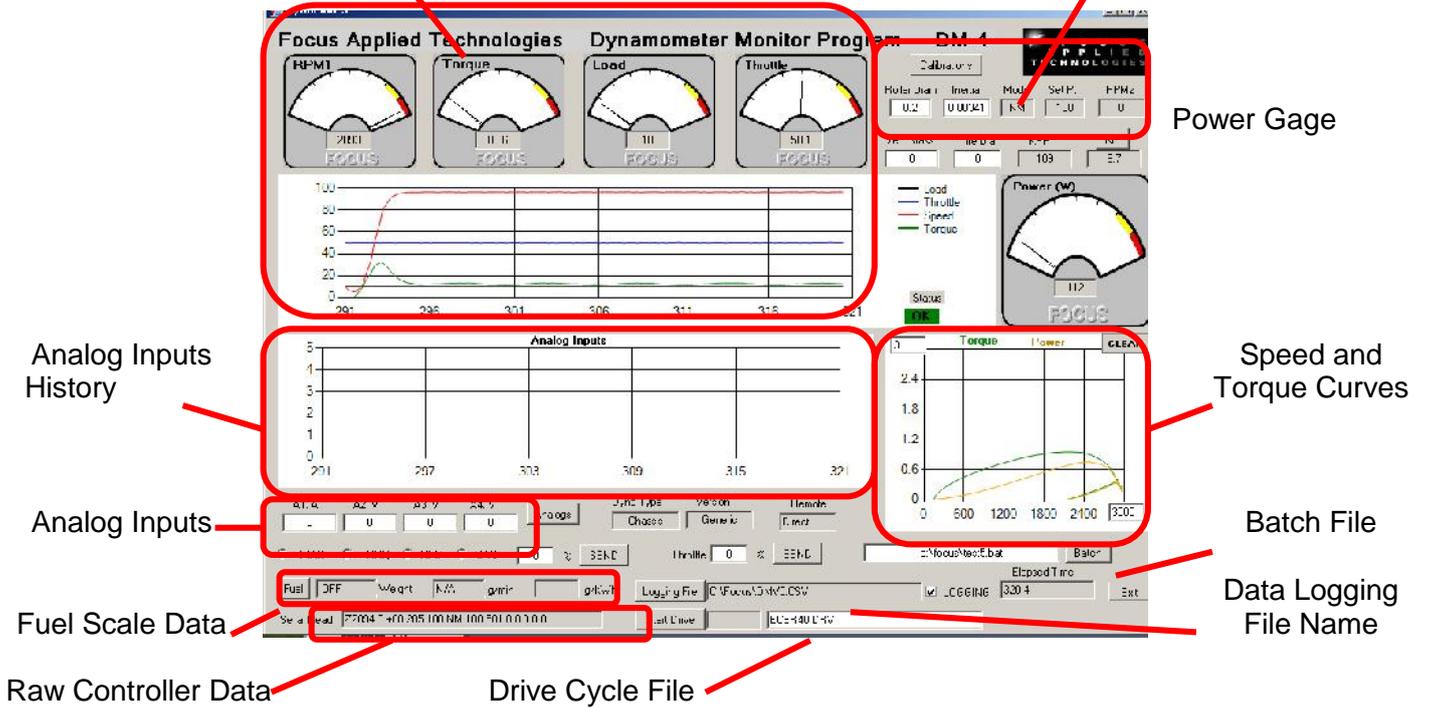
The next 4 factors (labeled A, V, V, V in this cal file) are the labels and factors of the Analog Channels 1, 2, 3 and 4 respectively, and the following 4 are the analog channels offsets. The Analog Inputs are 0-5V, and converted to Volts in the software. In this example we have a wide-band exhaust gas 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.

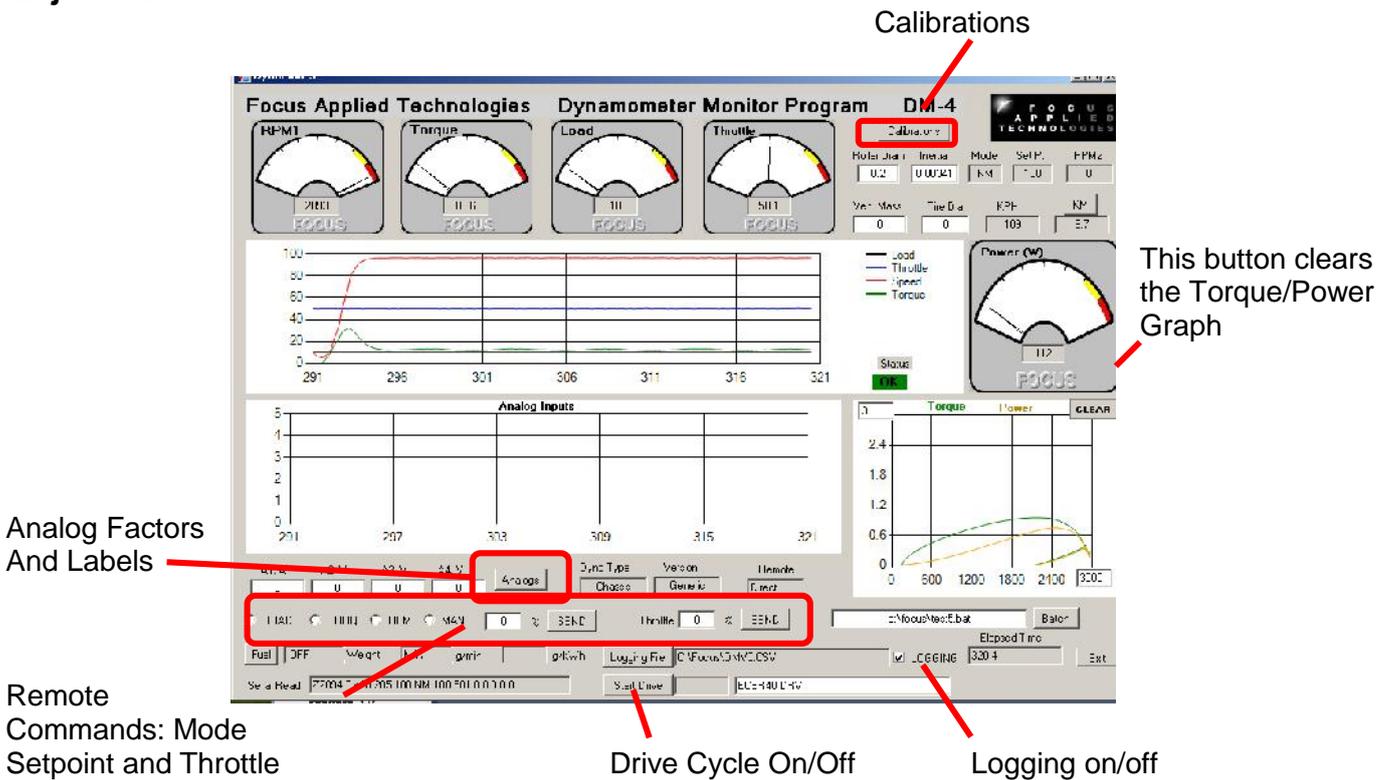
## Major Display Areas

Speed, Torque, Load and Throttle Gages and History

Various Calibrations and Auxiliary Factors

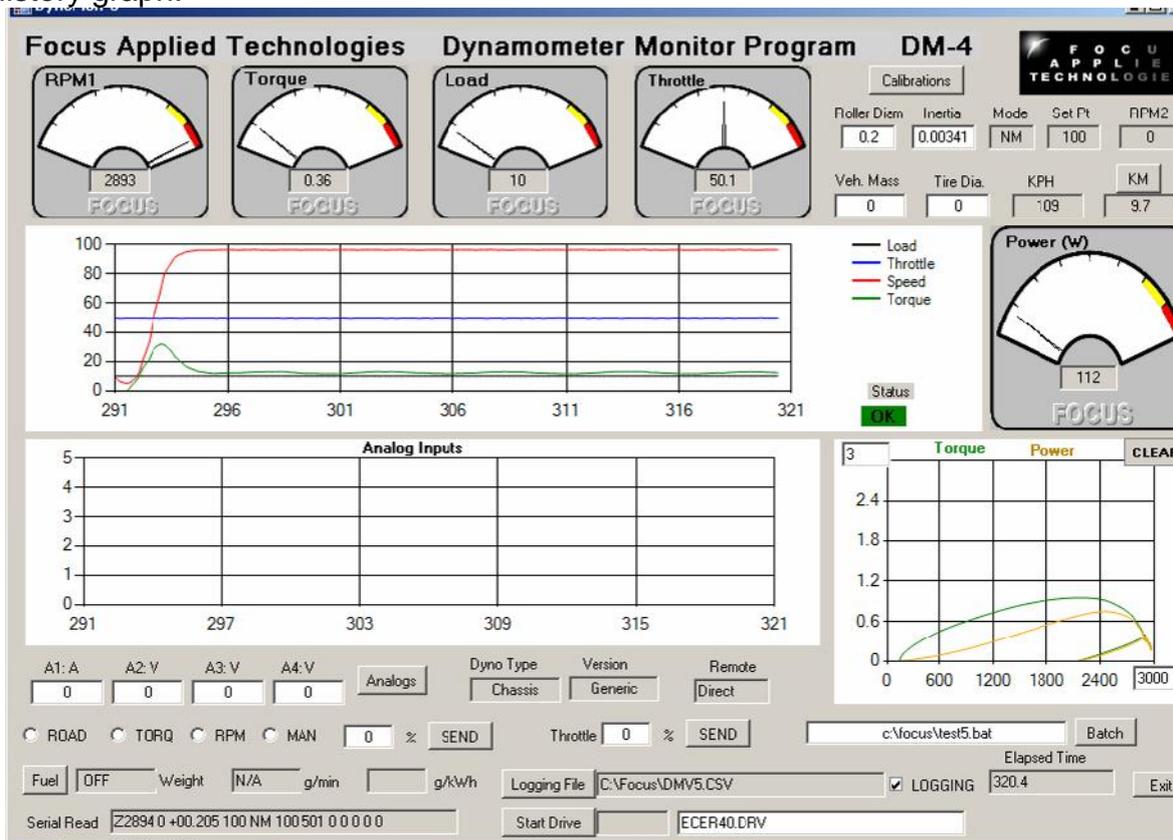


## Major Controls



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 shown 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 2<sup>nd</sup> speed input (RPM2) is also displayed, along with the speed (in km/hour) and an Odometer, which is resettable. 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 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.

## Analog Labels and Factors

The Analog labels and Factors can be entered in the dialog box opened by hitting the “Analog” button (lower left). Hit the button again to close.

|                | Units | Units/V | Offset Units |
|----------------|-------|---------|--------------|
| Analog Input 1 | &FR   | 3       | 8.5          |
| Analog Input 2 | V     | 1       | 0            |
| Analog Input 3 | V     | 1       | 0            |
| Analog Input 4 | V     | 1       | 0            |

Value = Volts \* Units/V + Offset

Change labels and calibration factor of the analog input channels.  
Hit the "Analog" Button again to accept the new values.

## 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 1<sup>st</sup> “hump” of the ECE-R40 drive cycle pattern.

| T      | V    |             |
|--------|------|-------------|
|        |      | 25.50, 10.5 |
| 0.50,  | 0.0  | 26.00, 9.0  |
| 1.00,  | 0.0  | 26.50, 7.5  |
| 1.50,  | 0.0  | 27.00, 6.0  |
| 2.00,  | 0.0  | 27.50, 4.5  |
| 2.50,  | 0.0  | 28.00, 3.0  |
| 3.00,  | 0.0  | 28.50, 1.5  |
| 3.50,  | 0.0  | 29.00,      |
| 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 |             |

## 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<sup>2</sup>, 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   | 888   | 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.

## 13. SAFETY PRECAUTIONS

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The Focus Applied Technologies Desk-Top Dynamometer is designed to be an inherently safe machine via the use of heavy duty mountings and base plate, disk guard, 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, disk and wires in good condition.
- Always make sure the test engine or motor is firmly secured to the dynamometer.
- NEVER TOUCH on a moving disk!
- Avoid loose items including cloths, cables, belts and loose small items which might fall into the gap between the disk and the dynamometer.
- 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.

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 as 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 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!**

## **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.

## 14. TROUBLE SHOOTING GUIDE

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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.

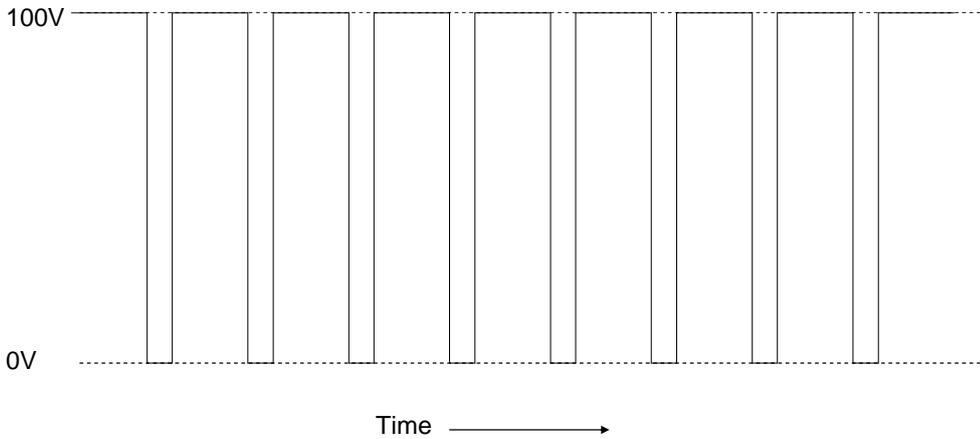
### **DYNAMOMETER POWER TEST**

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**

### Voltage of Dyno – (with reference to ground)



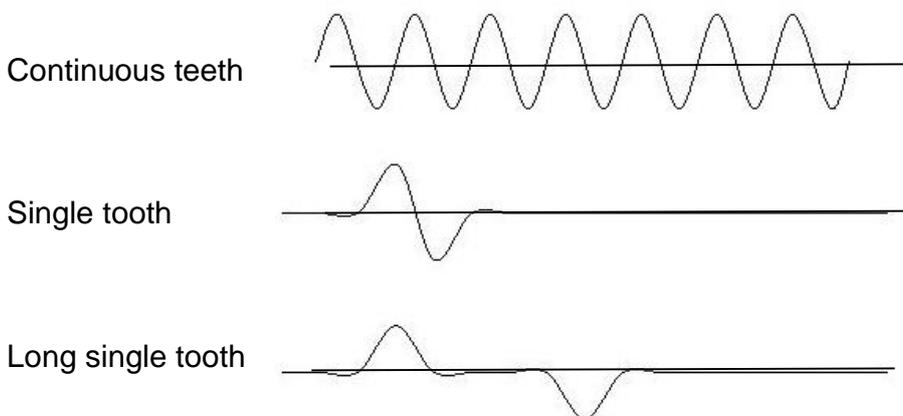
If you get this DC voltage, then the power supply, power switching transistor and controller are all working properly. If you do not, try resetting the circuit breakers, checking wire connections and trying again.

### SPEED SIGNAL TEST

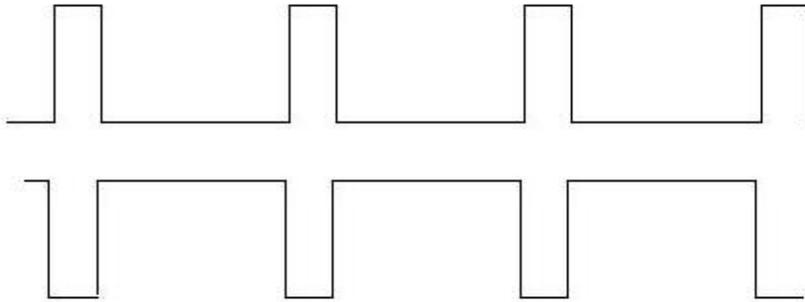
The speed signal must have sufficient amplitude to trigger the speed sensing circuitry. Typically, this will require a zero-to-peak amplitude of at least 0.5V, and a lower voltage of  $<0.1V$ . For accurate speed measurements, the signal should not have any noise exceeding this threshold. With the dynamometer 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, then 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



### Hall Effect type Speed Signal



Normal

---

Inverted

---

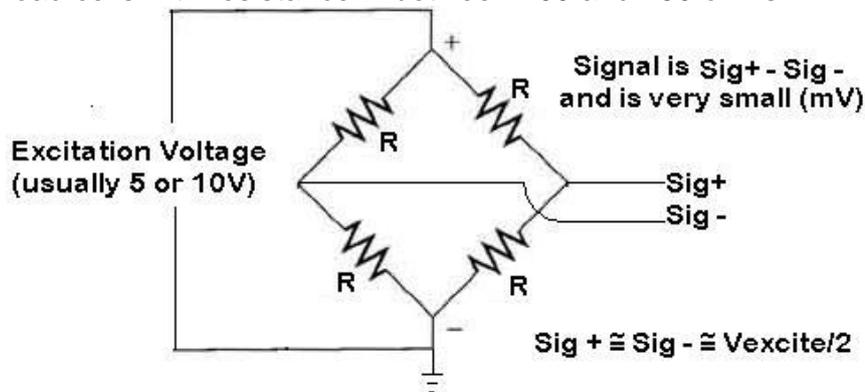
*NOTE: Some Hall type sensors may not go all the way to 0 volts. This may require raising the Upper Threshold (UT) and Lower Threshold (LT) levels to properly read. Make sure that UT voltage is greater than the LT voltage.*

### 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  $\frac{1}{2}$  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

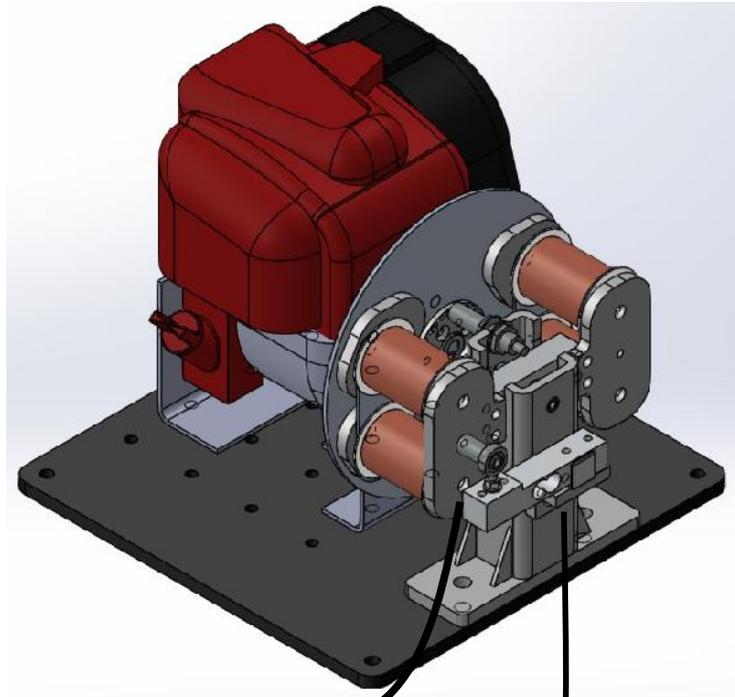
Any one of these faults may lead to signal drift, noise, no signal or signal pegged high or low. If your system is exhibiting these faults, you should check the resistance of between the leads and compare them to the table below.

## LOAD CELL RESISTANCE MEASUREMENTS

| <u>Leads</u>                    | <u>Resistance</u> |
|---------------------------------|-------------------|
| 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.

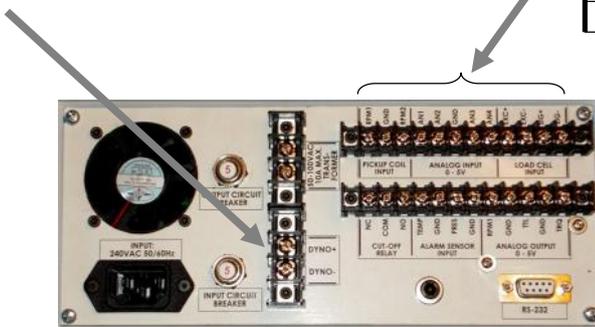
# 15. EXTERNAL WIRING DIAGRAM



Brown: Dyno +  
Green: Dyno -

Yellow: RPM1  
Grey: GND  
Brown: Excite +

Red: Excite +  
Black: Excite -  
White: Sig +  
Green: Sig -



Back side of Dyno Controller

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

The Dynamometer +/- power lines are connected to heavy (10A capable) wires on the power cable. 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 prime mover (AC Motor, DC Motor or ICE) is read from the Hall Effect sensor. The Speed Target Wheel at the hub of the prim mover, 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).

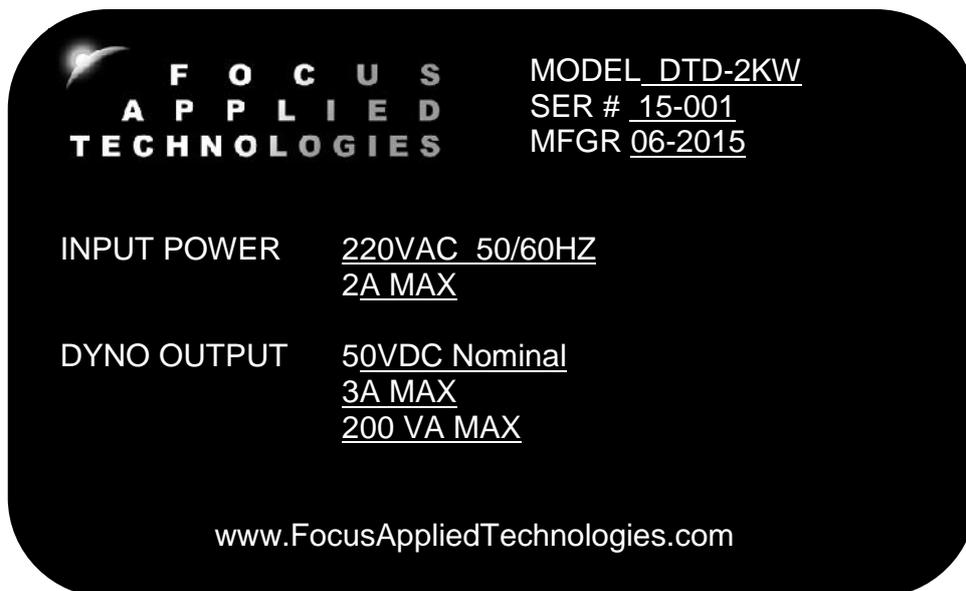
Serial port communications are via RS232: 9600 baud, No parity, 1 Stop bit. The cable should be a "straight through" cable connecting pins 2, 3, and 5 at both ends. The data from the controller will be decimal coded ACSII number for the speed, torque and other data separated by a space and terminated 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.



## **CONTACT INFORMATION**

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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 user's 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.



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

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Email:        [Sales@FocusAppliedTechnologies.com](mailto:Sales@FocusAppliedTechnologies.com)

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                  Sungai Jawi 14200  
                  PENANG, MALAYSIA