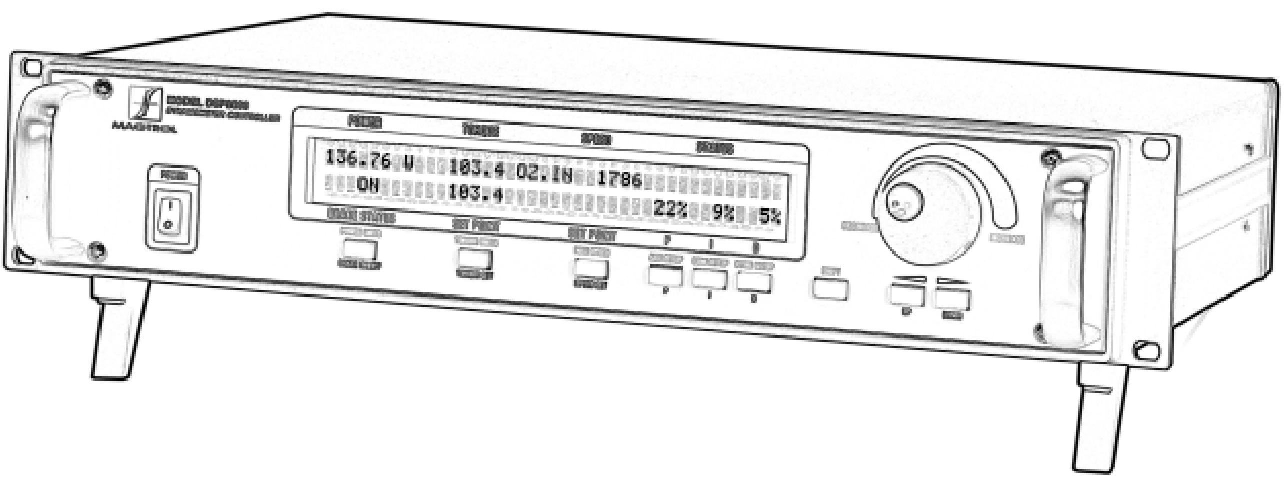
MAGTROL

Model DSP6000

High Speed Programmable Dynamometer Controller



User's Manual

MAGTROL, INC.

Sales and Technical Assistance

70 Gardenville Parkway
Buffalo, New York 14224 USA

Tel: (716) 668-5555 or 1-800-828-7844
Fax: (716) 668-8705

www.magtrol.com

Manufacturers of:

Motor Test Equipment
◆
Hysteresis Brakes and Clutches

74M041 062200

Safety Notes

WARNING

1. Make sure that all Magtrol dynamometers and electronic products are earth-grounded, to ensure personal safety and proper operation.

2. Check line voltage before operating the DSP6000.

3. Make sure that dynamometers and motors under test are equipped with appropriate safety guards.

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Table of Contents

1 - Introduction

ABOUT THIS MANUAL

This manual contains information about the DSP6000 Dynamometer Controller and procedures for optimal use. To obtain the best results from your unit, please follow the procedures for operation.

SHIPPING

Your DSP6000 was packaged carefully for shipping. Please notify your carrier and Magtrol Customer Service if you believe your unit was damaged in shipping.

UNPACKING YOUR DSP6000

1. Save all shipping cartons and packaging material until you inspect the DSP6000.
2. Inspect the DSP6000 for any evidence of damage in shipping.
3. Make sure the carton contains the following:
   - DSP6000 Dynamometer Controller
   - Line cord
   - User's Manual for the DSP6000
   - Calibration certificate

ABOUT THE MODEL DSP6000 DYNAMOMETER CONTROLLER

Magtrol's Model DSP6000 Dynamometer Controller provides superior motor testing capabilities by using state-of-the-art digital signal processing technology. The DSP6000 both controls the dynamometer and provides digital readouts on the front panel. The DSP6000 is designed to work with all Magtrol load cell dynamometers, including the following dynamometer models:

HD-100	HD-510	HD-800	ED-715
HD-106	HD-700	HD-805	ED-815
HD-400	HD-705	HD-810	HTD-100
HD-500	HD-710	HD-815	HTD-200
HD-505	HD-715	HD-825	HTD-300

FEATURES

Fast, full curve data acquisition
Free-run to locked rotor in seconds.

High-speed data acquisition
120 torque and speed points per second via IEEE (GPIB) bus.

Speed and torque operating modes
Each mode provides independent PID settings for improved dynamometer control.

Programmable digital PID values
Controlled and stored either with Magtrol M-Test software or manually.

Single point or programmed load control
Single or multi-point torque and speed stabilized testing using Magtrol M-Test software.

Two standard computer interfaces
RS-232 and IEEE-488.

Additional analog input
Accepts any ± 5 VDC transducer.

Vacuum fluorescent display
Displays torque, speed, power, auxiliary input and PID values.

Many torque measurement options
Includes English, metric, and SI torque readings as standard.

Closed box calibration of torque and auxiliary input
Eliminates need to open box for adjustments.

The DSP6000 is designed to work with any personal computer using an IEEE-488 or an RS-232 interface, or as a stand-alone unit. In a computer-controlled environment, the DSP6000 provides the following motor testing capabilities:

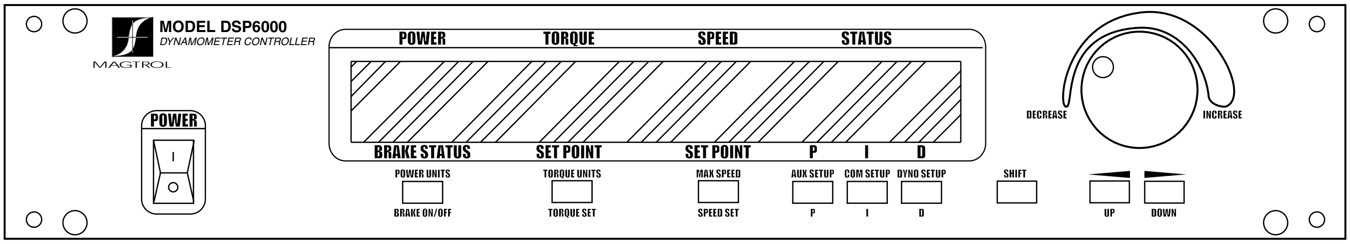
- Proportional (P), plus Integral (I), plus Derivative (D) closed loop control (PID loop).
- Torque (Q) and Speed (N) data acquisition at a rate of up to 120 readings per second.
- Automatic progressive loading in either decreasing or increasing speed mode.
- Ability to remove the Effects of Inertia from dynamically obtained data. (See Appendix B)
- Complete curve capability for most motor types, including single/poly phase induction, AC/DC series, PMDC, brushless DC, air and internal combustion (if suitably coupled).

Specifications

Dimensions	19" W x 13.8" D x 3.5" H
Weight	16.5 lb
Operating Temperature	18°C to 25°C
Relative Humidity	< 80%
Accuracy	Speed: 0.01% of reading from 10 RPM to 100,000 RPM Torque: 0.2% of range (± 2 V) Aux: 0.1% of range (± 5 V)
Temperature Coefficient	0.001% of range/°C
Aux. Input	± 5 VDC
Ctrl Out	0-3 VDC
Accessory Torque/Speed Output	Torque: ± 2 VDC Speed: 60 TTL pulses/rev, 50% duty cycle
Fuses (5 x 20mm)	Brake: 1.25A UL/CSA 250V SB 1A IEC 250V T Power (120V): 800mA UL/CSA 250V SB Power (240V): 315mA IEC 250V T
Power Requirements	75 VA
Voltage Requirements	120/240V 60/50 Hz
Maximum Speed	99,999 RPM
Maximum Torque	2000 units
Maximum Compliance Voltage	45 VDC

FRONT PANEL

Figure 1. Front Panel



The front panel provides a power switch, eight control buttons, a Decrease/Increase Dial, and Vacuum Fluorescent Display (VFD). The front panel controls and buttons, from left to right, are:

- Power switch
- Six double-function control buttons:

Primary Function	Secondary Function
BRAKE ON/OFF	POWER UNITS
TORQUE SET	TORQUE UNITS
SPEED SET	MAX SPEED
P	AUX SETUP
I	COM SETUP
D	DYNO SETUP

- Three single-function control buttons:
  - SHIFT (to enable secondary functions printed in blue above control buttons)
  - Up/Left arrow ◄ (scroll up, increase magnitude)
  - Down/Right arrow ► (scroll down, decrease magnitude)
- Decrease/Increase Dial

NOTE: Refer to the table, "Front Panel Controls and Buttons" later in this chapter for further explanation of button features and use.

Enabling Secondary Functions

To enable the secondary function of the double-function control buttons:

1. Press the blue SHIFT button and release it. (The word SHIFT appears in the display.)
2. Press a control button to enable the function shown in blue letters above the control button:

   POWER UNITS, TORQUE UNITS, AUX SETUP, COM SETUP or DYNO SETUP.
3. Press the SHIFT button again to exit the secondary function.

Front Panel Controls and Buttons

Controls/Single Function Buttons	Double-Function Buttons	To Use	Function
POWER		Press I to turn power ON Press O to turn power OFF.	Turns power ON or OFF.
	POWER UNITS	Press SHIFT and release; then press this button.	Sets power display to Watts.
	BRAKE ON/OFF	Press this button.	Toggles brake OFF or ON.
	TORQUE UNITS	Press SHIFT and release; then press this button.	Sets desired unit of measure. Press UP ◀ or DOWN ▶ button to see options. Press SHIFT to enable option.
	TORQUE SET	Press this button.	Shows setpoint for torque loading
		Press and hold this button until second beep.	Shows setpoint for open loop loading.
	MAX SPEED	Press SHIFT and release; then press this button.	Sets the speed range of the controller.
	SPEED SET	Press this button.	Shows setpoint for speed loading.
	AUX SETUP	Press SHIFT and release; then press this button.	Turns auxiliary display ON or OFF. Sets scaling of auxiliary input device.
	P	Press this button.	Adjusts proportional gain.
	COM SETUP	Press SHIFT and release; then press this button.	Adjusts GPIB primary address and RS-232 baud rate. Also adjusts display contrast.
	I	Press this button.	Adjusts integral.
	DYNO SETUP	Press SHIFT and release; then press this button.	Selects input torque units and speed encoder.
	D	Press this button.	Adjusts derivative.
SHIFT		Press this button and release, then press desired control button.	Actuates the function written in blue above control button.
UP/LEFT ◀		Press.	Increases magnitude of change when adjusting a numerical value (speed, torque or max. speed).
DOWN/RIGHT ▶		Press.	Decreases magnitude of change when adjusting a numerical value (speed, torque or max. speed).
DECREASE /INCREASE DIAL		Turn clockwise or counterclockwise.	Decreases or increases the parameter selected.

VACUUM FLUORESCENT DISPLAY (VFD)

The VFD provides information about the control functions, the motor under test, and an auxiliary input device (if connected). The displays, from left to right, are:

Top Row	Bottom Row
POWER (expressed in Hp or Watts)	BRAKE STATUS (ON or OFF)
TORQUE	SETPOINT (TORQUE)
SPEED	SETPOINT (SPEED)
AUX INPUT or STATUS DISPLAY	P
	I
	D

The DSP6000 is shipped with the Contrast setting at zero (lowest) in order to prolong display life. If it is necessary to increase the contrast for improved readability, use the lowest possible setting to achieve that result. Using a setting higher than necessary may cause display segments to burn-in over a period of time, resulting in uneven illumination from segment to segment.

STATUS DISPLAY MESSAGES

Message	Meaning
SHIFT	Shift buton was pressed.
AUX	Auxiliary unit is attached and enabled.
MAX SPEED	Maximum motor RPM.
I/O ERROR	Incorrect command was sent from computer.
UNITS	Torque unit of measurement.
FAST ACQ	Acquiring data in high-speed mode.
REMOTE	Remote control via PC enabled.
RAMP DOWN	Decrease motor speed by increasing load on motor.
RAMP UP	Increase motor speed by decreasing load on motor.

DISPLAYING DESIRED INFORMATION

Local control:

1. Press SHIFT and release; then press POWER UNITS to see UNITS displayed.
2. Press UP ◄ or DOWN ► to scroll through available choices.
3. Press SHIFT to exit.
4. Press SHIFT and release; then press TORQUE UNITS to see UNITS displayed.
5. Press UP ◄ or DOWN ► to scroll through options for units.
6. Press SHIFT to exit.
7. Press RECALL to view memory contents; last in = first out.
8. Press SHIFT to exit.

Remote control:

Refer to “DSP6000 Command Set” in *Chapter 4 - The DSP6000 with a PC* for a list of commands recognized by the DSP6000.

Auxiliary Input:

1. Press SHIFT and release; then press AUX SETUP.
2. Rotate Decrease/Increase Dial to select scale.
3. Press SHIFT to exit.

REAR PANEL

The rear panel provides connectors and receptacles for connecting to appropriate equipment.

Figure 2. Rear Panel

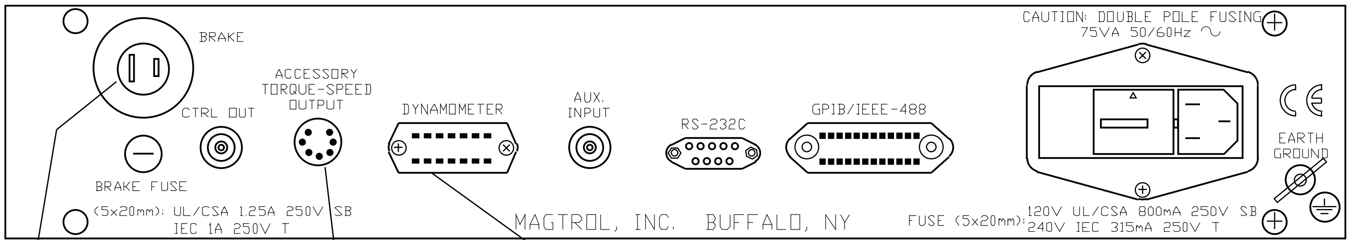


Figure 3. Brake Connector

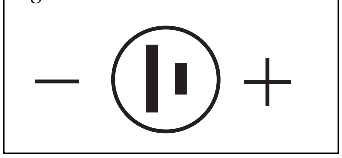


Figure 4. Accessory Torque/Speed Output

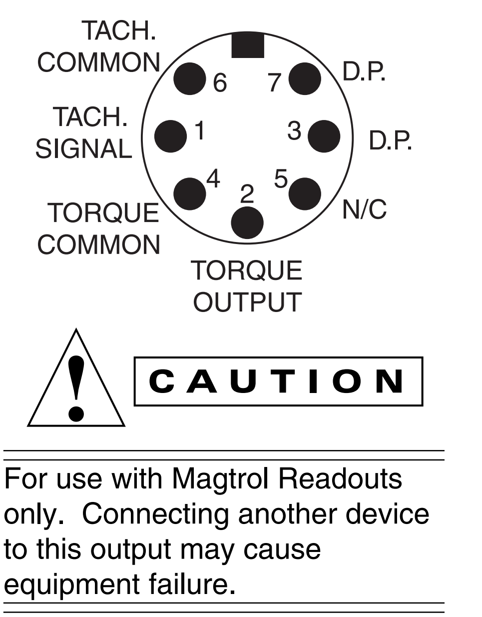
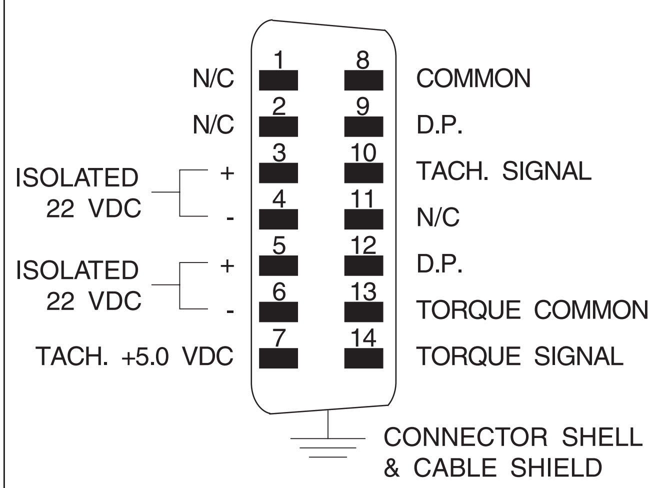


Figure 5. Dynamometer Connector



Rear Panel Functions

The rear panel, from left to right, provides the following functions:

Label	Function
BRAKE	Connect dynamometer brake cable here
BRAKE FUSE	Contains brake fuse (5 x 20mm) UL/CSA 1.25A 250V SB IEC 1A 250V T
CTRL OUT	Connect to Model 5241 Power Amplifier when using HD-825 Dynamometer
ACCESSORY TORQUE-SPEED OUTPUT	Connect accessory output cable here (optional). **CAUTION** For use with Magtrol Readouts only. Connecting another device to this output may cause equipment failure.
DYNAMOMETER	Connect dynamometer signal cable here
AUX INPUT	Connect auxiliary instrument cable here
RS-232C	Use this socket for RS-232 connector cable
GPIB/IEEE-488	Use this socket for GPIB cable (meets IEEE-488 specifications)
POWER	Attach power cord here
EARTH GROUND	Attach earth ground here

2 - About the PID Loop

The DSP6000 has PID adjustment capability for both the speed and torque modes to provide you with the best system response. The PID Loop comprises the following three variables:

P	=	Proportional Gain
I	=	Integral
D	=	Derivative

The setpoint is the desired load or speed. Error is the difference between the setpoint and the actual measurement.

P (PROPORTIONAL GAIN)

With proportional gain, the controller output is proportional to the error or to a change in measurement. Deviation from the setpoint is usually present. Increasing proportional gain will make the PID loop unstable. Increasing integral value eliminates this instability. For best loop control, set the proportional gain as high as possible without causing the loop to become unstable.

I (INTEGRAL)

With integral, the controller output is proportional to the amount of time the error is present. Increasing the integral value eliminates the offset from the setpoint. If the response becomes oscillatory, increase the derivative value.

D (DERIVATIVE)

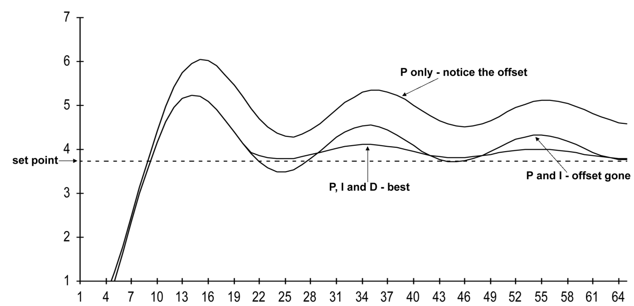
With derivative, the controller output is proportional to the rate of change of the measurement or error. Derivative can compensate for a changing measurement. Derivative takes action to inhibit more rapid changes of the measurement than proportional gain.

When a setpoint change occurs, the derivative causes the controller gain to go the "wrong" way when the measurement gets close to the setpoint. Derivative can be used to control overshoot. If derivative is used, higher gain and integral values are usually necessary.

Magtrol offers a comprehensive motor-test program which would satisfy most of your needs. Call Magtrol Sales at 1-800-828-7844 or 1-716-668-5555 to request your custom software.

NOTE: To set PID values, see *Chapter 3 - Installation*.

Figure 6. PID Loop



SETTING THE CORRECT PID'S FOR YOUR MOTOR

NOTE: Each type of motor may have it's own optimum PID setting.

NOTE: The PID settings are scaled to the maximum speed setting; therefore the maximum speed setting should be adjusted to just higher than the free-run speed of the motor being tested.

When testing a new motor where the optimal PID's are unknown:

1. Begin with the Proportional Gain (P) and the Integral (I) both set to a low value and the Derivative (D) set to zero. This will allow the best opportunity for finding the optimum in the lowest amount of steps.
2. Using the DSP6000 in the speed mode: Set the speed target at approximately 90% of the free-run speed.

3. Turn the brake to the ON position and observe how the actual speed moves toward the target speed.
4. If the speed moves slowly or not at all, increase the P until the target speed is achieved.
5. Turn the brake OFF.
6. Turn the brake ON and note how fast the free-run speed changes to the target speed.
7. If the speed conversion does not happen quickly, increase the I value.
8. Repeat steps 4-7 until the motor moves from the free-run to the target speed as quickly as possible without excessive overshoot.

Example:

Motor type:	AC
Free-Run speed:	1750

1. Set maximum speed to 1800
2. Set P = 5 I =5 D = 0
3. Set target speed to 1600
4. Turn brake ON—no response
5. Move P value to 10—still slow, not reaching 1600

Note: Increasing the P more will not increase the operating characteristics without first increasing the I value.

6. Turn brake OFF
7. Move I value to 10
8. Turn brake ON—Reaching 1600 very slowly
9. With the brake OFF, adjust the P to 15
10. Turn the brake ON—never reaching 1600
11. Turn the brake OFF. Decrease the P to 10 and increase the I to 15
12. Turn the brake ON—reaches 1600 Faster
13. Turn the brake OFF. Increase I to 20
14. Turn the brake ON—reaches 1600 Faster
15. Turn the brake OFF. Increase I to 25
16. Turn the brake ON—reaches 1600 Faster
17. Turn the brake OFF. Repeat

The larger the I value the faster the DSP6000 will move to the target number, but an I value too large will cause instability (oscillation). Once the optimum values are found, these steps should be repeated at different percentages of speed to ensure that they are the best combination for the entire speed range.

NOTE: The PID values for a speed stabilized test and a ramp test will vary. Therefore, PID adjustments may be needed when changing from a stabilized test to ramp testing with the same motor.

The D value has little or no effect on this type of testing, therefore the D value can remain at zero.

3 - Installation

Before installing your DSP6000, you should become familiar with the front and rear panels, as outlined in *Chapter 1-Introduction*.

WARNING

Make sure the DSP6000 is earth grounded before starting!

SETTING UNIT FOR LINE VOLTAGE

The DSP6000 will operate with either of the following power sources:

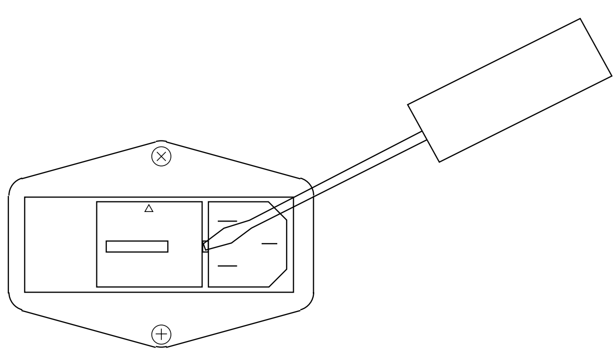
- 120V 50/60 Hz
- 240V 50/60 Hz

1. Find the line cord receptacle on rear panel. The line cord is a detachable NEMA Standard 3 wire.
2. Make sure the selector matches the power source (numbers should match the line voltage).

   If not:

   - Locate the power entry module.
   - Remove the line cord.
   - Insert a screwdriver into the slot and open the cover.
   - Slide the voltage selector so the desired line voltage appears in the window.
   - Install the appropriate fuses for that voltage.

Figure 7. Cover for Voltage Selector, Fuses



CHECKING YOUR DSP6000

CAUTION

Do not overload or stall the motor. Prolonged overload can cause the motor to overheat.

NOTE: To ensure that the DSP6000 is operational, a Magtrol Dynamometer with a test motor installed must be connected to the DSP6000. It is not required that the DSP6000 be connected to a computer.

1. Connect the DSP6000 to the dynamometer using the following cables:
   - 14-pin signal cable
   - 2-pin brake power cable
2. Turn on DSP6000 power.

   Desired results:

   - The display panel will show all segments of the VFD (series of rectangles), indicating that the DSP6000 is executing a self-test routine.
   - Message "MAGTROL MODEL DSP6000" appears.
   - Next screen “INPUT UNITS/ENCODER” appears.

   NOTE: The dynamometer torque units and the speed encoder can be selected now, or after the normal display panel appears.

   - Normal display panel appears.
3. Press P button and set to 20% with Decrease/ Increase Dial.
4. Press I button and set to 30% with Decrease/Increase Dial.
5. Press TORQUE SET button.
6. Adjust torque value so that it equals zero.

7. Start the test motor.
8. Allow the motor speed to stabilize at its no-load speed for a few seconds.
9. Press the BRAKE ON/OFF button to ON.
10. Press the TORQUE SET button.
11. Turn the Decrease/Increase Dial clockwise.

    Desired results:

    - The torque reading will increase.

      As brake power is applied, load is applied to the motor. The applied torque increases as the Decrease/Increase Dial is turned clockwise. For most motors, loading is indicated by motor speed reduction.
12. Reduce the torque load to zero by turning the Decrease/Increase Dial counterclockwise.

    Desired results:

    - The torque reading will decrease.
13. Press the BRAKE ON/OFF Button to OFF.
14. Use the SHIFT button to enable the MAX SPEED function.
15. Turn the Decrease/Increase Dial clockwise until the MAX speed reading is slightly greater than the motor's free-run speed.
16. Press the SPEED SET button - Turn the DECREASE/INCREASE DIAL until speed setpoint no longer increases (max. speed setting).
17. Press P button and set to 10%.
18. Press I button and set to 15%.
19. Press the BRAKE ON/OFF button ON.
20. Press the SPEED SET button.
21. Turn the Decrease/Increase Dial counterclockwise.

    Desired results:

    - The motor speed will decrease.

    NOTE: Adjust the motor's stability by adjusting the PID values. See *Chapter 2 - About the PID Loop*.
22. Turn off power to the test motor.

    NOTE: If the desired results did not occur, please see *Chapter 7 - Troubleshooting*.

NOTE: Although the DSP6000 can be used without a computer, it will only perform at a fraction of its capability.

SETTING DESIRED OPERATING PARAMETERS

NOTE: See *Appendix C: Front Panel/ Display Menu Flow Charts*.

Set Display to Desired Power Units (Watts or Hp)

1. Press and release SHIFT.
2. Press POWER UNITS.

Set Display to Desired Torque Units

1. Press and release SHIFT.
2. Press TORQUE UNITS.
3. Continue pressing TORQUE UNITS until the desired unit of measure is displayed.
4. Press SHIFT to exit.

Set Up Display for Dynamometer

1. Press and release SHIFT.
2. Press DYNO SETUP.
3. Press TORQUE UNITS until input unit matches dynamometer.
4. Press ENCODER until selection matches encoder installed on dynamometer (60 bit = standard).
5. Press SHIFT to exit.

Set Up Communications with PC

(If necessary)

1. Press and release SHIFT.
2. Then press COM SETUP.
3. Select GPIB ADDRESS. Press GPIB ADDRS until appropriate address appears. (See "Changing the GPIB Primary Address" in *Chapter 5 - The DSP6000 with a PC (Remote Control.)*
4. Select baud rate. Press RS-232 BAUD until appropriate baud rate appears.
5. Press SHIFT to exit.

Set Up Auxiliary Input

(If necessary)

See "Displaying Desired Information" in *Chapter 1 - Introduction*.

Set Torque Control

NOTE: See *Chapter 2 - About the PID Loop*.

1. Press the TORQUE SET button.
2. Use the UP ◀ and DOWN ▶ buttons and the Decrease/Increase Dial to adjust the setpoint to zero.
3. Press the P button.
4. Use the Decrease/Increase Dial to preset an initial value of 20.
5. Press the I button.
6. Use the Decrease/Increase Dial to preset an initial value of 30.
7. Press the D button.
8. Use the Decrease/Increase Dial to preset an initial value of 0.
9. Use the BRAKE ON/OFF button to turn the brake ON.
10. Start your motor under test.
11. Press the TORQUE SET button and adjust the setpoint to the desired load.
12. Check the torque display to make sure that the dynamometer loads the motor under test to that torque load.

NOTE: If the response is too slow or oscillatory, adjust the values for P, I, and D.

Desired results:

- The dynamometer should load the motor under test to the load point quickly with little or no overshoot when the BRAKE function cycles ON or OFF.

CAUTION

Do not exceed the capabilities of the dynamometer or the power source in use.

Motors draw very large currents when held at locked rotor, and overheating may result.

When using torque control, you cannot test induction motors beyond breakdown, except at locked rotor.

Set Speed Control

When using speed control, motors between 0 and 100 RPM cannot be tested unless the dynamometer is equipped with an optional speed encoder.

1. Use the SHIFT button to enable the MAX SPEED function.
2. Use the UP ◄ and DOWN ► buttons and the Decrease/Increase Dial to set a value equal to or slightly greater than the free-run speed of the motor under test.
3. Press the SHIFT button to exit the MAX SPEED function.
4. Press the SPEED SET button.
5. Use the UP ◄ and DOWN ► buttons and the Decrease/Increase Dial to set a speed equal to the max. speed.
6. Press the P button.
7. Use the Decrease/Increase Dial to preset a value of 10.
8. Press the I button.
9. Use the Decrease/Increase Dial to preset a value of 15.
10. Press the D button.
11. Use the Decrease/Increase Dial to preset a value of 0.
12. Use the BRAKE ON/OFF button to turn the brake ON.
13. Start your motor under test.
14. Press the SPEED SET button and adjust the setpoint to the desired speed.

Desired results:

- The dynamometer should load the motor under test to the desired speed quickly with little or no overshoot when the BRAKE button is cycled ON or OFF.

NOTE: If the response is too slow or oscillatory, adjust the values for P, I and D.

Set Open Loop Control

1. Use the BRAKE ON/OFF button to turn the brake ON.
2. Press and hold the TORQUE SET button until you hear a second beep.
3. The TORQUE SET POINT display will now indicate 0.00%.
4. Use the UP ◄ and DOWN ► buttons and the Decrease/Increase Dial to set a value of current equal to the percent of full scale output (1 Amp).
5. To exit the Open Loop Control mode, press any of the PID buttons or the SPEED SET button.

Desired results:

- The dynamometer should load the motor under test. Because the mode is open loop, the controller will not stabilize on speed or torque, but will apply a constant current to the dynamometer brake. The actual loading will change as the brake heats up or as other external factors change. The PID's have no effect in this mode.

Set Up I/O Parameters

1. Press and release SHIFT.
2. Press SETUP.
3. Press the DOWN ► button twice.
4. Press SHIFT.
5. Press UP ◄ or DOWN ► until you see the desired contrast level.

6. Press SHIFT.
7. Press UP ◄ or DOWN ► until you see the desired GPIB address.
8. Press SHIFT.
9. Press UP ◄ or DOWN ► until you see the desired RS-232 baud rate.
10. Press SHIFT to exit.

SETTING DYNAMOMETER LOAD

1. Press the UNITS DISPLAY button.
2. Use the Decrease/Increase Dial to adjust the current output to 0%.
3. Use the BRAKE ON/OFF button to turn the brake ON.
4. Start the motor under test.
5. Use the UP ◄ and DOWN ► buttons and the Decrease/Increase Dial to adjust the loading on the motor.

CAUTION

Do not exceed the capabilities of the dynamometer or the power source in use. Motors draw very large currents when held at locked rotor, and overheating may result. When using open loop current control, induction motors cannot be tested beyond breakdown, except at locked rotor.

USING INTERNAL MEMORY

Storing Data Points

1. Press and release STORE. The VFD will indicate STORE followed by a number. This indicates the memory location that contains the data.
2. Continue pressing STORE at each desired point.

Recalling Data Points

1. Press and release RECALL. The VFD will indicate RECALL followed by a number. This number indicates the memory location that is being displayed. The order of recalled data is LAST IN = FIRST OUT (LIFO). A "M" also appears to the right of the SPEED display to let the user know that the displayed data is from memory and not real time data.
2. Continue pressing RECALL until all the desired data is retrieved. Once data has been recalled, it is lost from internal memory.

Exiting the Memory Mode

1. Press and release SHIFT.

Clearing the Memory

1. Press and release SHIFT.
2. Then press CLR MEM.

5 - The DSP6000 with a PC (Remote Control)

The DSP6000 can be used with a computer to control a dynamometer and to transmit data from motor testing directly to the computer. Using the DSP6000 with a computer enables the unit to perform at its full capacity.

ABOUT THE GPIB INTERFACE

(General Purpose Interface Bus)

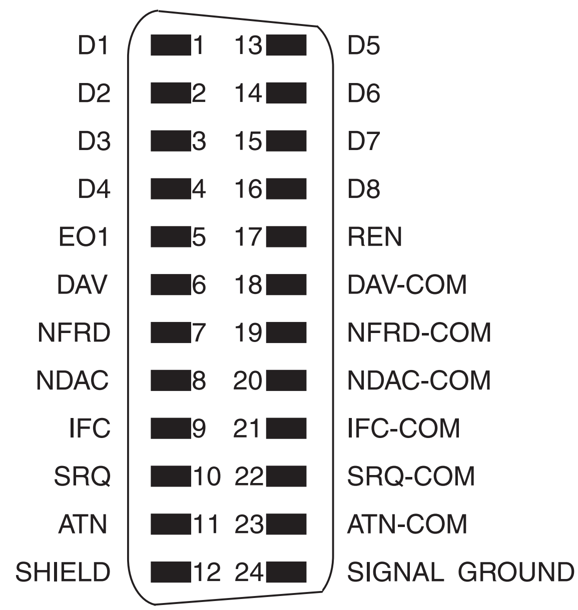
Magtrol instruments use the GPIB (IEEE-488 Standard) for computer-to-instrument interfacing because:

- The GPIB parallel interface is faster than serial interfaces.
- The GPIB enables testers to access up to 15 instruments on one port. Because typical motor testing requires that at least five separate parameters be synchronized, a system of easy, fast access to more than one instrument is essential.
- The GPIB has rigid data formatting and hardware standards. These standards help to ensure that all functions will work properly when the hardware and software are installed.

NOTE: The GPIB interface is not standard on most computers. An interface card and driver software must be installed. Magtrol recommends National Instruments Corporation hardware and software.

- An IEEE-488 cable must also be installed between the computer and the DSP6000.

Figure 8. GPIB (IEEE-488) Interface



Installing the GPIB (IEEE-488) Connector Cable

CAUTION

Make sure both the computer and the DSP6000 are turned OFF before installing the GPIB connector cable.

1. Connect one end of a high-quality, double-shielded cable to the DSP6000 GPIB connector.
2. Connect the other end to the GPIB interface in your PC.

Changing the GPIB Primary Address

Each instrument serviced by the GPIB has its own Primary Address code, which enables the computer to obtain readings from the instrument. The factory default setting on the DSP6000 is 09.

Some PC interfaces can access from one to fifteen 4-bit primary addresses. Other interfaces can access as many as thirty-one 5-bit primary addresses. The DSP6000 uses the 4-bit format.

1. Press the SHIFT button and release.
2. Press the COM SETUP button to set the primary address.
3. Press the button below the GPIB address display to increase by 1 (range 0–15).
6. Press SHIFT to input the address.

CHECKING THE DSP6000-TO-PC CONNECTION

NOTE: Make sure that the DSP6000 and its host computer are communicating before acquiring data.

1. Make sure the primary address is set correctly for the DSP6000 (see above).
2. Set the input variable to 15 characters (13 variable characters and the two required data termination characters CR and LF. (See "Programming" later in this chapter.)
3. Issue output data command "OD" and read 15 characters according to the instructions for your GPIB interface.

Desired results:

- Torque/speed data will be returned
- The error message I/O ERROR does not appear on the display panel.

NOTE: If the desired results did not occur, please see *Chapter 7 - Troubleshooting*.

PROGRAMMING

NOTE: Check the manual provided with your software for full instructions.

1. Use the following information to answer the formatting questions asked when installing your GPIB software.
   - All GPIB data acquisition systems require the use of data termination characters. The DSP6000 uses the GPIB standard termination characters "Carriage Return (CR)-Line Feed (LF)." Provide them in that order.

CODES FOR CR - LF

	BASIC	HEX	DEC
CR =	CHR$(13)	0D	13
LF =	CHR$(10)	0A	10

2. Set the timeout for at least one second if asked to set a communication fault delay timeout.
   - If the communication fault delay timeout is too short, or if the computer resets the interface too quickly, the host instrument may stop responding.

DSP6000 COMMAND SET

When entering a command code:

1. Type all characters in uppercase ASCII format.
2. End all commands with a CR-LF (hex 0D-0A).
3. Do not string multiple commands together in one line.

The character # represents a floating point numerical value following the command. Leading zeroes are not required.

NOTE: If a command is not recognized, the I/O ERROR message will appear in the Status Display.

Command Set for DSP6000

Command Category	Command Code	Function	Explanation
Communications	**H**	Sets high data acquisition rate (120 samples per second)	The Controller outputs data at 120 S/s (Using an RS-232 interface, the rate is 60 S/s.) Use this command during the ramp up/down when a short test time is required.
Communications	**L**	Sets low data acquisition rate (3.8 samples per second)	The Controller outputs data at 3.8 S/s (default rate).
Communications	**OA**	Prompts to return to auxiliary input data string	"Output Auxiliary" prompt to return the value at the AUX INPUT x AUX SCALING factor.
Communications	**OD**	Prompts to return speed-torque-direction data string	"Output Data" prompt to return data string with this format: SxxxxxTxxxxxRcrlf or SxxxxxTxxxxxLcrlf R or L is the shaft direction indicator, as viewed looking at the dynamometer shaft, where: R = right; clockwise (CW) L = left; counterclockwise (CCW) The speed will equal the displayed value and the torque will be in the same units as displayed on the front panel.
Ramp	**PD#**	Sets ramp down rate to #RPM per second	Specify a speed range (A, B, C, D, E, F#) AND a stop speed (S#) before using this command. This command programs a decreasing shaft speed at a rate of #RPM per second. Once initiated, the Controller will load to locked rotor unless instructed to do otherwise.
Ramp	**PR**	• Resets ramp up or down • Sets speed to max. speed • Turns brake off	This command resets the ramp function, halting the ramp's progress, and returns the motor to free-run.
Ramp	**PU#**	Sets ramp up rate to #RPM per second	Specify a speed range (A, B, C, D, E, F#) AND a start speed (S#) before using this command. This command increases the shaft speed at a rate of #RPM per second.
Ramp	**S#**	Sets start or stop speed for ramp to #RPM	When this command is used with the PD (Program Down) command, the Controller will ramp down to this speed and halt. When this command is used with the PU (Program Up) command, the Controller will load immediately to this speed and ramp up to free-run.
Setup	**M1**	Enables front panel controls	Use this command to enable front panel control of most functions.
Setup	**M0**	Locks out front panel controls	Use this command to lock out the front panel controls, so that the Controller settings can be changed only by using the computer with either the GPIB (IEEE-488) or the RS-232 interface. **Note:** The brake ON/OFF switch on the front panel still functions.

Command Category	Command Code	Function	Explanation
Setup	**R**	Resets as follows: • Manual control ON • Low data acquisition rate • Brake OFF	Use this command to cancel any previous commands. **Note:** These settings are the power-on default settings.
Setup	**UA#**	Sets auxiliary input scaling to #	This command sets the scaling factor for the auxiliary input to # units/volt. The range is 0.0 to 10000.0. Programmed value # is not saved at power down.

Setup	**UE#**	Sets encoder pulse count to #	This command selects the pulse count option for speed transducing. The pulse count defaults to 60-bit if out of range.
			The standard encoder supplied with all Magtrol Load Cell Dynamometers is 60 pulses/revolution. Optional 600 and 6000 pulse encoders are available for low-speed applications.
			Codes for pulse count # are:
			0 = 60-bit
			1 = 600-bit
			2 = 6000-bit
			Programmed value # is not saved at power down.

Setup	**UI#**	Sets dynamometer torque units to #	**Note:** For Hp and watts calculations to be correct, the correct dynamometer torque units must be specified. Values for # are:
			0 = oz.in. 5 = kg.cm.
			1 = oz.ft. 6 = N.mm.
			2 = lb.in. 7 = N.cm.
			3 = lb.ft. 8 = N.m.
			4 = g.cm.
			Torque units default to 0 (oz.in.) if out of range. Programmed value # is not saved at power down.

Setup	**UR#**	Sets readout torque units to #	This command sets the torque unit conversion for the torque readout.
			Values for # are:
			0 = oz.in. 5 = kg.cm.
			1 = oz.ft. 6 = N.mm.
			2 = lb.in. 7 = N.cm.
			3 = lb.ft. 8 = N.m.
			4 = g.cm.
			Torque unit conversion defaults to 0 (oz.in.) if out of range. Programmed value # is not saved at power down.

Speed	**A**	Sets max. speed to 2000 RPM	Commands A, B, C, D, E and F# set a speed range for the Controller. One of these commands must be specified before using the speed or ramp mode.
Speed	**B**	Sets max. speed to 4000 RPM	
Speed	**C**	Sets max. speed to 8000 RPM	

Command Category	Command Code	Function	Explanation
Speed	**D**	Sets maximum speed to 16,000 RPM	Commands A, B, C, D, E and F# set a speed range for the Controller. One of these commands must be specified before using the speed or ramp mode.
Speed	**E**	Sets maximum speed to 32,000 RPM	
Speed	**F#**	Sets max. speed to # RPM	
Speed	**N**	• Resets speed point to maximum speed • Sets speed mode OFF • Sets brake OFF	Use this command, sent alone, to reset any previous speed-stabilized setting to the maximum speed range.
Speed	**N#**	• Sets speed point to # • Sets brake ON	Use this command to load the motor under test to a specific speed value #. Issue a speed range command (A, B, C, D, E, F#) first for best dynamic response. The Controller is functioning with the dynamometer as a closed loop system. Adjust the speed PID values to tune the response.
Speed	**ND#**	Sets speed derivative to #	Derivative value # can be any number from 0 to 99.
Speed	**NI#**	Sets speed integral to #	Integral value # can be any number from 0 to 99.
Speed	**NP**	Sets speed proportional to # gain	Proportional gain value # can be any number from 0 to 99.
Torque	**Q**	• Resets torque to 0.0 • Turns torque mode OFF • Turns brake OFF	This command resets any previous torque-stabilized command, and returns the motor to free run.
Torque	**Q#**	• Sets torque point to # • Turns brake ON	This is a closed loop command with its own set of PID parameters. The units defined will be the same as those displayed by the Controller.
Torque	**QD#**	Sets torque derivative to #	Derivative value # can be any number from 0 to 99.
Torque	**QI#**	Sets torque integral to #	Integral value # can be any number from 0 to 99.
Torque	**QP#**	Sets torque proportional to # gain	Proportional gain value # can be any number from 0 to 99.
Misc	**X**	Prompts to return % current output	This command returns the % current value in the format "I##.##". The value will be between 0 (no loading) and 99.99 (full loading).
Misc	**I#**	Sets current output to #	The power supply outputs a fixed value of current. Use any value # between 0 and 99.99%. (99.99% = 1 Amp.)

ACQUIRING SPEED-TORQUE DATA

Speed-torque data is a fixed-length string in ASCII format with a floating point decimal. Use the following string format:

SdddddTdddd.R[cr][lf]

or

SdddddTdddd.L[cr][lf]

where . . .

S = Speed in RPM. No leading zeroes are used.

d = Decimal digit 0 through 9

T = Torque in units selected during setup. The torque value always contains a decimal point.

L = Counterclockwise dynamometer shaft rotation (left)

R = Clockwise dynamometer shaft rotation (right)

. = Decimal point. The decimal point location depends on the specific dynamometer and torque range in use.

NOTE: The [cr] and [lf] characters will not display.

Example:

If a motor is running at 1725 RPM clockwise, with the dynamometer loading the motor to 22.6 oz.in., the DSP6000 will return:

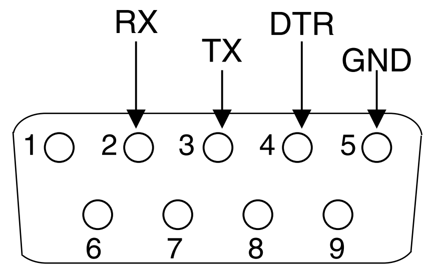
S 1725T22.60R

By manipulating the string, the speed-torque and shaft direction (if required) can be extracted. Then separate numerical variables can be assigned to them for data processing.

SELECTING THE BAUD RATE FOR THE RS-232 INTERFACE

The DSP6000 communicates with the host computer through a DB-9 interface connector. The connector pin-out is: 2-RX, 3-TX, 4-DTR, 5-GND. No other pins are connected.

Figure 9. Connector Pin-Out



The DSP6000 is equipped with an RS-232 (serial) interface. To select the baud rate:

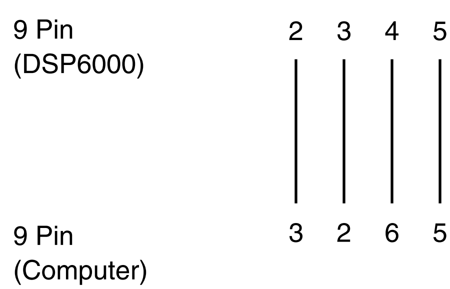
1. Press SHIFT and release.
2. Press the COM SETUP button.
3. Press the button under the RS-232 display to cycle through the following available baud rates:

300	2400	9600
600	4800	19200
1200		

Other important communication parameters are:

- No Parity
- 8 Data Bits
- 1 Stop Bit

To wire your own serial communications cable, use the following wiring diagram:



A cable may also be purchased from your local electronics store. A RadioShack #26-152 cable and #26-264 null modem adapter are known to work. The null modem adapter must be used on the computer end of the cable.

6 - Calibration

CLOSED-BOX CALIBRATION

The DSP6000 features closed-box calibration. The advantage of closed-box calibration is that the user does not have to disassemble the case or make mechanical adjustments. However, the calibration of the Accessory Torque Output must be done internally with Offset and Gain trim pots.

The Torque readout and Auxiliary Input can be calibrated using external reference sources. Correction factors for Offset and Gain are stored in nonvolatile memory. They remain in effect until the user or the calibration house updates them.

The front panel displays the actual correction factors above the ZERO and GAIN readouts. Record these values before calibration. In the unlikely event of a Controller failure, it can re-initialized by pressing and holding the P, I nad D buttons while turning the power on. All internal memory and setups will be lost. After re-initializing, reprogram the GAIN and ZERO values into memory.

CALIBRATION SCHEDULE

Calibrate your DSP6000:

- After any repairs are performed
- At least once a year; more frequently to ensure required accuracy

BASIC CALIBRATION PROCESS

The basic calibration process consists of four procedures which must be performed in the following order:

1. Initial Procedure
2. Torque Offset and Gain
3. Accessory Torque Output Offset and Gain
4. Auxiliary Input Offset and Gain

To calibrate the DSP6000, you will need:

- External voltage reference of 0 to 5 volts DC
- Digital multimeter (DMM) with VDC accuracy of 0.05% or better

INITIAL CALIBRATION PROCEDURE

NOTE: Record the actual correction factors displayed before proceeding with calibration.

1. Allow the DSP6000 to stabilize in an environment with:
   - An ambient temperature of 18°C to 25°C
   - Relative humidity less than 80%
2. Turn on the DSP6000.
3. Allow the DSP6000 to warm up for at least 30 minutes.
4. Enable the calibration mode as follows:
   - Turn instrument power OFF
   - Press in and hold the UP ◄ and DOWN ► arrow buttons simultaneously
   - Turn instrument power ON
5. Continue pressing the UP ◄ and DOWN ► arrow buttons until the display shows the software revision date.
6. Press the SHIFT button once.

NOTE: To exit CALIBRATE mode without making any changes, press the SHIFT button six times.

TORQUE OFFSET AND GAIN

1. Connect the external voltage reference common to Pin 13 of the dynamometer input connector.
2. Connect the external voltage reference high to Pin 14 of the dynamometer input connector.
3. Apply +2.000 VDC.
4. Press the GAIN button.
5. Adjust the gain by turning the Decrease/Increase Dial until the displayed voltage equals the reference voltage.

NOTE: The magnitude of change per revolution can be increased by pressing the UP ◀ button or decreased by pressing the DOWN ▶ button.

6. Apply 0.000 VDC.
7. Press the ZERO button.
8. Adjust the Decrease/Increase Dial until the display indicates 0 mVDC.
9. Repeat steps 3 through 8 to complete this procedure.
10. Record the correction factors displayed above the ZERO and GAIN readouts for future reference.

Accessory Torque Offset and Gain

1. Connect the DMM common to Pin 4 of the Accessory Torque-Speed Output connector.
2. Connect the DMM high to Pin 2 of the Accessory Torque-Speed Output connector
3. Apply 0.000 VDC
4. Adjust R24 (OFFSET) on the circuit board for 0 mVDC on the DMM.
5. Apply +2.000 VDC.
6. Adjust R25 (GAIN) on the circuit board for +2.000 VDC on the DMM.

Auxiliary Input Offset and Gain

1. Press the SHIFT button once. Display indicates AUX INPUT calibration.
2. Connect the external voltage reference to the Auxiliary Input BNC connector.
3. Apply +5.000 VDC.
4. Press the GAIN button.
5. Adjust the gain by turning the Decrease/Increase Dial until the displayed voltage equals the reference voltage.

NOTE: The magnitude of change per revolution can be increased by pressing the UP ◀ button or decreased by pressing the DOWN ▶ button.

6. Apply 0.000 VDC.
7. Press the ZERO button.
8. Adjust the Decrease/Increase Dial until the display indicates 0 mVDC.
9. Repeat steps 3 through 8 to complete this procedure.
10. Record the correction factors above the ZERO and GAIN readouts for future reference.
11. Press the SHIFT button once to return to default display.

Alternate Calibration Procedure

The DSP6000 can also be calibrated by using a certified dynamometer, calibration beam, and weight instead of an external voltage reference.

NOTE: Magtrol suggests you do NOT use this method. By using the alternate calibration procedure, you are calibrating the DSP6000 to a specific dynamometer, not to a reference standard. If you connect the DSP6000 to a different dynamometer, the resulting torque reading may be incorrect.

1. Connect the chosen dynamometer to the DSP6000 using the 14-pin signal cable and the 2-pin brake cable.
2. Attach the calibration beam to the dynamometer shaft.
3. Enter the calibration mode.
4. Press the BRAKE ON/OFF button ON to apply full loading to the dynamometer.
5. Hang the weight on the calibration beam pin and level the beam.
6. Press the GAIN button.
7. Adjust the gain by turning the Decrease/Increase Dial until the displayed voltage equals the reference voltage.

NOTE: The magnitude of change per revolution can be increased by pressing the UP ◀ button or decreased by pressing the DOWN ▶ button.

8. Remove the weight for ZERO adjustment.
9. Press the ZERO button.
10. Adjust the Increase/Decrease Dial until the display indicates 0 mVDC.

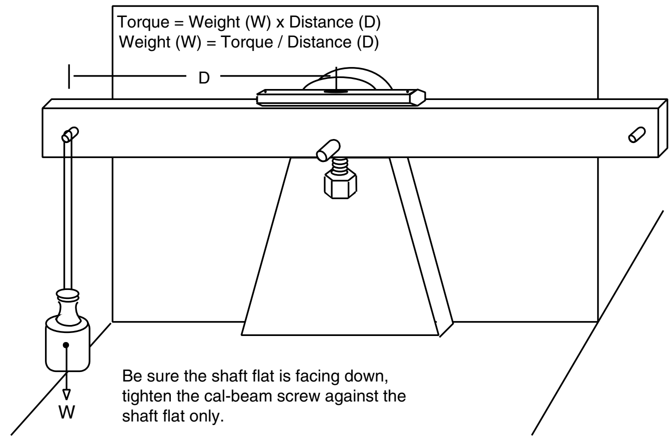
NOTE: The mV output of the dynamometer will be equivalent to the Full Scale Torque Rating, disregarding any decimal point.

Example:

Magtrol's HD-400-6 Dynamometer has a full-scale torque of 40.0 oz.in. The distance from the center of the dynamometer shaft to the pin on the calibration beam is 5 inches. Placing an 8 oz. weight on the pin will produce a torque of 40.0 oz.in. The mV output of the dynamometer will be 40.0 minus decimal point or 400.

11. Repeat steps 5 through 10.
12. After completing calibration:
    - Press the BRAKE ON/OFF button OFF to remove loading from the dynamometer.
13. Remove the calibration beam from the dynamometer shaft.
14. Proceed with your desired motor testing.

Figure 10. Alternative Calibration



7 - Troubleshooting

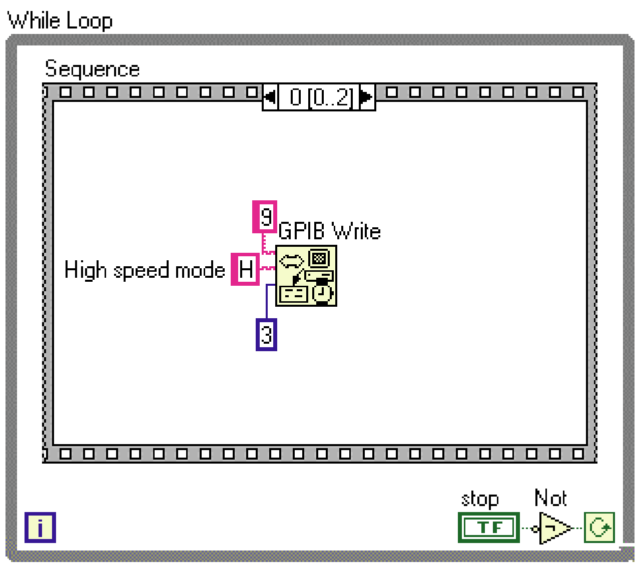
PROBLEM	REASON	SOLUTION
Display indicates I/O ERROR	Command does not match the unit's programmed set of instructions.	Use correct command and format.
Speed command sent, but Controller does not respond.	Communication occured but the Controller is not loading the motor.	Adjust PID values.
Mechanical power reads much higher or lower than expected.	Torque units are incorrect.	Set torque input units to match the specifications on dynamometer nameplate.
No GPIB communication	Setup error and/or hardware fault.	Check: • GPIB address of Controller • GPIB cable: should be functioning and attached to Controller and computer interface card.
No RS-232 communication	Setup error and/or hardware fault.	Check: • Baud rate of Controller • Pinout of serial cable • Cable attachment to Controller and serial interface port of computer.
Dynamometer shaft does not turn smoothly when BRAKE is OFF.	Salient poles were set up on the rotor by having brake current applied with no shaft rotation.	Start the motor and bring up to speed. Press BRAKE button ON. Adjust output current up to a value at least 25% of the maximum torque rating of the dynamometer in use (if possible). Reduce output current to 0.

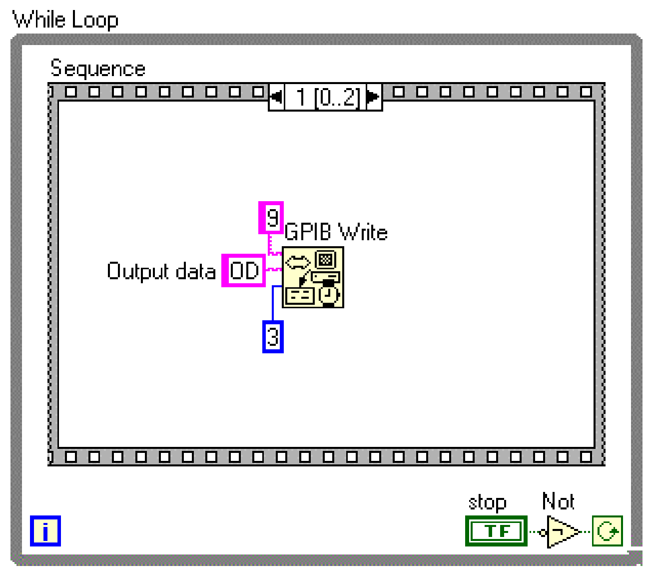
If you require additional assistance, please contact
Magtrol Customer Service at 1-800-828-7844 or 1-716-668-5555

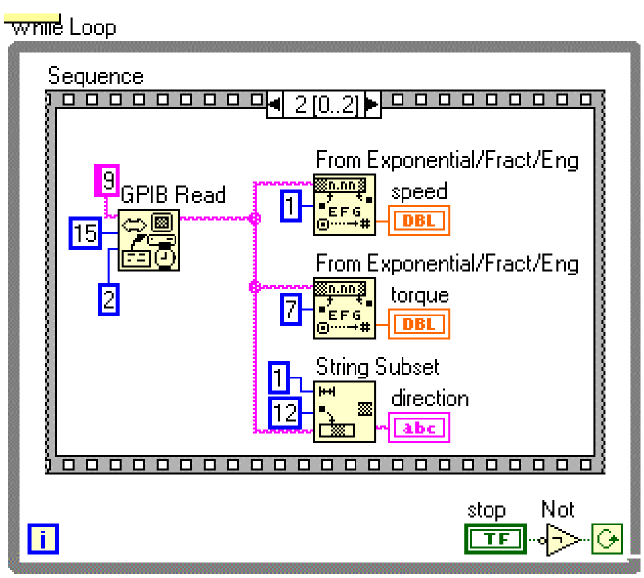
Appendix A: LabVIEW® Programming Examples

Magtrol offers a comprehensive motor-test software program to satisfy most of your programming needs. To order your software, call Magtrol Sales at 1-800-828-7844 or 1-716-668-5555.

SIMPLE READ

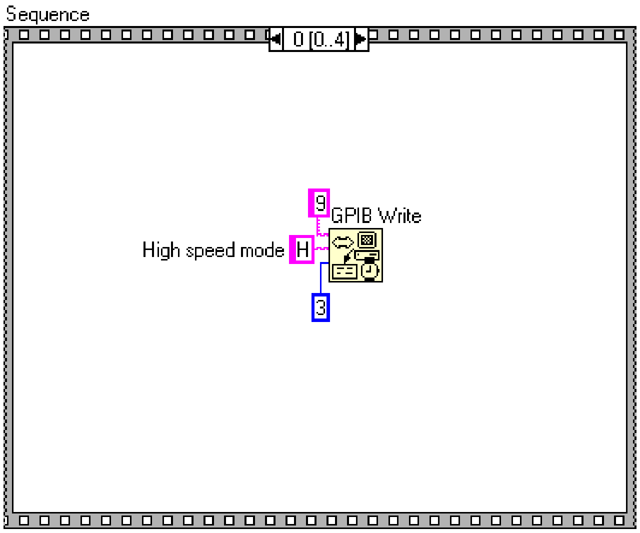


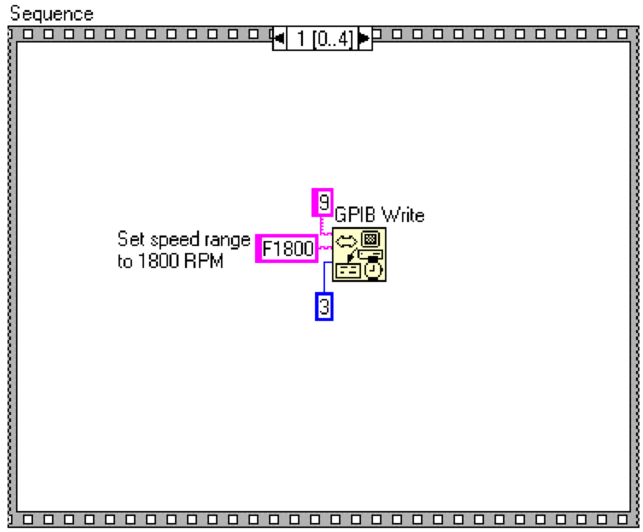


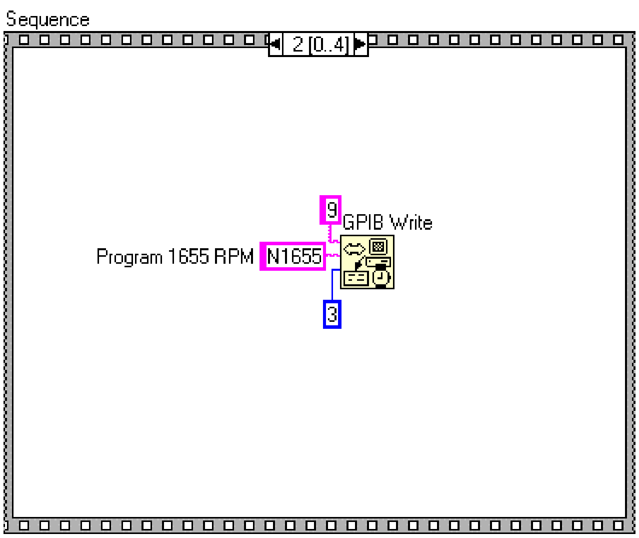


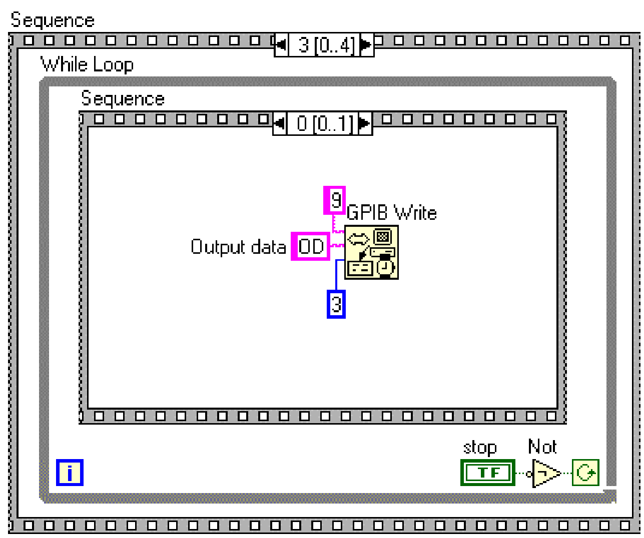
TORQUE STABILIZED

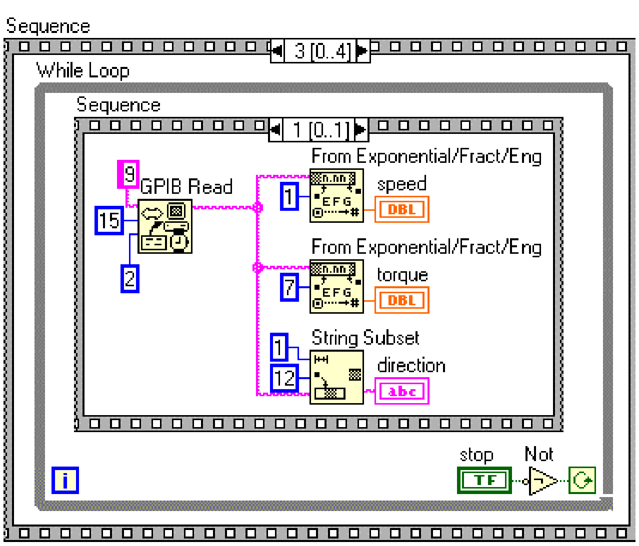
SPEED STABILIZED











INERTIAL EFFECT ON MOTOR TEST DATA

A major advantage of the DSP6000 is its ability to obtain full motor performance data (free run to locked rotor) by continuous load application with an absorption dynamometer. Data acquisition is fast, resulting in minimal motor I^2R losses, and loading characteristics simulate actual end-use applications.

When a motor is accelerating or decelerating, the measured torque is the sum of the true motor torque ± the inertial torque, or stored energy, of the system. Unless inertial torque is excluded, motor performance will vary in proportion to the rate of acceleration or deceleration.

This type of error can produce problematic test results. For example, during rapid deceleration, system inertia can produce apparent efficiency greater than 1.0. This error may occur if output power is divided by input power without extracting the stored energy in the system.

Since "inertial effect" is only a factor when speed is changing, and because inertial torque is proportional to the rate of change, inertial value may be expressed as a unit of torque *per* change in RPM *in a given period of time*. With the DSP6000, properly adjusted PID values yield constant change in RPM so that the inertial torque can be expressed as a constant.

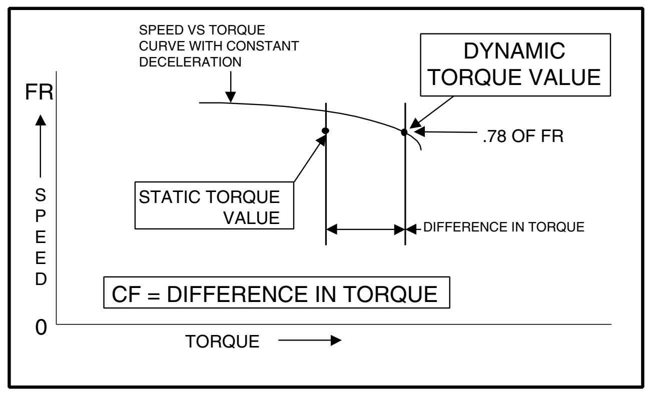
PROCEDURE FOR INERTIA CORRECTION

1. Determine the torque Correction Factor (CF) as follows:
   - Adjust the PID loop properly
   - Establish a torque value equal to the inertial torque.
2. Use the "Program Down" command (PD#) to ramp to 75% of the free-run speed.
3. Select a data point on the performance curve where speed will be approximately 78% of the free-run speed. Let this represent the dynamic speed-torque value.
4. Immediately program your DSP6000 (Nddddd) to a speed equal to the dynamic speed value. When the speed stabilizes, use this as the *static torque value*.

CF = Dynamic Torque - Static Torque

To correct your data, subtract the CF from each torque point obtained during the ramp.

Example:

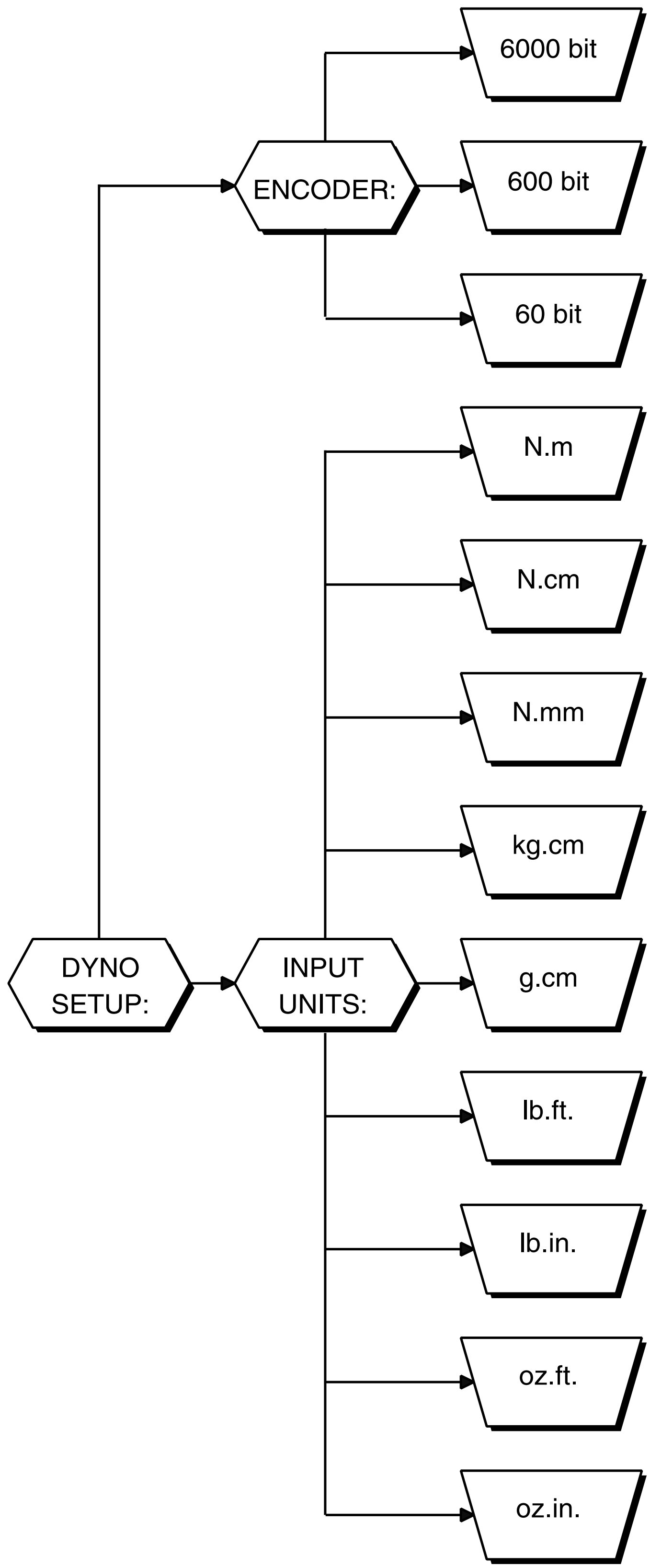


Key Conditions

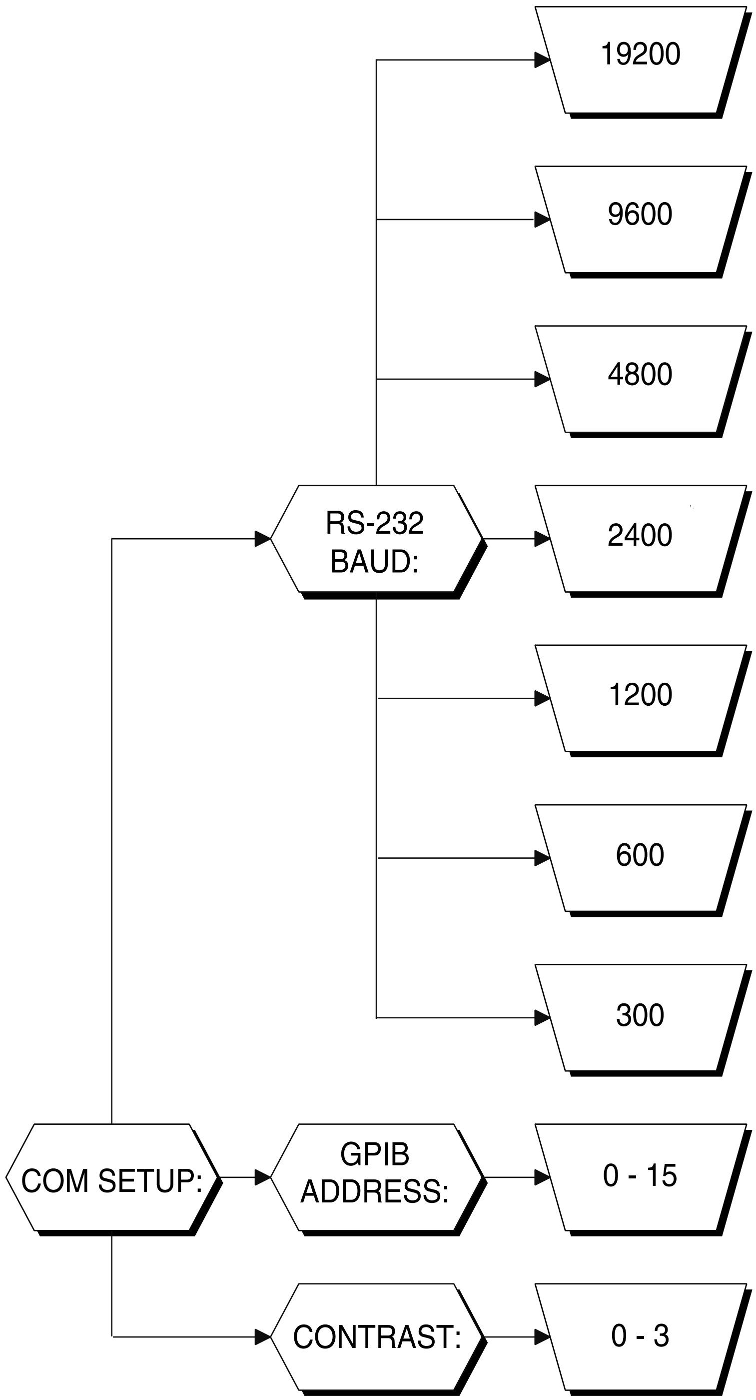
- **Select appropriate value**. The test point selection of 78% is typical for an induction motor. Use a value in the linear portion of the motor curve where there is a substantial torque change with speed.
- **Acquire data rapidly**. Rapid data acquisition is necessary so that motor heating does not degrade performance by adding a false difference between the static and dynamic torque values.
- **Use a regulated power source**. The input line voltage must be stable for the time necessary to perform the test. Torque varies by the square of the change in line voltage.
- **Obtain new CF value for various deceleration/ acceleration rates**. The CF is only valid for its specific ramp rate. To calculate other CF rates, use the following equation:

  CF_{new} = (CF_{old} /ramp rate) X new ramp rate

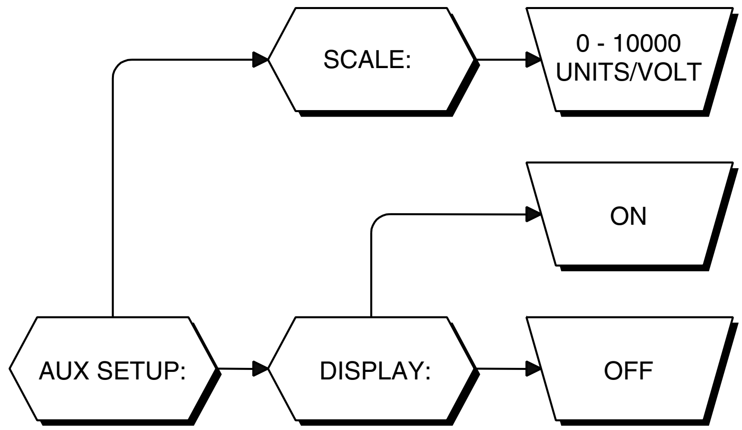
DYNO SETUP MENU



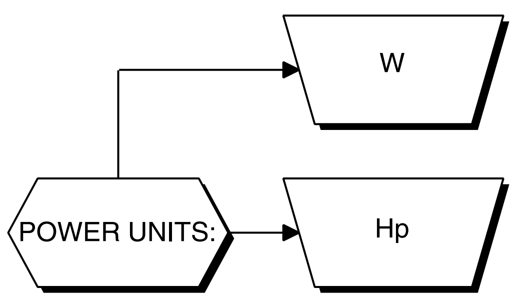
COM SETUP MENU



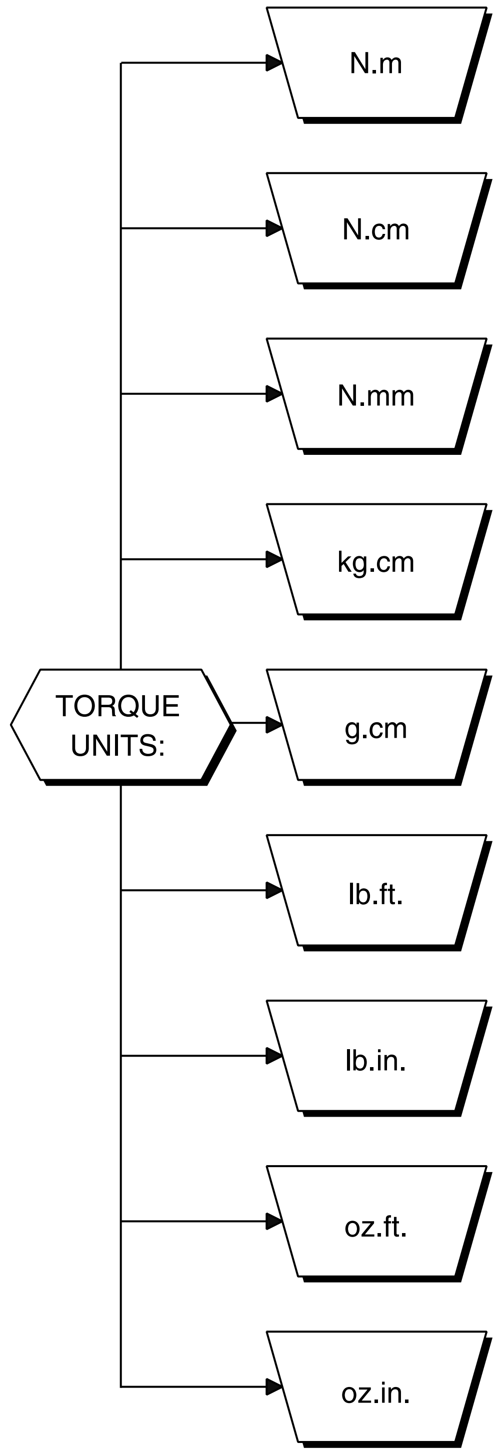
AUX SETUP MENU



POWER UNITS MENU

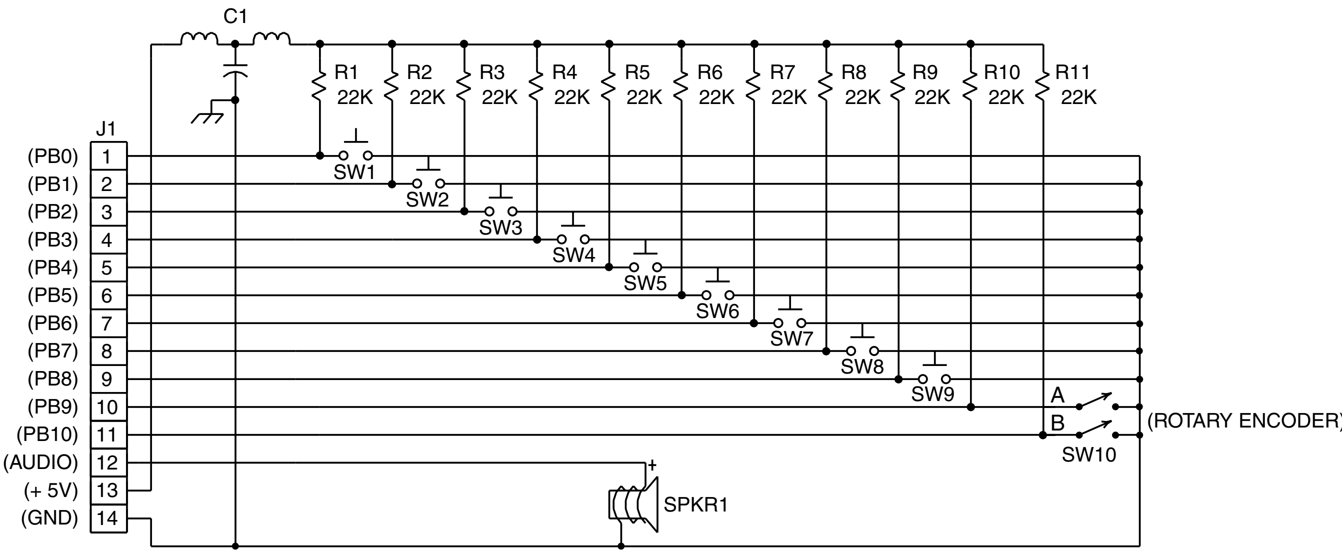


TORQUE UNITS MENU

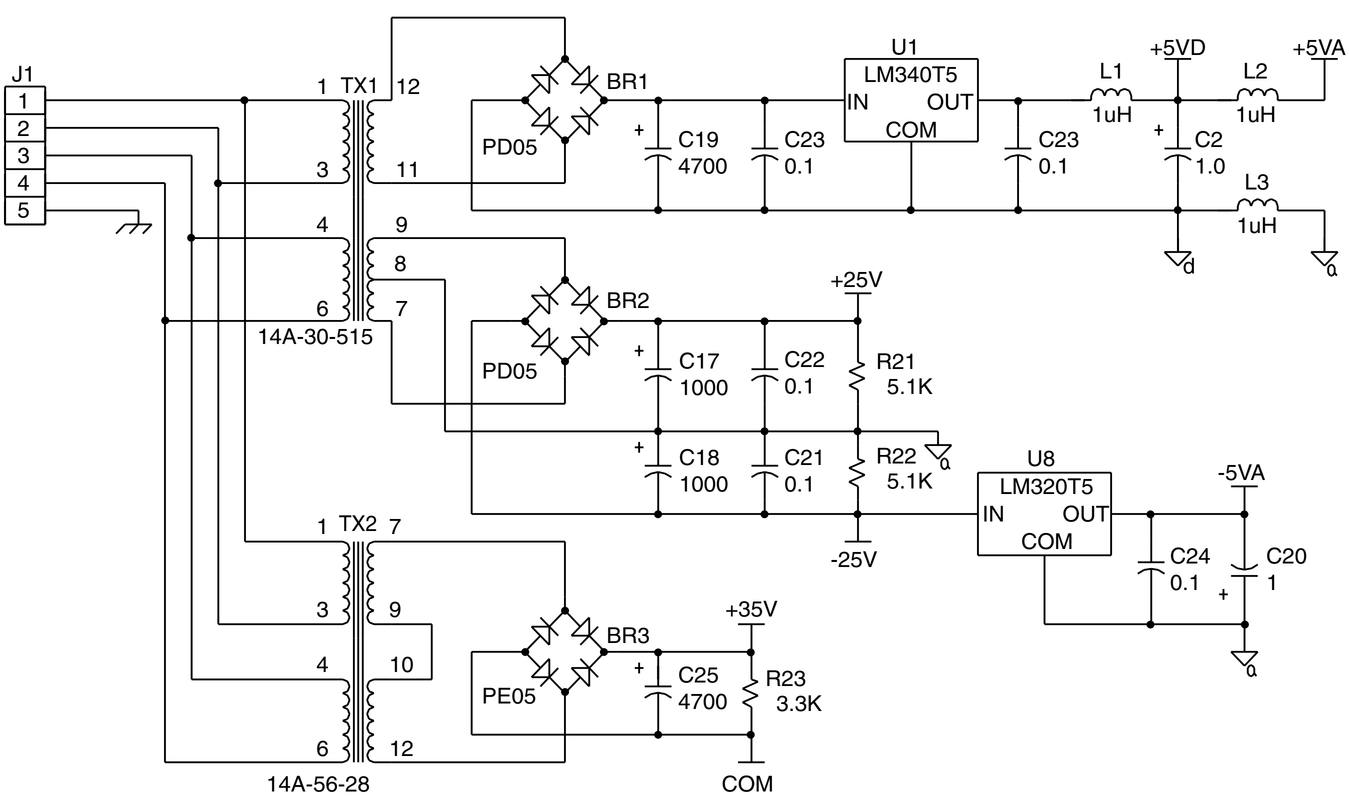


Appendix D: Schematics

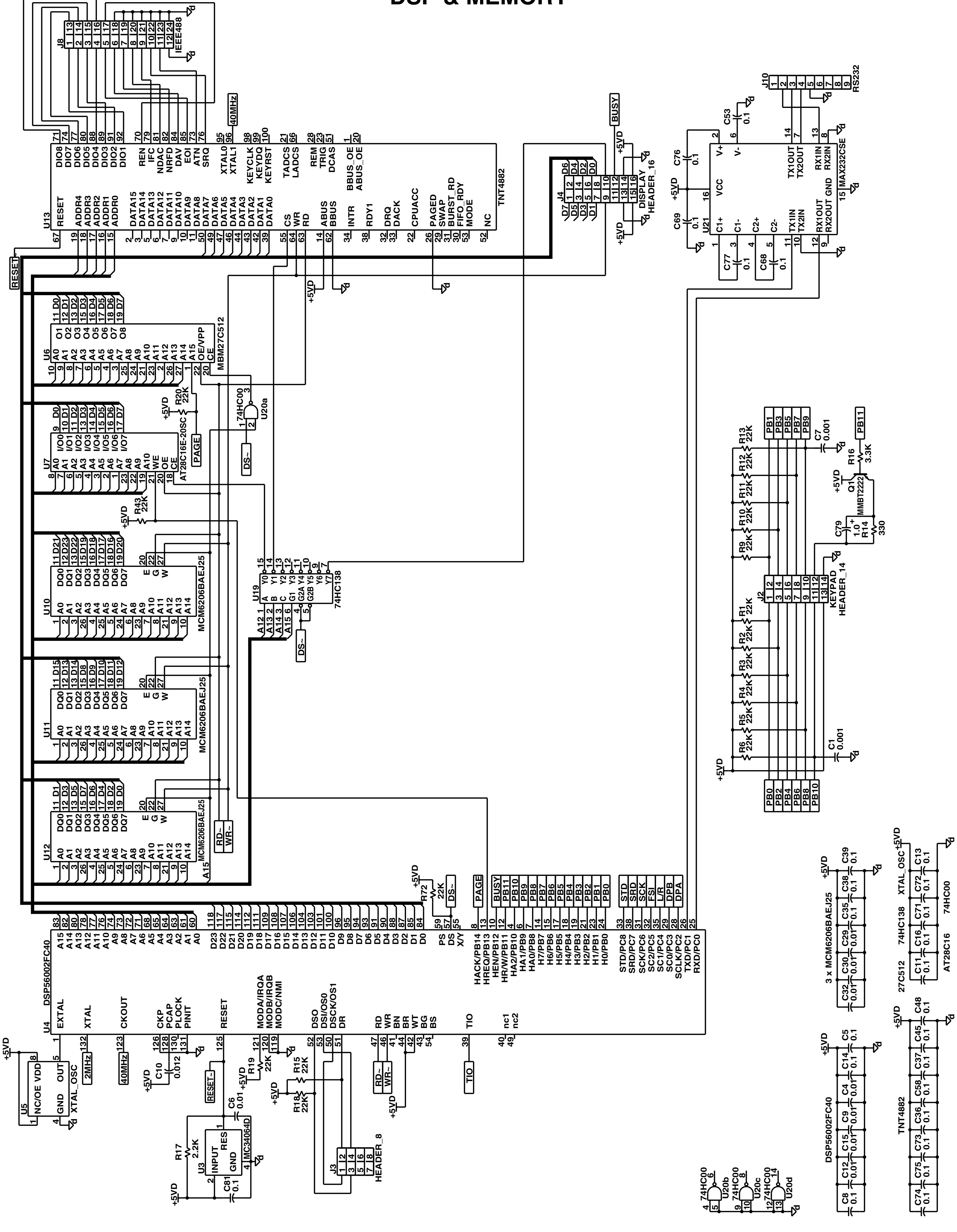
ENCODER/SWITCH BOARD



POWER SUPPLY

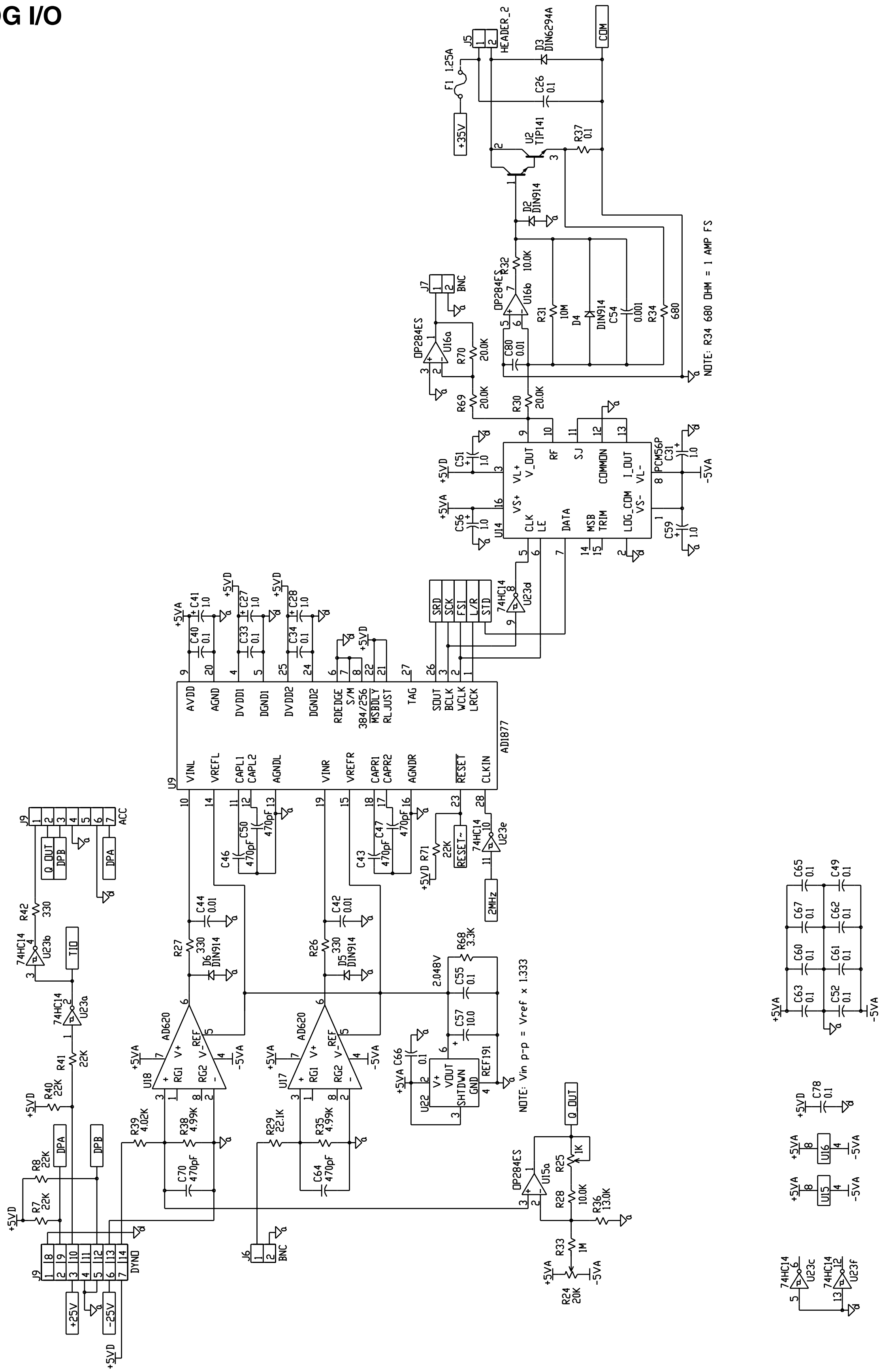


DSP & MEMORY



DSP56002FC40
TNT4882
MAX232CSE
MBM27C512
AT28C16E-20SC
MCM6206BAEJ25
74HC138
IEEE488
RS232
KEYPAD HEADER_14
DISPLAY HEADER_16

ANALOG I/O


+35V
F1 1.25A
J5
HEADER_2
D3
DIN6294A
COM
C26
0.1
U2
TIP141
R37
0.1
D2
DIN914
R32
10.0K
OP284ES
U16b
R31
10M
D4
DIN914
C54
0.001
R34
680
NOTE: R34 680 OHM = 1 AMP FS
J7
BNC
U16a
R70
20.0K
C80
0.01
R69
20.0K
R30
20.0K
PCM56P
U14
C31
C51
C56
C59
+5VD
+5VA
-5VA
AD1877
U9
SRD
SCK
FS1
L/R
STD
74HC14
U23d
C40
C41
C33
C27
C34
C28
AVDD
AGND
DVDD1
DGND1
DVDD2
DGND2
RDEDGE
S/M
384/256
MSBDLY
RLJUST
TAG
SDUT
BCLK
WCLK
LRCK
VINL
VREFL
CAPL1
CAPL2
AGNDL
VINR
VREFR
CAPR1
CAPR2
AGNDR
RESET
CLKIN
C46
C50
470pF
C43
C47
R71
22K
RESET~
U23e
2MHz
C44
0.01
C42
R27
330
D6
R26
D5
R68
3.3K
2.048V
C55
C57
10.0
C66
U22
REF191
VOUT
SHTDWN
GND
NOTE: Vin p-p = Vref x 1.333
AD620
U18
U17
RG1
RG2
V+
V-
REF
R39
4.02K
R38
4.99K
R29
22.1K
R35
4.99K
C70
C64
J6
Q_OUT
U15a
R25
1K
R28
10.0K
R36
13.0K
R33
1M
R24
20K
J9
ACC
DPA
DPB
TIO
R42
330
U23b
U23a
R41
22K
R40
22K
R8
22K
R7
22K
DYNO
+25V
-25V
C65
C49
C67
C62
C60
C61
C63
C52
C78
U16
U15
U23c
U23f

Glossary of Abbreviations and Terms

BNC .... bayonet, locking-type connector
CCW .... counterclockwise (turn to left)
CF .... correction factor (inertia correction factor)
CR .... carriage return
CW .... clockwise (turn to right)
D .... derivative
D/A .... digital to analog converter
DMM .... digital multimeter
FR .... free-run speed
GPIB (General Purpose Interface Bus) .... parallel interface port; interchangeable with IEEE-488
Hp .... horsepower; measure of mechanical power
Hz .... hertz; frequency
I .... integral
I/O .... input/output
LF .... line feed
local .... manual control (use front panel controls)
mVDC .... millivolts DC
N .... speed
NEMA .... National Electrical Manufacturers Association
P .... proportional; proportional gain
PID .... proportional, integral, derivative
PMDC .... permanent magnet DC
Q .... torque
remote .... computer control (uses programmed controls from computer)
RPM .... revolutions per minute
SI .... Systeme Internationale units of measure
S/s .... samples per second
V .... volts; typically AC
VDC .... volts DC

Magtrol Limited Warranty

Magtrol, Inc. warrants its products to be free from defects in material and workmanship under normal use and service for a period of one (1) year from the date of shipment. Software is warranted to operate in accordance with its programmed instructions on appropriate Magtrol instruments. This warranty extends only to the original purchaser and shall not apply to fuses, computer media, or any other product which, in Magtrol's sole opinion, has been subject to misuse, alteration, abuse or abnormal conditions of operation or shipping.

Magtrol's obligation under this warranty is limited to repair or replacement of a product which is returned to the factory within the warranty period and is determined, upon examination by Magtrol, to be defective. If Magtrol determines that the defect or malfunction has been caused by misuse, alteration, abuse or abnormal conditions of operation or shipping, Magtrol will repair the product and bill the purchaser for the reasonable cost of repair. If the product is not covered by this warranty, Magtrol will, if requested by purchaser, submit an estimate of the repair costs before work is started.

To obtain repair service under this warranty, purchaser must forward the product (transportation prepaid) and a description of the malfunction to the factory. The instrument shall be repaired at the factory and returned to purchaser, transportation prepaid. **MAGTROL ASSUMES NO RISK FOR IN-TRANSIT DAMAGE.**

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CLAIMS

Immediately upon arrival, purchaser shall check the packing container against the enclosed packing list and shall, within thirty (30) days of arrival, give Magtrol notice of shortages or any nonconformity with the terms of the order. If purchaser fails to give notice, the delivery shall be deemed to conform with the terms of the order.

The purchaser assumes all risk of loss or damage to products upon delivery by Magtrol to the carrier. If a product is damaged in transit, PURCHASER MUST FILE ALL CLAIMS FOR DAMAGE WITH THE CARRIER to obtain compensation. Upon request by purchaser, Magtrol will submit an estimate of the cost to repair shipment damage.

MAGTROL

70 Gardenville Parkway ◆ Buffalo, New York 14224
Phone: (716) 668-5555 ◆ (800) 828-7844 Fax: (716) 668-8705
Web site: www.magtrol.com ◆ E-mail: magtrol@magtrol.com